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MEATS AND CURED MEATS: THE NEW FRONTIERS OF SUSTAINABILITY

ENVIRONMENT, HEALTH, SAFETY, CULTURE, ECONOMY AND ETHICS IN MEAT SUPPLY CHAIN

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and ethics in meat supply chain

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THE "SUSTAINABLE MEAT" PROJECT

The global challenge of the agri-food sector over the next few years entails guaranteeing safe and sustainably produced food to a growing population which is expected to reach 9.7 billion people by 2050. In this context, the livestock sector is today called upon to play its part and face **unprecedented challenges**.

On the one hand, according to FAO estimates, it will be necessary to guarantee an average **increase of 30% in the availability of foods of animal origin (meat, milk and eggs)** by 2050, in a sustainable scenario to be implemented above all in developing countries (Source: FAO 2018. The future of food and agriculture). On the other, this necessity cannot disregard the fact that these foods, in addition to being nutritious, healthy and safe, are also produced in an environmentally sustainable way with processes that guarantee animal health and well-being, as well as being made available at **affordable prices for all**, which represent for sector operators an adequate source of income which is not wasted. To help feed the world population and at the same time guarantee all these requirements, it is essential that the sector operates on the **basis of the highest scientific standards**, overcoming simplifications and ideological impositions which - although not supported by any evidence - unfortunately continue to have a large resonance in the debate public.

The sustainability of livestock systems is an extremely complex issue, difficult even to deal with at regulatory levels, as demonstrated by the problematic approach of the European Farm to Fork strategy, whose literal application could lead to a progressive and irreversible dismantling of European livestock production.

Despite the many different points of view, there is however one important fact: livestock farming in modern society plays a fundamental role for the **environment, human health, animal health, the economy and society**. This sector, in fact, is worth around **170 billion Euro in Europe alone and directly employs more than 4 million people**.

It is into this background the Sustainable Meats project was inserted, initiated in 2012 by volition of the main Italian associations of breeders and producers of beef, pork and poultry, in order to take an active part in the debate, with no intention of convincing those who choose not to consume any, but rather to offer the point of view of the supply chain and consequently contribute to a constructive and transparent dialogue with all citizens, especially with those who on the other hand consciously choose to use these foods. This publication is the revision of the first 2018 edition, respect to which all the chapters have been updated and enriched with new scientific evidence on the most current topics.

The chapter on **nutrition** reports the most recent studies showing that red meat does not pose a health risk and that the worldwide consumption of meat has contributed to the prolongation of life expectancy. Furthermore, it carries out an in-depth study on meat substitutes, from those "cultured" in the laboratory to plant-based products, with relative metabolomic analysis and an evaluation of these ultra-processed foods with new models such as Nova score. The **environment** chapter again offers important new ideas on carbon farming, on the new metric for calculating the impact of climate-altering gases (GWP*), on the role of food supplements in reducing methane emissions in ruminants, on livestock supply chain digitalisation, on regenerative agriculture and on the enormous prospects linked to the development of bioenergy and the circular economy.

The printing of this book and its publication were financed by the Sustainable Meat Association as part of its programs for the promotion and dissemination of scientific research in the livestock production sector, thanks to the activities of the scientific committee and other contributors.

"For every complex problem there is an answer that is clear, simple, and wrong." (H. L. Mencken)

IS IT LEGITIMATE TO RAISE ANIMALS FOR OUR OWN PURPOSES?

We initiate this book on meat and cured meat sustainability in Italy with a difficult question: is it legitimate to raise and sacrifice animals for our own ends? Instinctively, most people give one of two diametrically opposed answers, i.e., either "yes" or "no", while a small minority, after careful reflection, answers "maybe". The advocates of "yes" will try to justify their position with arguments that refer to the prevalence of the human species over others (basic in many religions, but not in all), to utilitarianism (preferred by those who have a layman's approach), to tradition (thought with low brain energy expenditure), to the evolution of our species (thought with higher energy expenditure) and, finally, to the reciprocity of the advantages for human-animal contractors (thought with high energy expenditure). The "no" proponents, a much more comfortable side of the contemporary dialectic, will restrict the arguments to anti-speciesism (basic in many disciplines of holistic thought) and to the denial of any utility in the interspecific union homo-animalia (thinking at the expense of brain energy nothing), with the aggravating circumstance of the sufferings of the latter to satisfy the needs of the former (basic in the animalist ideology-religion, with serious collateral reverberations in the more recently coined ecologist one). Finally, the scant minority of the "perhaps", will begin to put together a chain of "distinctions", which can hardly be included in the few lines of this premise, but are a productive signal of a still open debate and for which it will be difficult to find a final answer. If indeed, following the teaching of Luciano Floridi, full Professor of Philosophy and Information Ethics at the Internet Institute of Oxford University, Philosophy is rather the science of questions asked well than the relative answers, albeit adequate to the quality of questions, the themes of ethics and morals applied to our relationship with animals pose many questions which are, and will be, difficult to answer. Among other things, the ethics of man-animal relations is considered amongst the most controversial and ancient topics of human thought, starting with the Pythagoreans and ending with present-day moral philosophers, and anticipates, by several centuries, the one now emerging which concerns artificial intelligence as an alien entity capable of self-determination even to the detriment of our species.

Returning to our question whether it is permissible to raise and sacrifice animals for our ends, let us restrict the field to those of breeding aimed at the production of food, of meat in our instance, leaving out other cases, although logically connected, such as animals for circuses, competition, pets, military and scientific use, zoological gardens, present in natural environments infested with tourists and for decoration (see goldfish, among others). The introduction to this book obviously puts me on the side of those who initially answer this question "maybe", and then move resolutely towards the "yes". This premise is necessary to introduce the arguments on the basis of which in my opinion, and not only my opinion, a positive answer can be given on the legitimacy of animal farming, an answer which cannot be merely philosophical, that is to say open to the principle of non-contradiction with Floridi's position mentioned above, but only operational, aimed at clearing the field, represented by the following pages, *of the original doubt whether we are talking about a right or wrong thing, and this is the task of applied ethics, and consequently whether the societies that practice livestock farming are reprehensible, and this is the task of morality.*

At this point I introduce another question that anticipates the main one of which it can be considered a presupposition: do animals have rights? To answer, we must first define the concepts of "perceptiveness", "consciousness", "awareness" and "ability to elaborate mental representations". All living organisms are perceptive, in the sense that they receive physical or chemical signals from the surrounding environment, perceiving by capturing them with suitable sensors, feeling them, in the sense that they are processed through biochemical and biophysical pathways, and react appropriately to them. In this respect, all animals are perceptive beings. Many animals are conscious, that is they respond to external stimuli, as perceptive beings, through a mental project aimed at optimising actions and reactions aimed at the perpetuation of the species (Darwin docet). Therefore, livestock animals are undoubtedly conscious beings: in fact, to perform an invasive manipulation on a bull, for example to extract an annoying cyst surgically, we have to make him unconscious with sedatives or anaesthesia, otherwise he will somehow make us unconscious. Awareness, on the other hand, is a very rare trait in animals and concerns the possibility of recognising oneself as an active agent in relation to the surrounding world. To discover this faculty, livestock psychologists use the mirror test which has been fully passed only by chimpanzees and some corvids (the domestic dog, for example, does not pass, even if the test is enhanced with the aid of smells). Finally, mental representations are the ability to elaborate symbols and to compare them, distinguishing them, with reality (real I should say, but the discussion would be long; let's say phenomenal, even if the word is demanding). Only Homo, in particular our species - but the debate among paleoanthropologists is ongoing about the extension of this property to other hominins as well - possesses this quality. Having said that, what are the conditions necessary for animals to be bearers of rights? If rights (and specular duties) are a human construct based on a social pact – which codifies constitutions, laws, courts, forms of representation, etc… – then only forms of life endowed with the ability to operate mental representations can arrive at a highly symbolic outcome such as that constituted by the conventional rules that regulate human communities. From this it follows that animals, all animals, cannot be holders of rights as they are not part of the symbolic community made up only of human beings. From which it follows that since there are no laws of horses for horses, nor of hens for hens, or even less equine

Wainer Vaccari
(Modena 1949),
Melanconia, 1992.
Oil painting on canvas, cm 200 x 250
(Private Collection).

and fowl courts, judges and lawyers, the ***so-called animal rights are simply our duties towards them****. And these obligations do not concern only animals, but also other living beings, both single and inserted in ecosystems. This asymmetry represented by the presence of duties in the absence of rights, is the fulcrum of the reasoning by which* ***the right to a life without unnecessary suffering and which responds as much as possible to the needs of animals is our right*** *(like that of being able to enjoy clean air, be able to be educated and cared for, respect nature, etc.) which corresponds to the specular duty to respect, defend and protect animals, a duty that has recently been included in the Italian Constitution (Article 9 of the Italian Republic recognises the protection of the environment, biodiversity and ecosystems by regulating the methods and forms of animal protection). Yet at the same time, even the satisfaction of food needs (which we share with the instinctual need for survival common to all species) becomes a primary right when we make it such through the universal declaration of the right to food (an act that is not equally adopted by the raccoon community, as one instance). This right puts us in a position to demand a healthy and accessible diet for all people and products of animal origin are an integral part of the satisfaction of this primary need undertaken as a universal right for humanity.*

At this point one could object that our species would survive very well without consuming food of animal origin, but this position is immediately refuted by the medical observation of the need for artificial supplements to vegan diets, a clear demonstration of the biological need for meat, milk, eggs and fish which forms the basis of the right to food. Nor is it worth lingering on the supporters of the so-called passive rights of animals (an oxymoron): they irresponsibly use marginal cases, represented for our species by people unable to communicate or in a state of permanent unconsciousness, equating them to animals (superior they say, but what are superior animals? Where do we place the limit?) and consequently extending rights to these, but passively (?), proper to humans. Marginal arguments are branded by dialectics as false and misleading because, through the intermediate cases, any action can be justified.

Therefore, we must raise livestock animals to respond to ***one of our primary rights, food,*** *without however failing another right of ours, the* ***respect and well-being of animals*** *at all stages of life, which correspond to the relative duties both towards us and towards them, but also towards the environment and society as a whole. Having clarified that it is legitimate to raise animals for our own food purposes, this book will illustrate how we can do it in a sustainable way, with techniques and methods capable of safeguarding animal welfare, preserving the environment, respecting cultures, health and the landscape and represent an economic value of strategic importance for Italy.*

Giuseppe Pulina
Full Professor of Ethics and Sustainability of Animal Production, University of Sassari, President of the Sustainable Meat Association.

WE WON'T SAVE THE PLANET WITH A MEATLESS DIET

The food systems of actual human society appear to cause 20-30% of greenhouse gas emissions responsible for climate change, 70-75% of water consumption through the use of more than 50% of the earth's surface potentially subtracted from the good common. I write "appear" because the numerical values of the impacts and related risks are very different from place to place and have wide ranges of uncertainty depending on the measurement methodologies adopted.

If this data refers to average values of the world's entire agricultural area, instead the increase of their trends on a global scale is absolute. A reduction is evident only in local areas of excellence, such as our Made in Italy, where innovative technological and cultural practices have been implemented for some time. The causes are different. In the first place, entrepreneurial mismanagement and the ignorance of administrators whose consequences are exacerbated by the environmental, social and geopolitical events in progress in many places on the planet. Events that we are all personally experiencing. From climatic variations, to pandemics, to wars, to migratory flows of people fleeing from man-made and climate-generated catastrophes, to the lack of food for a growing world population... It is useless to narrate anything other than hypothesize that from this context of social, environmental and economic emergencies arises the need of our species to adopt a new diet, which is sustainable and which can feed a paradoxically growing world population.

A new diet, a diet that saves the entire planet. In an impressive and effective way in communicative jargon this diet is given the name of sustainable diet. The sustainable diet is therefore the icon of a political change, of a change of behaviours and actions that affects consumers and through them, the administrators of politics.

This brief introduction is not the right place to delve into how to design a sustainable diet – a book of mine on the subject will soon be released – but I just want to underline that its realisation requires the application of a methodology, a technical-scientific paradigm. Yes, precisely technique and science that contrast ideologies and illusions about good and bad foods which in recent years have only generated confusion in the consumer, opening the doors to commercial speculation and lobbying by partisan interest.

Greenwashing and Healthwashing, the falsehoods reported in media communications, books and also unfortunately on labels, are the order of the day. It becomes a show, creating psycho-collective alarm, feeding illusions through alarmism. An emblematic example of this is meat in itself accused of being unsustainable.

So, we ask ourselves, is it true that we should not eat meat to save the planet? Is it true that animal husbandry has unsustainable environmental impacts? Is it true that it is better to eat only vegetables, various seeds, superfoods, high-protein insects?

You will find the answers in this book. By reading you will discover, that with data in hand, through scientific publications and research projects, the production and consumption of meat - when produced and consumed correctly - in addition to being directly essential to human health, contributes to well-being indirectly thanks to the beneficial effects on the environment of the agri-forest ecosystem. Thanks to its perusal, the reader will be able to confidently affirm with a manifesto of statements, against the tide today, that positions the livestock supply chain amongst the most sustainable of human activities! The meat supply chain:

- ***preserves biodiversity**, creating and preserving the landscape in mountainous and hilly areas;*
- ***produces ecosystem services**, through the cultivation of resources and the recycling of biomass;*
- ***supports many interconnected supply chains**;*
- ***cooperates in ecological transition** thanks to the production of renewable energies;*
- ***contributes to food security** by producing a wide range of wholesome food products of high biological value and functional for local and global markets;*
- ***creates bioeconomy and circular economy;***
- ***develops economy** through the involvement of millions of people as operators and workers;*
- ***leads social development** since the origin of agriculture.*

The consequences of "a world without farms" could radically alter reality, affecting an economic, social and cultural heritage that is fundamental to our country, undermining an environmental and landscape balance based also on the presence and actions above all of ruminants in the geographical areas where they have always been present.
But then why is the contrary continually professed? The answer, too, between the pages of the book. Those who believe with conviction that meat is bad for the planet are probably only looking at the tip of some iceberg, not measuring it as a whole, transposing the specific case to the absolute according to a non-scientific opinion-forming approach. Instead, the analysis and judgments must be contextualised in correct scenarios, through scientific measures, with due analysis of the uncertainties of evaluation. We wrote about this in the first interdisciplinary volume in 2018 which is updated in this new volume with even more relevant data and insights treated in boxes and in simplified infographics. We will never get tired of repeating this.
I just have to wish you a good reading and a good reflective exercise so that our decisions are always based on truth and freedom of choice.

Ettore Capri
Full Professor of Agricultural and Environmental Chemistry, Director of the European Sustainable Agriculture Observatory, Catholic University of the Sacred Heart - Piacenza and Cremona.

MEAT AND THE ENVIRONMENT

- THE PRODUCTION OF MEAT AND CURED MEATS: A COMPLEX SYSTEM
- IMPACTS ON CLIMATE CHANGE: CARBON FOOTPRINT
- IMPACTS ON WATER: WATER FOOTPRINT
- IMPACTS ALONG THE SUPPLY CHAIN
- INITIATIVES TO IMPROVE THE SUSTAINABILITY OF FARMS
- THE ENVIRONMENTAL IMPACTS OF THE DIET: THE ENVIRONMENTAL HOURGLASS

Introduction

THE LIFE CYCLE ASSESSMENT (LCA) METHODOLOGY ALLOWS THE CALCULATION OF THE ENTIRE AGRI-FOOD CHAIN'S ENVIRONMENTAL IMPACTS

THE EUROPEAN PRODUCTION SYSTEM HAS THE LOWEST ENVIRONMENTAL IMPACT PER KG OF PROTEIN

WHEN CONSUMED FOLLOWING THE MEDITERRANEAN DIET MODEL, MEAT HAS AN ENVIRONMENTAL IMPACT SIMILAR TO THAT OF OTHER FOODS

The debate on the impacts of food often leads to a punctual comparison of environmental indicators referring to the production of 1 kg of various foods. While providing useful information for the improvement of supply chains, these rankings are of little significance for a few reasons. The first is nutritional: it is very clear, for example, that ***the comparison between salad, rice and meat is wrong regardless, because these foods have different "functions" and contribute in a complementary way to human health.*** *This is discussed in the chapter on nutrition, but it will also be mentioned in this chapter. Entering the environmental merits, the classification of foods based on their impact can lead to the conclusion that those with the most impact, such as meat, must be eliminated to reduce the pressure on the environment. Even this consideration is not particularly consistent with reality because it would suggest that some agricultural or livestock supply chains can be cancelled.*

Those who know how agri-food production works, on the other hand, have very clear the ***constant integration between the various productions*** *to the point that talking about different products is (almost) incorrect. On the other hand, it would be much more coherent to imagine agri-food production as a single large system characterised by many products and as many by-products which almost always find use in the same sector* ***following the principles of the circular economy,*** *which is very fashionable today in the processing industry, but has been known to farmers and breeders for centuries. Entering the point of animal husbandry and the production of meat and cured meats, the debate should therefore not be on the "if" but on the "how" by pushing producers (agricultural and industrial) to constantly improve performance by reducing impacts. In this context, the calculation of impacts becomes a useful reference, facilitating comparisons with oneself or with similar processes, provided, however, that the indicators are interpreted correctly, avoiding misleading considerations such as, for example, those made when dealing with absolute water consumption without referring it to its availability where consumed.*

Finally, further attention must be paid concerning the fact of using kg as a reference unit. There is no doubt that meats and cured meats are among the foods characterised by the greatest environmental impacts when the analysis is carried out per kg of product. Considering that a correct diet involves the balanced consumption of all foods, a correct analysis should consider the ***frequency of consumption and the portions suggested by nutritionists:*** *the multiplication of impacts and quantities is the basis of the* ***Environmental Hourglass,*** *icon of the Sustainable Meat project. According to this representation,* ***eating meat in the right amount does not lead to a significant increase in an individual's environmental impact.***

1 THE PRODUCTION OF MEAT AND CURED MEATS: **A COMPLEX SYSTEM**

The global demand for products of animal origin is increasing, especially in developing countries, thanks to progressive urbanisation, demographic growth and the increase of population's incomes: it is estimated that demand will grow by at least 30% in a sustainable scenario[1], to feed a world population that will reach the objective of 9.7 billion people by 2050. Against this backdrop, global meat production is projected to more than double respect to 2000, from 229 million tonnes to 465 million tonnes in 2050, and that of milk to rise from 580 to over 1,000 million tonnes.

The increase in demand for these products represents a great opportunity for over **1.3 billion** people who have their source of livelihood and income precisely in livestock farming. But this demand can only be satisfied through the rapid expansion of modern forms of farming, aimed at making production systems increasingly sustainable from both an economic and environmental point of view.

This growth in fact must be managed in a context of limited natural resources, as the livestock sector is one of the major users of agricultural land, mainly for grazing and secondarily for the production of raw materials.

Therefore, if on the one hand animal husbandry is under the spotlight for reasons of environmental sustainability, on the other it is good to remember that this sector supplies food with a high nutritional value and with important, positive economic and social implications, contributing to food security and the protection of more difficult territories and rural areas as a whole.

1.1 Animals and plants: a circular system

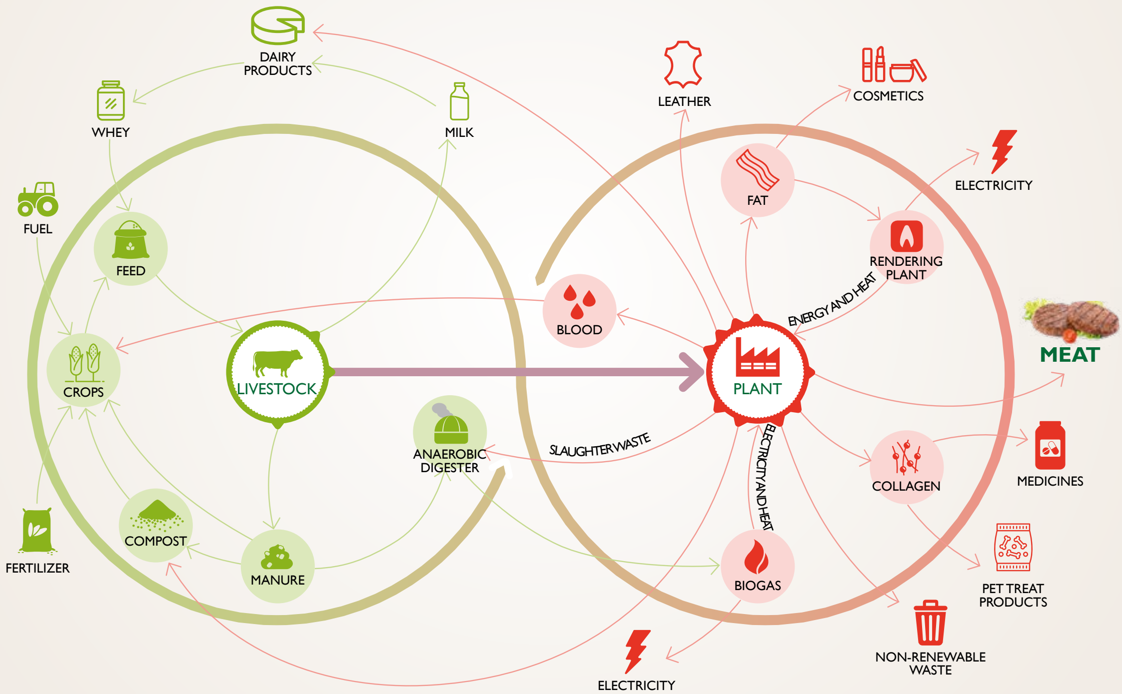
Compared to other industrial sectors, the agri-food sector is certainly the most complex because it is conditioned by the many **interactions between the various production chains** which are substantially integrated into a **model** that can be defined as **circular.** This term has returned "in fashion" in recent years, when one of the main challenges for the sustainability of industrial systems has become precisely that of changing the growth model: from **linear** (extraction of raw materials, transformation and disposal of waste) to **circular, thus maximising the reuse and recovery of waste.** One of the most current definitions of circular economy is that of the Ellen MacArthur Foundation[2] which defines it as **"an economy designed to be able to regenerate itself".** Hence the recent variants of this type of approach that have led to **regenerative agriculture and animal husbandry**[3].

Thinking properly about it, the **circular economy is an approach that farmers and breeders have known very well** and for a long time because the integration between the various material flows is one of the aspects that guarantees the proper functioning of a farm: **straw** which remains from the cultivation of cereals, for example, is often **used for animals (as forage or in bedding)** while the manure (manure and sewage), if properly treated, constitute a valid aid in the **fertilisation of the land.** Focusing on the meat sector, from a quick look at the figure below, one can immediately understand how **bovine supply chain is one of the most complex and circular systems** that exist. In fact, the bovine supply chain produces - in addition to **meat - milk, leather**, many **co-products** generated in the slaughtering phase, destined for the most varied of uses.

In this last field, research and industrial innovation are certainly important to maximise the possibility of reuse. One of the most famous examples is that of the calf **abomasum** which is used for the production of **natural rennet** and is still considered qualitatively the best for the production of all **PDO cheeses.**

A direct fallout of this consideration is the fact that calculating the environmental impacts of a food product and then comparing these with those of a second food without **considering its context**, interaction with the various production chains and nutritional characteristics is a logical error which leads to **partial and often misleading conclusions.**

THE CIRCULARITY OF THE BOVINE SUPPLY CHAIN



1.2 Reducing impacts by seeking efficiency

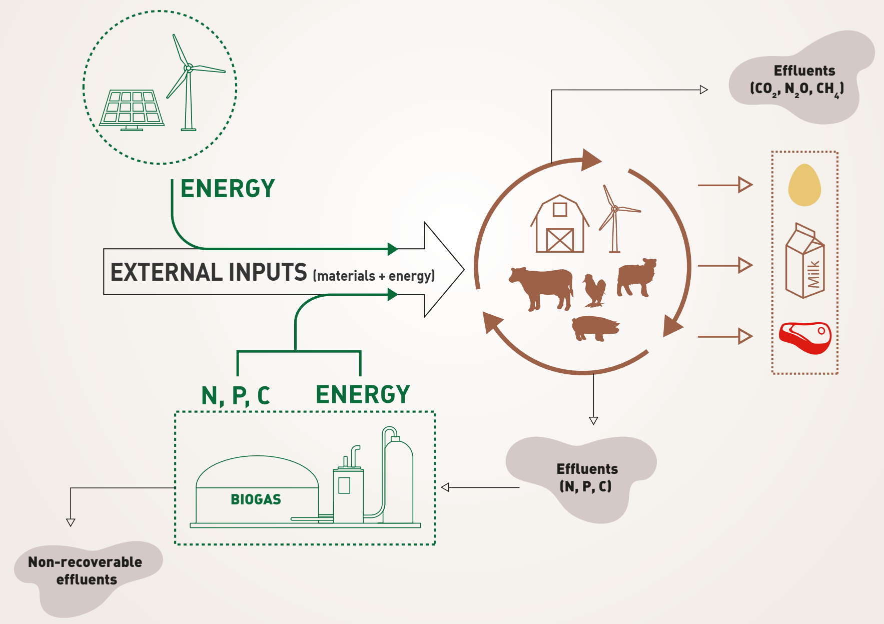
Focusing attention on the environmental impact, it is clear that **the will of operators to reduce pressure on ecosystems** is inextricably linked to the **search for efficiency** which, as is known, is the measure of the resources used to achieve an objective. While the pursuit of economic efficiency is based on a fairly intuitive approach (reducing costs with the same revenues), increasing the environmental efficiency of an agricultural and even more a livestock supply chain, means producing more with fewer material and energetic resources.

Compared to economic efficiency, however, the calculation of environmental efficiency is not as immediate. The main difficulties derive from three aspects.

1. **Dealing with living beings** opens the discussion to many aspects of an **ethical nature** (for example, less space for farmed animals entails lower environmental and economic impacts). Although the quality of life of animals and the pressure on the natural environment fall into two different fields of study (in fact in this book they are treated in two separate chapters), the connections between the two are very close making it often impossible to address one without also considering the other one.

2. The profound integration of agri-food chains creates a **balance of relationships**

PRODUCING MORE WITH LESS: GREATER EFFICIENCY ALSO MEANS GREATER ENVIRONMENTAL SUSTAINABILITY



and flows that must be considered every time a decision is made. For example, the decision to start the effluents generated by a farm for biodigestion has repercussions both on the system that produced the material and on the farms that receive it (or that should have received it). It is therefore clear that the analysis cannot be trivialised with the evaluation of a single process, but as far as possible with the analysis of the **production systems in their entirety.**

3. Once the problems of an ethical nature have been overcome and the network of relationships between the systems in question have been reconstructed, then **difficulties of a methodological nature** arise in the phase of impact analysis. In fact, when the analysed system generates two or more different products (as happens in the case of animal husbandry) the total impact must be distributed proportionally between each of them. In other words, given as 100 the impact of breeding an animal, how much of this must be attributed to the meat obtained? How much to any eventual descendants generated during its life? How much to other products such as milk in the case of bovine? What about effluents used as fertilizer or to produce energy? The correct distribution of the impact must therefore follow appropriate methodological rules, known as "**allocation**" rules.

There are many questions but the answers are not always able to provide all the solutions sought after. So how can this environmental efficiency be increased?. As is often said, **virtue lies in the middle.** In other words, it is necessary to study the system thoroughly and build a picture (as complete and coherent as possible) of all the elements involved and the relationships between them. Environmental relations, animal welfare, but also social and economic. After that, it is **necessary to identify priorities** on the environmental front and develop strategies capable of effectively addressing them without however compromising the priorities in other areas. The path towards a greater degree of sustainability is therefore tortuous, but possible: it is just a question of finding the right balance.

1.3 How to read the impacts

It is therefore clear, from what has been said so far, that when talking about sustainability one cannot focus only on environmental issues, but the analysis must also be extended to other aspects, such those of as social, economic and animal welfare.
Having said that, this chapter aims to enhance environmental issues above all: it is therefore advisable to immediately clarify some technical aspects, essential for the correct understanding and interpretation of the following sections.

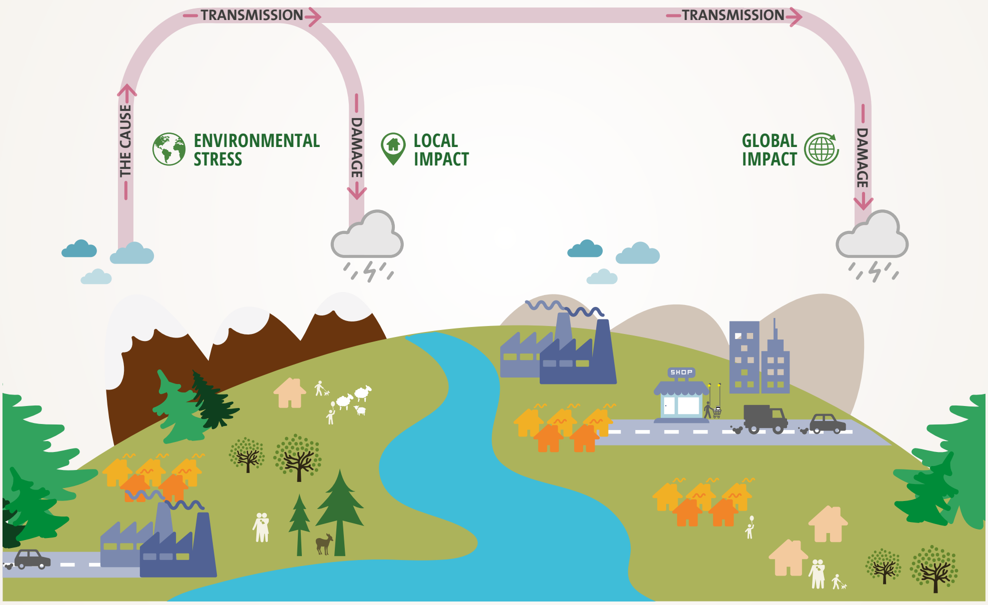
1.3.1 The importance of context

Very often the term "environmental impact" confuses two phenomena which are, in reality, clearly differentiated: in fact, it would be more correct to distinguish between **environmental stress factors** and **environmental impacts**, as summarised in the following infographic. An **environmental stress factor** is any interaction between a human activity (for example a production process) and the environment, while the **environmental impact** is the alteration (positive or negative) that the environment undergoes. The introduction of pollutants into a river is an environmental stress factor, but the damage to aquatic organisms caused by the substances released is an environmental impact. The distinction between cause and effect might seem like a purely academic distinction, but it's actually very useful for describing better the next concepts. In particular, it should be emphasised that the relationship between environmental stress factors and environmental impacts is not always obvious and can be influenced by various causes.

One factor is **time**: under certain conditions, the environment has the capacity to almost immediately neutralise the effects of the perturbation and return (almost) to its initial state. However, this natural phenomenon has limits: when the environmental stress factors are excessive and too pressing, the ability of ecosystems to "**self-repair**" fails and the environmental impact manifests itself. A little like what happens when alcoholic drinks are consumed: it does not create problems if the doses and frequencies of consumption are such as to allow the body to dispose of the alcohol contained. On the other hand, when you exaggerate with consumption (as in the case of too frequent or excessive environmental aspects) then you get drunk (high impact) and sometimes the damage is irreversible.

GLOBAL AND LOCAL IMPACTS: CAUSE OR EFFECT

"THE ENVIRONMENTAL STRESS FACTOR IS THE CAUSE, THE ENVIRONMENTAL IMPACT IS THE EFFECT (DAMAGE)"



Then there are the dimensions of the **environment** in which one aspect manifests itself: if a production process is characterised by a repeated emission of 10 grams of pollutant into the water, the relative impact will be very different if this happens in a small mountain lake or in the middle of the Atlantic Ocean (due to dilution effect).

Other phenomena that influence the difference between aspects and impacts are the **chemical-physical and biological mechanisms** that operate in the environment following the release of a potentially dangerous substance or the irrational use of biocidal practices. This is, for example, the case of fertiliser excess: once nitrogen is added to the soil, the biochemical reactions of the soil leads to the formation and release of nitrous oxide (N_2O) into the atmosphere, which has a direct climate-altering impact decidedly greater than the indirect one due to the release of CO_2 for the production of the initial nitrogen fertiliser.

A further variable to be taken into consideration is the **distance** between the manifestation of the environmental stress factor and the environmental damage generated. If, for example, the machinery of an important production plant generates noise in places that are very distant from each other, the environmental stress factors (therefore the noise) will not accumulate and each machine will only cause annoyance (damage, therefore the environmental impact) to people nearby. In this case we speak of **local impacts.** When, on the other hand, the environmental stress factor concerns the consumption of a global natural resource, such as oil or the release of pollutants that pervade the atmosphere, such as CO_2, the entire world population is damaged. In this case we speak of global impacts.

1.3.2 Impacts and their indicators

It has been said that an **environmental stress factor** can cause a positive or negative alteration on the environment, i.e., an **impact**, with which to measure it is necessary to identify an **indicator.** To explain with another example, if a business process involves the emission of gases into the atmosphere (environmental aspect) it is possible that some of these gases are climate-altering, i.e., they contribute to global warming (impact). To measure this impact, the Carbon Footprint indicator is typically used. Quantifying the carbon footprint of an emission first of all means converting the contribution of each climate-altering gas into the **quantity of CO_2** which, released into the atmosphere, **would have caused an equivalent contribution to global warming**: once all gases are quantifiable with reference to the same unit of measurement, the carbon footprint of the company's emissions is simply their sum, expressed in kg CO_2 eq. Generally, the lower the value of the indicator, the less impactful the process is.

To measure an environmental impact are one or more indicators exist, which can be quantified in various ways.

The **Life Cycle Assessment (LCA) method** (described better in section 1.3.3) is excellent for indicators that quantify an impact on a global scale (for example, quantifying the carbon footprint, an indicator of global warming). The LCA method is useful in this case as it takes into account the impacts generated along a product's entire supply chain - **from the cultivation of raw materials to distribution and consumption** - regardless of the geographical area in which these impacts were generated. On the other hand, the LCA approach has some limitations in the

analysis of local impacts: in fact, the sum of all impacts along the supply chain could lead to conclusions that are inconsistent with the characteristics of a specific local situation. The most typical example of this possible inconsistency is that of water consumption. The total value of water consumed along a complex process is not significant if it is not referred to local conditions, for example the availability of water in the catchment area where the activities being evaluated are located. In other words, it is very clear that limiting the analysis to numerical data only (regardless of the context) from the question "does the consumption of 10 litres of water in Israel have a greater impact than 20 litres in Sweden?". Questionable conclusions could be reached.

Extricating oneself from the complex world of environmental indicators, subject to constant revision and improvement work by the international scientific community, is not trivial. The best approach is always the same: start from the context. In other words, **the ideal solution is to select a set of global and local indicators capable of capturing key aspects of the product under analysis and then interpret their values consistently with their scientific significance.**

1.3.3 The LCA analysis

One of the most used methods for quantifying the environmental impacts of a production system is the analysis of the life cycle (Life Cycle Assessment, LCA), an approach regulated by the international standard ISO 14040.

A key aspect to understand its potential and limits is the fact that **it is not a direct measurement tool, but an analogue model** that will never be able to capture all the complexity of the real world. However, this should not be seen as a disadvantage, but as a challenge to the continuous improvement of the models. Despite having been subjected to various criticisms, the LCA method remains an **effective** tool, capable of investigating the effects of many environmental aspects. The investigation carried out with the LCA method typically leads to three consequential results:

- **quantify** (albeit with some approximation) the various sources of impact linked to a process;
- **identify** possible areas for improvement;
- **compare** similar processes, provided they are analysed with the same approach (same assumptions, same quality of data used, same calculation algorithms).

The last point is the most delicate, and must be addressed carefully. The fact is that the **LCA method** arose in the world of industry, only to be **adapted to the agri-food supply chains at a later time.** This adaptation, which certainly brings many advantages, however suffers from conceptual and operational limitations which must necessarily be taken into account when analysing the results.

A first aspect concerns the complexity. Agricultural or livestock systems are only apparently simple: compared to industrial ones, they are influenced by many more variables (climate, cultivated varieties, diseases, crop precessions, etc.) which makes its control much more complex, as well as a precise analysis of the impacts. As agronomists say, "everything changes when it rains outside": if, for example, a heavy hailstorm hits an apple orchard during flowering, the harvest will be severely penalised and with it the data on the environmental impacts referring to

the kg of apples produced. In a case like this, is it possible to evaluate the farmer as "less sustainable"?

Another limit concerns the **functional unit.** When analysing the production of an object, the usual tendency is to relate the environmental impacts to a production unit, for example the emissions generated per kg of steel, per kWh of electricity, and so on. When the same assessment is transposed to the world of food, interpretation can be difficult: **livestock farming or intensive agriculture systems**, for example, **lead to minor impacts per unit of product**, but can create local problems (for example, release of nitrogen to groundwater) if the processes are not adequately managed. Those who study the food and livestock supply chains should, therefore, give much more weight to local impacts than what is done in the analysis of industrial processes. In this sense there are environmental aspects such as biodiversity, ecosystem services, **soil carbon sequestration**, which allows a more in-depth view of the systems and contribute to a better valorisation of any process improvement actions.

The fact that the impacts of cultivation are influenced by what happens over the years should shift the attention of analysts from the impact of 1 kg of crop (e.g., wheat) to the impact of 1 hectare of field or even the impact of 1 hectare for a certain period of time, for example the length of a crop rotation (typically 4 years), thus including all the crop systems involved.
Another aspect of the need for a careful choice of the functional unit in the case of agri-food chains is the nutritional quality of the products made. By way of example, if quality pasta can be obtained with durum wheat with a higher protein content, it is probable that lower cultivation yield varieties will have to be used or, in any case, a greater supply of fertilisers will be necessary at crop level. The same is true for handcrafted products which always have a greater impact than "industrial" ones. What are we going to do about sustainability? Pay close attention to the comparison between the products that are taken into consideration. In the case of wheat, for example, it might make sense to compare the productions per kg, but normalising them to a given protein concentration in order to obtain information that is comparable in the best possible way.

Finally, an operational limit. While the activities of an industrial system take place in a few well-defined production plants, in the case of agricultural or livestock supply chains, production can take place in hundreds if not thousands of farms scattered throughout the territory. In truth, this limit is gradually overcome by IT tools for data collection which, if used correctly, can transform the problem into a value: that of having an almost total coverage of primary data which allows us to represent very precisely the impacts of even very complex supply chains.

NUTRITIONAL LCA (NLCA)

In 2021, FAO[4] launched a project aimed at further developing the LCA methodology in the environmental and nutritional fields. The project involved 30 sector expert researchers from 18 countries. The ***key aspect*** *around which the entire project revolves is* ***the function attributed to food.*** *In other words, in carrying out any LCA analysis it is essential to uniquely identify and define the function of the product (or process) studied, as all impacts will be reported in relation to a unit of this function. An* ***nLCA*** *is an LCA study in which* ***the impact of a food is not related to its mass*** *(e.g., impacts related to the production of 1 kg of food)* ***but to its nutritional value.***

However, there is a difficulty, namely the fact that with 'nutritional value' we indicate a set of characteristics related to food, not a single aspect. For example, characteristics such as the quantity of one or more nutrients (e.g., ***protein, glucidic, lipidic****) or the correct quantity based on the quality of the nutrients (e.g.,* ***energy content****) fall into the 'nutritional value' category. To simplify the choice of functional unit, some recent studies have explored the integration of various nutritional characteristics into an aggregate value: the* ***NRF index*** *(Nutrient-Rich Foods Index)[5]. A food's NRF summarises in a single number a series of nutrients to be encouraged (nutrients that are essential or at least important for the prevention of certain diseases) or to be limited (nutrients that can be poten-*

tially harmful and therefore must be consumed in moderation). It is worth noting that the classification of a nutrient into one of these two groups basically depends on the whole diet, which varies in different parts of the world and between different target populations.

By way of example, two studies are reported below in which various foods were compared on the basis of some of their nutritional characteristics. The first study[6] compared the environmental impact of 15 foods, including beans (Fabaceae), cauliflower (Brassica oleracea), beef, fish, corn, milk, peas (Pisum sativum), potatoes (Solanum tuberosum), quinoa (Chenopodium quinoa) and rice (Oryza sativa). For each food, the impact was recalculated three times, i.e., using three alternative functional units: amount of food (specifically, 100 g of edible fraction); quantity of food necessary to provide 13 g of total essential amino acids (regardless of the deficiency of some amino acids); amount of food needed to supply all the individual essential amino acids for a 70 kg man. The first functional unit is a fixed quantity of food for all products (100 g of edible fraction), and has registered higher carbon footprint values for beef and fish. The shift to specific functional units for essential amino acids, however, resulted in a marked reversal in the rankings, with beef, cauliflower and rice showing better environmental performances than the other 12 products.

The second study[7] used as an example refers to the concept of Nutrient-Rich Foods Index in that it uses a single functional unit (nutrient density) which itself takes into account at the same time a high content of nine essential nutrients (proteins, fibre, vitamins A, C and E, calcium, iron, magnesium and potassium) and three nutrients to limit (saturated fat, sodium and added sugars). The study fails to fully take into account the nutritional complexity of the foods investigated: for example, it does not distinguish between polyunsaturated and monounsaturated fatty acids, nor between different essential amino acids. Furthermore, the study does not take into account the cooking process and quantifies the impacts associated with the bulk food production phase alone. However, although partial, the results show a new perspective. For example, they show that lean cuts have half the impact of untrimmed cuts.

What has been said so far leads to three considerations:

- *the functional unit in an nLCA study can be defined in many ways, taking into account both the nutritional characteristics of the food and the consumers of this food (nutritional needs and dietary habits of the target population);*
- *nLCA studies should be undertaken by multidisciplinary teams involving nutrition and health scientists as well as environmental scientists;*
- *the boundaries of the studied system should include all phases of the product life cycle, as the final processing, storage and cooking of a food can significantly modify its nutritional value.*

EVALUATION OF PROTEIN QUALITY HALVED THE ENVIRONMENTAL IMPACT OF MEAT AND DAIRY PRODUCTS

By Susanna Bramante

The real environmental impact of meat and dairy products is half of that calculated so far. *This is confirmed by a study[1] which evaluates the environmental impacts of foods on the basis of their complete nutritional value. Calculating the environmental footprint per unit of protein produced does not provide an accurate assessment of the impact of food, as* ***proteins are not all the same in terms of nutritional quality*** *and therefore the nutritional value of foods varies considerably.*

In the study, the researchers measured the quality of proteins with the ***DIAAS[2] method****, Digestible Indispensable Amino Acid Score, which evaluates the digestibility of the essential amino acids by attributing them a score in values lower or higher than 100. In practice, a DIAAS of over 100 indicates that the protein has very high digestibility and quality, such as animal source foods (ASF), and is a good protein completion for foods that have lower quality, such as plant foods[3].*

In fact, ***animal proteins show the highest DIAAS because they are complete with all the essential amino acids, highly digestible and quickly absorbed;*** *on the contrary* ***plant proteins are incomplete,*** *with limiting amino acids and linked to fibres and* ***anti-nutritional compounds*** *which restrict and, in some cases, compromise their digestibility and absorption. For this reason, the functional units for calculating the environmental impacts of ASF must take into account this fundamental difference with respect to plants: in substance, since their nutritional power is greater per unit of food, consequently their impact on the environment must be commensurate with this superiority. In the study cited[1], the researchers considered, taking them from specialist literature, the DIAAS of four ASF (beef, cheese, eggs and pork) and four plant foods (nuts, peas, tofu and wheat), and used them to assess the environmental impact of these foods based on their nutritional value.*

All animal products had more than 100% DIAAS, while plant protein sources scored below this threshold, with wheat scoring a particularly low (43%).

With this new method of reference to the functional unit it is possible to ***calculate more accurately the environmental impact*** *of animal products considering that it has been practically halved, in the case of beef, while those associated with vegetable products, such as for example wheat bread, increased by almost 60%. Basically, plant foods having a lower protein quality, must be taken in higher quantities in order to obtain the same protein benefit compared to animal foods, which determines an increase in production at population level, with consequently a higher environmental impact, to reach the same recommended intake level.*

This study highlights the need to consider the overall nutritional value of foods in order to calculate their true environmental impact, because ***simply relying on the content of nutrients rather than on their quality,*** *as undertaken up until now,* ***is not sufficient*** *to make realistic* *comparisons among nutritionally very different foods. According to the authors, comparing apples and nuts, or meat and wheat, even under the sole aspect of iso-protein intake, makes little sense therefore and leads to misleading environmental footprint results, because the different protein qualities do not make them directly comparable. It is therefore essential to* ***consider protein quality as a complementary functional unit*** *in the evaluation of the nutritional life cycle, the so-called n-LCA, in addition to the digestibility and bioavailability of all bio-active substances, even non-protein ones, such as micronutrients. Ultimately, the authors suggest that environmental impact experts integrate science into the Environmental Footprint assessment method of the entire LCA, in order to provide accurate and transparent results on food sustainability and the correct tools to reduce the environmental impacts of the entire food chain.*

[1] *McAuliffe G.A., Takahashi T., Beal T., Huppertz T., Leroy F., Buttriss J., Collins A.L., Drewnowski A., McLaren S.J., Ortenzi F., van der Pols J.C., van Vliet S., Lee M.R.F., Protein Quality as a Complementary Functional Unit in Life Cycle Assessment (LCA), Int J Life Cycle Assess, 2023, 28(2):146-155 doi: 10.1007/s11367-022-02123-z.*

[2] *Lee TK W., Weisell R., Janice A., Tomé D., Kurpad A.V., Uauy R., Research Approaches and Methods for Evaluating the Protein Quality of Human Foods Proposed by an FAO Expert Working Group in 2014. The Journal of Nutrition, 2016, (146): 929–932, https://doi.org/10.3945/jn.115.22210.*

[3] *Burd N.A., Beals J.W., Martinez I.G. et al., Food-First Approach to Enhance the Regulation of Post-exercise Skeletal Muscle Protein Synthesis and Remodeling, Sports Med. 2019, 49 (Suppl 1): 59–68, https://doi.org/10.1007/s40279-018-1009-y.*

2 IMPACTS ON CLIMATE CHANGE: **CARBON FOOTPRINT**

One of the main issues of debate regarding the sustainability of meat and cured meats is their contribution to climate change. An in-depth study of this topic therefore is essential, in order to give the problem both the right weight and understand how to correctly evaluate available data.

2.1 How many emissions are generated?

The global warming and climate changes that our planet has been experiencing over recent decades are caused by the **enhancement of a natural phenomenon** known as the "greenhouse effect". **Such effect is linked to the atmospheric increase of so-called climate-altering gases (also known as greenhouse gases, or GHGs), which capture part of the solar radiation reflected from the Earth, effectively increasing the atmospheric temperature.** Greenhouse gas emissions are a phenomenon that has always affected the Earth: think, for example, of the natural emissions from volcanoes, spontaneous fires, oxidation of organic matter, respiration of organisms, etc. Without these emissions, and without the resulting greenhouse effect, the temperature of our planet would be around -15°C, unsuitable for hosting life as we know it.

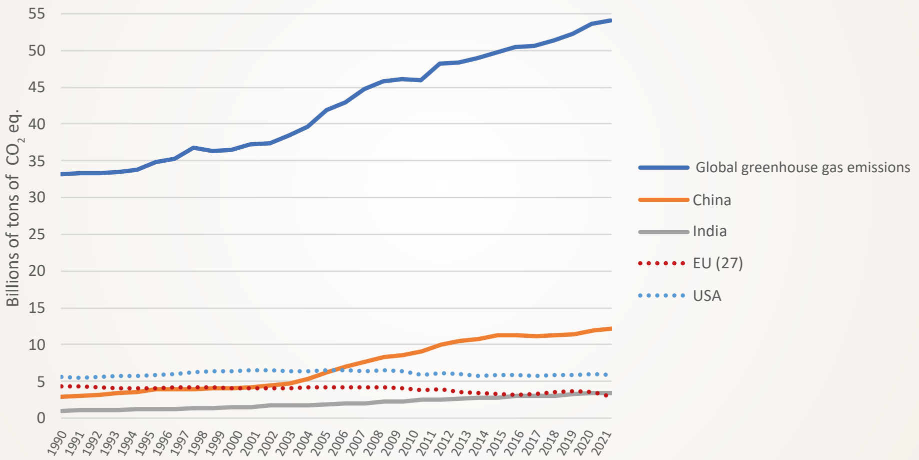
Although this effect is in some cases (political, media, and to a minor extent scientific) not acknowledged or considered irrelevant, one fact is certain: starting from the industrial revolution of the 19th century, greenhouse gas emissions have constantly increased. Not for natural causes, but because of the intensification of human activities, as shown on the next page (+54% during the period 1990-2019).

Analysing the same data by production sector, it is possible to observe how the use of fossil fuels for the production of energy is one of the first sources of emission increase, followed by transport, manufacturing and construction industries and, **in fourth position, from agricultural production.** As also confirmed by the FAO[9], the latter is in fact **responsible for just over a tenth of global emissions.**

To have a complete picture of the entire agri-food chain, the impacts linked to the **change in land use**, closely connected to the methods of agricultural production (e.g., deforestation), and those upstream and downstream of the agricultural phase (e.g., production of fertilisers, food processing and cooking), are indicated in the graph generically as the **industrial phase.** The percentage contribution of the three components varies greatly between developed and developing countries. In the former, in fact, the industrial phase represents more than half of the overall impact, above all due to the disposal of food waste (an issue closely connected to that of waste) and the processes of retail sale and home cooking of food. In developing countries, the situation is opposite to the one just described.

GLOBAL GREENHOUSE GAS EMISSIONS, BY COUNTRY

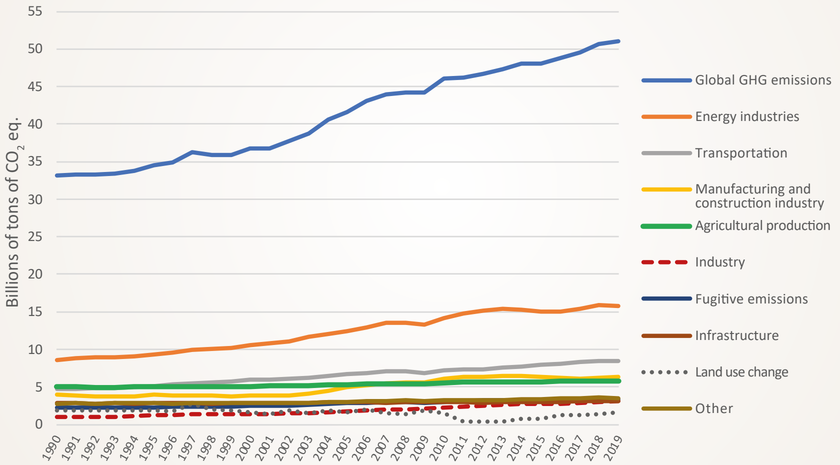
in billions of tons of CO_2 eq.



Source: Our World in Data[8].

GLOBAL GREENHOUSE GAS EMISSIONS, BY PRODUCTION SECTOR

in billions of tons of CO_2 eq.



Source: Our World in Data[8].

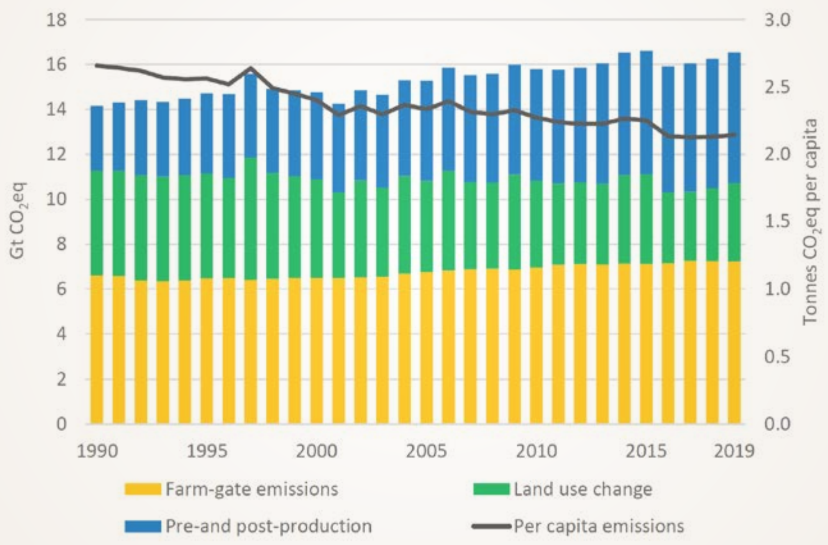
Taking into account the three components, globally **the entire agri-food chain accounts for around 30% of greenhouse gas emissions** (data FAO[9]).

2.2 The impact of agricultural production has been reduced over the last 30 years

In addition to analysing agricultural production in absolute values, comparing its emissions with those of other productive sectors, it is equally interesting to **verify the trend of these emissions over the years in relation to the increase in population.** The data clearly show that over the last 30 years **the annual per capita emissions** of the main productive sectors have remained substantially constant or even increased, albeit with large differences between the various world economies. **Agricultural production is the only one that shows a constant reduction** (about 20% in the time period 1990-2019), demonstrating the fact that innovation makes it possible to produce an ever-increasing amount of food with a limited increase in impacts.

FAO data confirm the virtuosity of the agricultural sector: in the figure below, the trend of emissions per kg of food shows how these have gradually reduced over the last sixty years, especially for livestock supply chains. The production of cereals, on the other hand, shows a slightly different trend, probably due to the fact that productivity increases in this sector are linked in particular to the increase in energy-intensive inputs (fertilisers and pesticides), whilst in livestock production increases are accompanied by the reduction of inputs related to animal maintenance.

GLOBAL GREENHOUSE GAS EMISSIONS FROM THE AGRI-FOOD SYSTEM
by life cycle stage and by per capita emissions

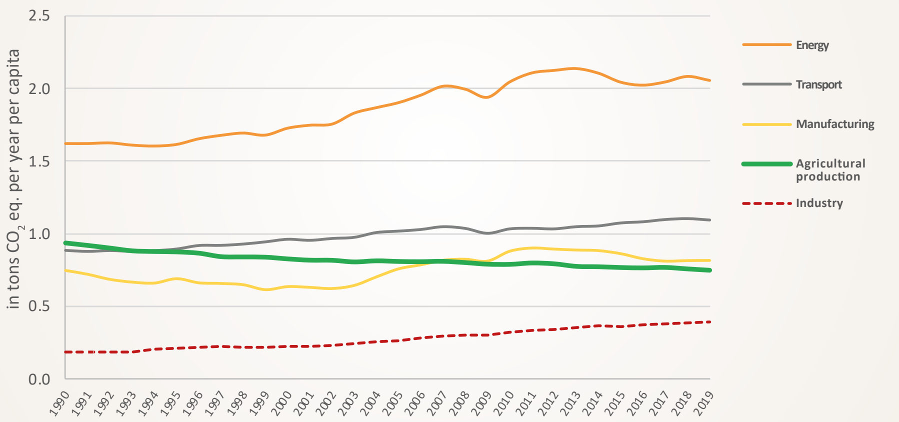


Source: FAOSTAT Analytical Brief 31[9].

Although the global trend of livestock supply chains appears to be clearly improving, in absolute terms the production of meat inevitably has a greater impact than the production of vegetable products. The reason is easy to understand: in the case of vegetables, the cultivation processes are immediately followed by the industrial phases (processing, distribution, conservation, cooking, waste disposal), while the production of meat requires a **double step**: the cultivation of cereals and farm-

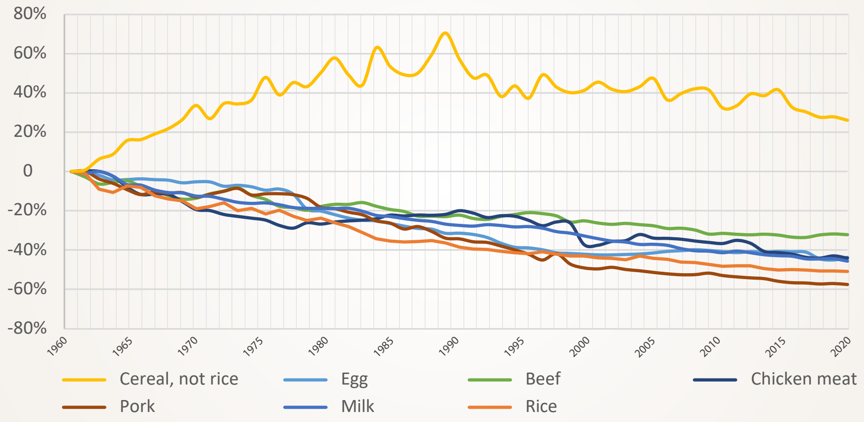
GREENHOUSE GAS EMISSIONS PER CAPITA, BY PRODUCTION SECTOR

in tons CO_2 eq. per year per capita



Agricultural production is the only one that shows a significant reduction.
Source: Our World in Data[8].

GREENHOUSE GAS EMISSIONS PER TON OF FOOD PRODUCED



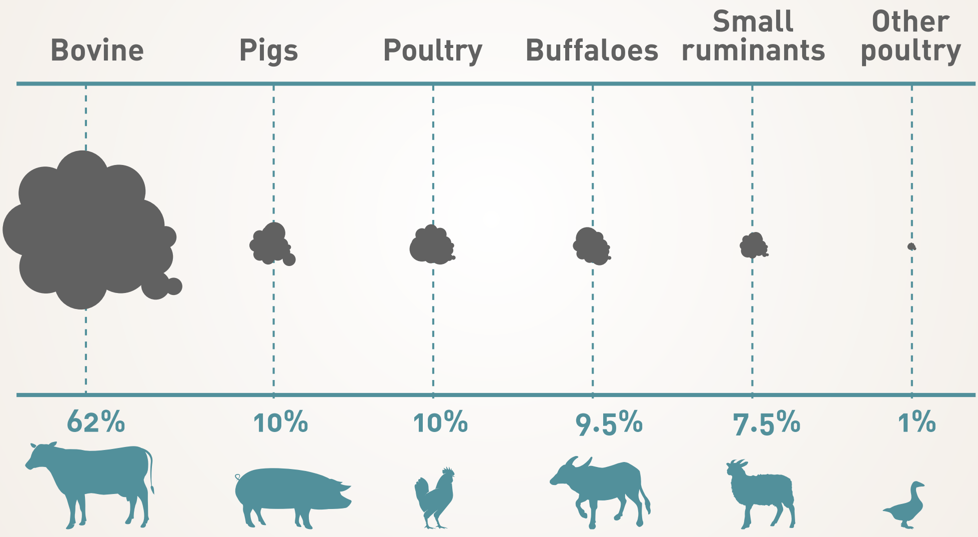
The data refers to the period 1960 – 2020 and the various trends are shown as changes (positive or negative) compared to 1960.
Source: Faostat[10].

ing animal head. The farming process is a complex phase of the supply chain, with extremely variable impacts depending on the farming practices and the species raised. Globally, greenhouse gas emissions from the livestock sector are mainly attributable to bovine farming (about 62%), followed in importance by pigs, poultry and buffaloes (about 10% each) and finally by small ruminants (7%) and other poultry (1%).

If it is true that meat greenhouse gas emissions are inevitably greater than those attributable to vegetable products, it is equally true that the nutritional properties of the latter are absolutely not comparable to those foods of animal origin. The key to greater sustainability is therefore not to completely abolish meat products, but to lower their impacts as much as possible through the continuous improvement of farming practices. At the same time, however, **conscious consumption of these products is equally important, especially in terms of per capita quantities.** In this regard, it is estimated that in the next decade the increase in population and the improvement of living conditions (income growth) in developing countries will lead to a drastic increase in the quantities consumed (compared to the global average for the period 2018-2020, an increase of +14% is estimated by 2030). In Italy and in many other high-income countries, on the contrary, the volumes consumed are stabilising (as better shown in **section 5.2 of the Nutrition chapter**) and instead there is an increasingly marked preference for fine cuts of meat. The reasons are to be

GREENHOUSE GAS EMISSIONS FROM VARIOUS LIVESTOCK SECTORS

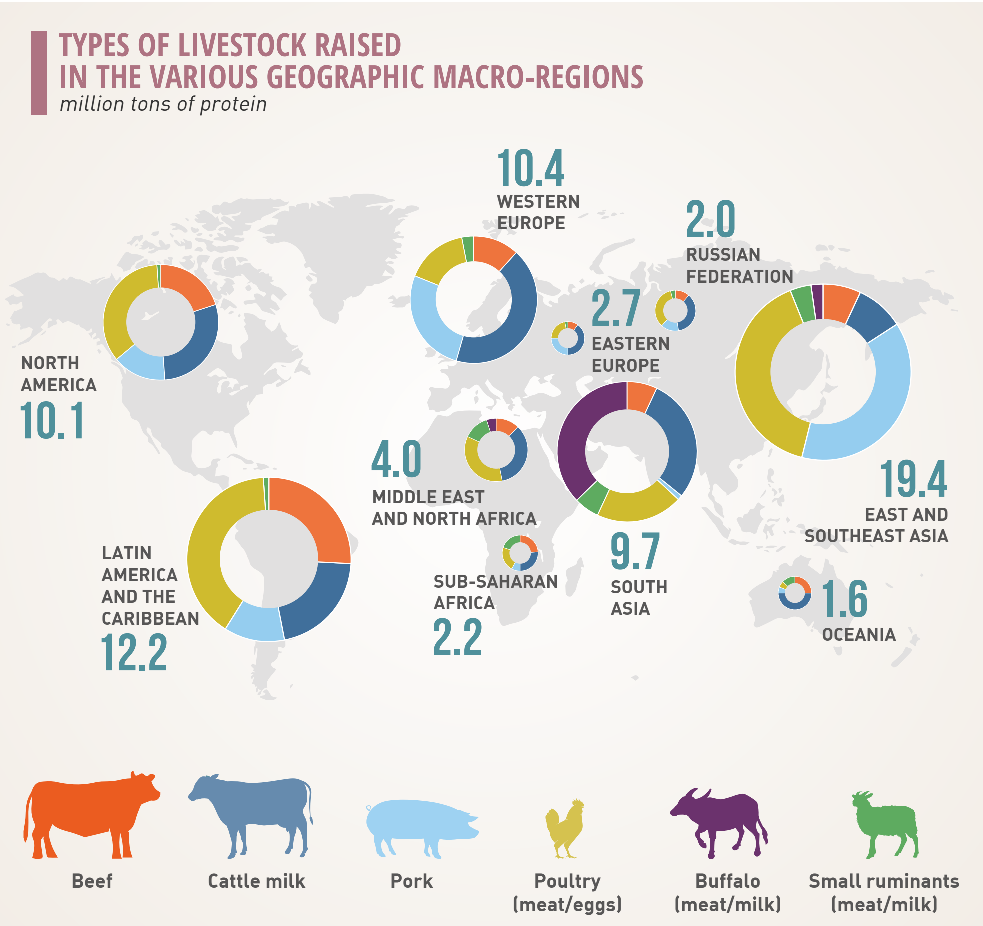
in million tons of CO_2 eq.



Global aggregate values.
Source: FAO-GLEAM [11].

found both in the changes in consumer preferences and in the aging of the population[12].

Obviously, a comparison based only on the global contribution to the greenhouse effect is **simplistic and scientifically incorrect**: in fact, each species supplies various types of goods (meat, milk, eggs, but also wool, leather, etc.) and sometimes even services (for example, buffaloes are still today one of the main driving forces in the rice fields of South East Asia[13]) and therefore represent a precious resource from many points of view.



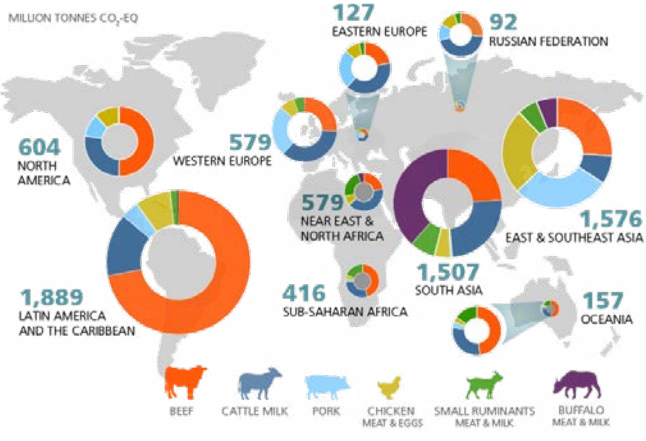
The numbers indicated represent the production in terms of millions of tons of protein (meat, milk, eggs) ready for consumption, net of waste.
Source: FAO-GLEAM [11].

GLEAM
A PROJECT TO MEASURE THE ENVIRONMENTAL IMPACT OF FARMS

Among the many activities of FAO, the GLEAM (Global Livestock Environmental Assessment Model[11]) project is certainly worthy of note, aiming to analyse, through the life cycle analysis (LCA), the environmental impacts in the worldwide production of meat and to identify possible improvement actions.

*An important aspect concerns the **differences** in production between the various areas, **both in terms of species reared and farming systems:** in **South America** the farming of beef prevails, with mostly extensive systems; in **Asia** production is rather focused on dairy cattle and pigs, but a significant share can also be attributed to buffalo farming; **North America** is a large producer of beef in "industrial" systems, while production in **Europe** is of the semi-intensive type, with a fairly balanced distribution between species (and a slight prevalence of pigs). These differences in terms of species and farming systems obviously also correspond to differences in terms of emissions. The most impacting species remains the bovine (meat and dairy), above all due to the methane generated by enteric fermentations, while the least sustainable system (for which there are therefore the highest emissions per unit of production) is extensive farming. One conclusion of a political-strategic type that can be reached is that the interventions to improve the sustainability of the livestock sector must be calibrated on the peculiarities and needs of the regions to which reference is made. For example, a reduction in per capita consumption would be desirable in regions where they are very high (for example in North America). Where, on the other hand, the environmental impacts are very low and consumption is fairly in line with nutritional suggestions, such as in Europe for example, probably the most important aspect for citizens could be that of animal welfare, on which further improvements to already very advanced regulations are certainly possible.*

BREAKDOWN OF GREENHOUSE GAS EMISSIONS
divided by geographical area and by species



The numbers shown represent production in terms of carbon footprint (millions of tons of CO2 eq.).
Source: FAO-GLEAM [11].

2.3 Global vision and local vision: attention to the interpretation[13]

The analysis of data relating to climate-altering gas emissions must be conducted with great precaution to avoid misinterpretations due to the geographical scale of the problem.

Assuming that CO_2 emissions generate a global impact closely correlated to the production phase of goods and services, it can be misleading to analyse them in a partial way, attributing them to different areas in the world or dividing them between different production chains. For example, one aspect to pay attention to is the tracing of the impacts that lead to the production of an asset (upstream processes). Think of any good (item of clothing, smartphone, computer, etc.): in most cases, its emissions are attributed to the geographical area (e.g., China) in which the object was produced, without considering the fact that this asset was then purchased and used elsewhere. Without also considering the fact that it derives from the assembly of various components, often coming from different countries around the globe. A specular aspect of the first is the tracing of the impacts downstream of the production of the good. In the case of agriculture, if we take corn as an example, a global vision does not allow us to distinguish its destiny in a simple and unambiguous way: energy production, human nutrition, animal feed? And, if it was intended for livestock, how to attribute it to the supply chains of eggs, milk or meat?

This example, as well as many others (think of soybeans), lead to the conclusion that when global emissions are analysed, the more its broken down in detail, the more the risk of making mistakes or, worse, arriving at misleading considerations, is very high. So, what is the best way to "handle" the data related to climate-changing emissions? Two very different and sometimes complementary approaches can be recognised.

One **approach** is of the **macroscopic** type, starting from global and absolute data (annual emissions) and is used to understand the general dynamics, as in the case of macroeconomic analyses. For example: in terms of reducing the carbon footprint, what is the advantage of investing in renewable energy? What is the impact of deforestation? These are typical examples of macroscopic analyses, useful for framing an entire production sector in terms of carbon footprint. From this perspective, however, it is difficult to find a direct correlation between sectors, for example between the consumption of a specific food and deforestation.
Another approach, of the "**analytical**" type, putting the products at the centre of the analysis using the typical (but not exclusive) vision of the life cycle analysis. In this case, the assessments are useful for identifying the critical issues present in specific points of a production chain and maximising its efficiency to reduce impacts. **From this perspective, given the high level of detail, it is much more complex and trickier to arrive at considerations of a global or in any case of a large scale.**

2.4 The biogenic carbon cycle

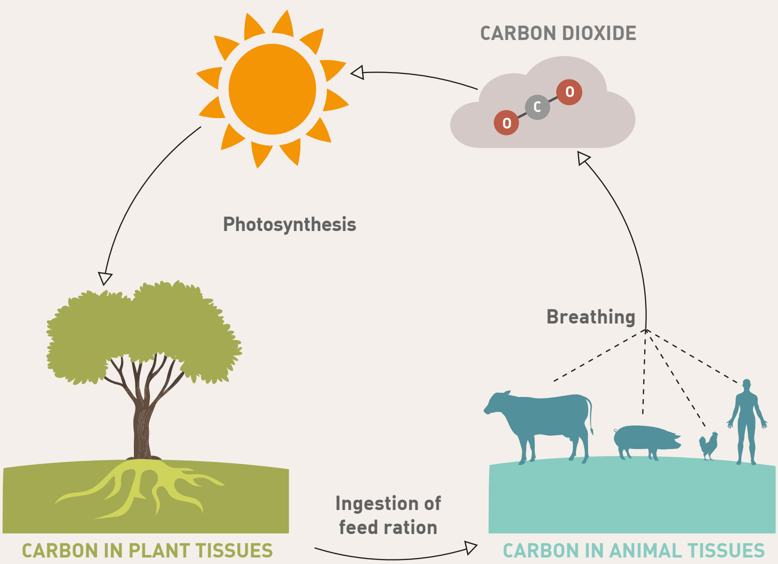
The calculation of the greenhouse gas impacts of an agri-food system must primarily address the issue of the so-called "**biogenic emissions**".

As mentioned above, the climate changes we are concerned about today are the result of the increase in climate-altering gas emissions due to human activities, whereby, for example, **respiration (of plants, animals and microbes), natural emissions from volcanoes and natural fires are not counted.**

While in the case of fossil fuels it is clear that the carbon cycle is "open" (burning **coal, oil and natural gas releases CO_2** molecules which will return to fossil fuel only in millions of years), in the case of agricultural production, however, the **cycle** is "**closed**" not in fossil times, but biological, in the sense that the growth of photosynthesizing biomass (plants, algae or bacteria) allows the absorption of part of the CO_2 emitted, in theory all that of biogenic origin and also part of the fossil one engaged in the production system.

This last aspect opens the discussion between experts from various disciplines: to what extent are agriculture and animal husbandry a problem and to what extent a solution? **If it is true that agricultural and livestock systems are a source of greenhouse gases, it is also true that agri-ecosystems are capable of absorbing part of the emissions with a cyclical flow regulated by a continuous exchange between plants, animals and surrounding environment.** The interest in this approach is constantly augmenting also because agricultural and livestock operators see the opportunity to enhance some practices by generating carbon credits to be used for offsetting operations inside or outside their value chain. Let us try to understand what are the elements that make this subject complex.

BIOGENIC CARBON CYCLE
simplified version



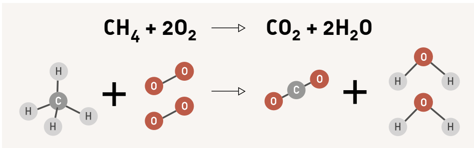
Livestock, like all other aerobic (i.e., living by respiration) living things, including humans, are constantly producing carbon dioxide as a result of respiration.

However, **the net emissions of carbon dioxide for which livestock is directly responsible are nil.** What does this mean? By simplifying the process as much as possible, the **carbon** removed from the atmosphere (through the process of photosynthesis) **passes from the plant tissues to the animals that feed on it.** Once ingested, a small part of the carbon is **'stored' inside the animal's tissues** or in its milk and egg products (**carbon** is in fact the basis of all organic macromolecules: **proteins, lipids, carbohydrates and nucleic acids**), and most of it is re-emitted into the atmosphere in the form of carbon dioxide, due to the animal's respiration process, thus making it available again to plants for photosynthesis (figure on previous page). Consequently, **all CO_2 emitted by animals, plants and microbes** is a part of this natural cycle, called the biogenic carbon cycle. Being part of a balanced system, this CO_2 is therefore not included among the climate-altering gases emitted by human activities responsible for the greenhouse effect.

However, there is an exception that concerns ruminants.

In this case, a portion of the organic carbon 'trapped' in plant tissue does not pass into the tissues of the animals that feed on it, nor is it emitted by respiration, but almost immediately returns to the atmosphere in the form of methane (CH_4). In fact, **during the feeding process, the ingested plant material reaches the rumen, where it ferments and is then digested thanks to the presence of an anaerobic microbial population** (that is, which breathes without oxygen). **During this fermentation process methane is generated (ruminal methanogenesis), which is mainly expelled through the animal's airways.** Another important source of methane is represented by animal manure which, if not properly managed, can contribute to this category of emissions.

Unfortunately, the greenhouse effect of a methane molecule is greater than that of a carbon dioxide molecule, so if a carbon atom is removed and then re-emitted into the atmosphere in the form of CO_2, we can speak of a system in equilibrium, with zero net balance. But **if in the face of CO_2 absorption, CH_4 is emitted, the balance is lost in the short term and there is a net contribution to the greenhouse effect.**



Oxidation of methane into carbon dioxide.

But this occurs only if there is a continuous increase in the amount of livestock methane emissions. In fact, while a CO_2 molecule has an active life in the atmosphere of thousands of years, methane is rapidly oxidized to CO_2 over a few decades (it has a half-life, i.e., its concentration halves, of 8.6 years and practically disappears after 50 years). Therefore, if the methane emission from livestock remains constant, **the system regains balance** and, if it decreases, the livestock system can even help "cool" the atmosphere. This phenomenon is well known by global warming physicists who, by measuring the concentration of methane contained in air bubbles trapped in the ice of Greenland or Antarctica, have been able to correlate the earth's cooling with this reduction.

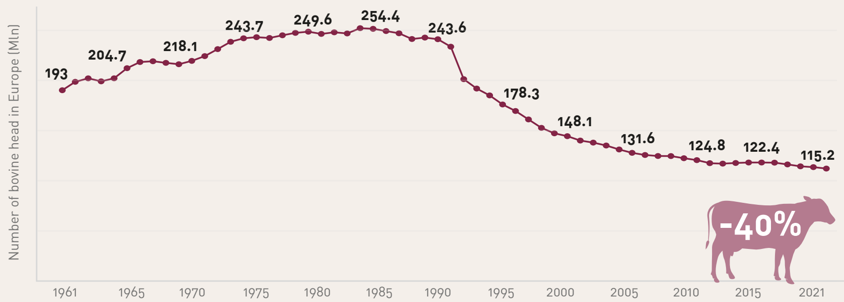
However, since methane is so quickly removable from the atmosphere, the achievement of the mitigation objectives can be pursued more quickly and effectively by reducing the emissions of this gas rather than by controlling those of CO_2.

It is precisely for this reason that the scientific community is dedicating ever greater efforts to the search for effective mitigation strategies, such as, for example, increasingly digestible feed formulations, various techniques for better management of animal manure, up to experimental techniques for the capture of methane directly from the atmosphere.

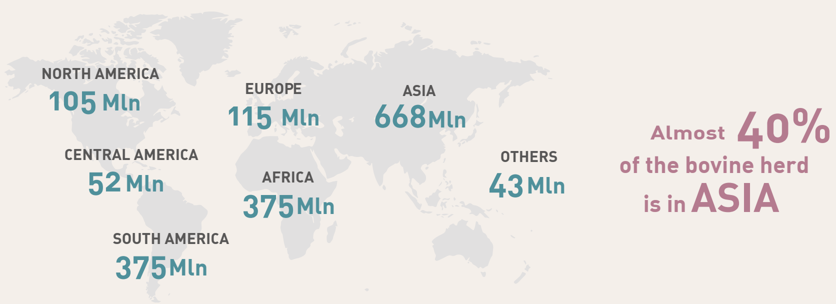
Given these considerations, it is necessary to evaluate world stocks and analyse its growth dynamics over the last 60 years. The bovine and buffalo herd in the world increased by 70% from 1 billion head in 1961 to 1.7 billion in 2021, while in Europe it fell by 40%. Note how out of 1.7 billion bovine in the world, 40% are found in Asia, China and India.

ALMOST HALVED IN EUROPE THE NUMBER OF BOVINE HEAD

from 1961 to 2021



WORLD BOVINE STOCK: 1,733 MILLION HEAD



Source: FAOSTAT (Cattle and buffaloes).

RECENT DEVELOPMENTS IN THE USE OF GLOBAL WARMING POTENTIAL (GWP)

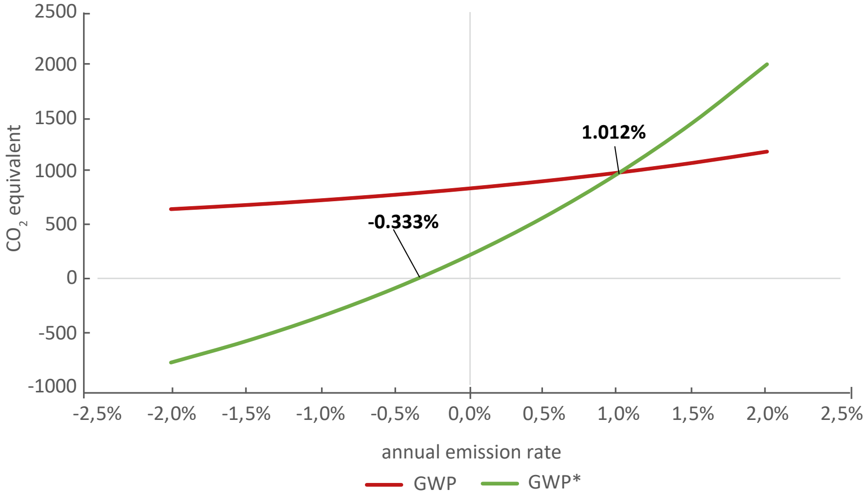
By Fabio Correddu

Global warming is a phenomenon linked to the increase in atmospheric concentration of the so-called greenhouse gases (GHG). The greenhouse effect is actually a natural phenomenon, which consists in capturing part of the solar radiation re-emitted by the earth's surface, effectively increasing its temperature. Without this phenomenon, the temperature of our planet would be around -15°C, unsuitable for hosting life as we know it.

For decades, the increase in GHG concentration linked to human activities has been the object of research institutes and of national and international organizations. This is due to the strong correlation with the increase in temperatures recorded over the same period (IPCC, 2001). The various greenhouse gases contribute in different ways to global warming, according to the energy they are able to re-emit in the form of radiation and according to the time they remain in the atmosphere. For the same mass considered, methane contributes more to heating than CO_2 but, thanks to some natural processes, its concentration decreases much more rapidly (a few decades) than CO_2 which instead remains in the atmosphere for hundreds to thousands of years. The global warming potential (GWP) is a metric introduced by the Intergovernmental Panel on Climate Change (IPCC, 1990) to facilitate comparison of the effect of different greenhouse gases and of various sectors on global warming, in order to plan shared mitigation strategies. In particular, the GWP measures how much energy 1 ton or kg of a given GHG absorbs in a given period of time, with reference to the same quantity of CO_2. It is therefore expressed in terms of CO_2eq and reference is often made to a time span of 100 years. Following this approach, 1 kg of methane has a global warming power (GPW_{100}) equal to what 28kg of CO_2 would have over a period of 100 years. Similarly, 1 kg of N_2O has a GPW_{100} of 298 since 1 kg of N_2O causes a greenhouse effect 298 times greater than that of a kg of CO_2, over a period of 100 years. The GWP values were also calculated for different time scales (GWP_{20}, GWP_{100}, GWP_{500}), but the choice of the IPCC, later adopted by the Kyoto Protocol (1997) and by the Paris Agreements (2015), fell on the time reference of 100 years. Although this metric is now widely accepted and used, various critical issues have emerged especially in recent years. First, considering that mitigation policies aim to contain the temperature increase in the next few decades, the adoption of a metric based on a 100-year time span does not seem fully justified (Allen et al., 2016). On the other hand, as also reported by the IPCC (2013), no metric can be able to compare all the consequences due to different emissions, and any metric will have limitations and uncertainties. ***The main problem related to the GWP, regardless of the time scale used, is that it considers gases with a short permanence***

in the atmosphere (e.g., methane) in the same way as a gas with a long permanence (i.e., CO_2). The fact that CO_2 has a permanence in the atmosphere for **millennia** while that of **methane** for a few **decades** means that the effect on global warming has completely different dynamics. In this sense, **CO_2** is also defined as **an accumulation pollutant while methane as a flux pollutant** (Lynch et al., 2021). The differences in the warming dynamics between the two types of gas are evident especially when scenarios of emissions variation (decrease or increase) are taken into consideration. For example, assuming we begin to reduce CO_2 and CH_4 emissions to zero, in a short time (10-20 years) we will have a reduction in the concentration of methane, until a constant value is reached; the impact of CH_4 on global warming will follow the same trend, as the reduction of its concentration; as far as CO_2 is concerned, a reduction in emissions will not be followed by a reduction in its atmospheric concentration until after a few millennia; for this reason the impact of CO_2 does not decrease. Reducing the emission rate acts to slow the rate of contined increase of impact until it becomes constant when emissions are equal to zero (Allen et al., 2016; Cain et al., 2019). This is one of the reasons why mitigation policies are mostly oriented towards a reduction of methane emissions, rather than those of CO_2. As a consequence, the sectors most responsible for methane emissions, including livestocks, are put under pressure. In response to the critical issues arising from the use of GWP, new metrics have been proposed (Shine et al., 2005; Allen et al., 2016, 2018; Cain et al. 2019; Collins et al., 2020). These new approaches take account of the different behaviours of the gases (flows, emissions, half-life) and allow to achieve more realistic values when increasing or decreasing GHG emission scenarios are considered. Among the new approaches, the GWP*, proposed by a research team from Oxford (Allen et al., 2016; 2018), represents a new way of using the classic GWP, which always compares GHG with CO_2, but takes into account short half-life gas variations in a given period of time, allowing to calculate more realistic scenarios, when considering hypotheses of increase or reduction of emissions over time. An evolution of the GWP* has been proposed by Cain et al. (2019), which takes into account both the impact related to stocks and that related to changes in short-lived gases, for a specific period of time. The proposed equation ($ECO_2\text{-}e^* = GWP_H \times [r \times (\Delta ESLCP/\Delta t) \times H + s \times ESLCP]$) consists of two parts which represent the contributions of the short half-life gas relative to its accumulation over time and to its dynamics of increase or decrease. In fact, the product $GWP_H \times ESLCP$ is nothing more than the calculation of the classic CO_2eq for a short-life gas (SLCP) considering a GWP at a given time H (e.g. for methane 28 CO_2eq in 100 years); the other product GWPH x (ΔESLCP/Δt) x H (which is exactly the equation proposed by Allen et al., 2016) instead represents the impact related to a variation of a short half-life gas (ΔESLCP) in a specific period of time (Δt) and H represents the time considered in the calculation of the GWP. In the equation there are also two coefficients r and s which multiply the two terms of the equation. These coefficients represent the weights that are given to the

COMPARISON OF IMPACT ESTIMATIONS IN CO_2 EQ. OF METHANE IN 30 YEARS



Comparison of estimates of the global warming impact (in terms of CO2 eq) of methane over 30 years, calculated using GWP (in red) and GWP (in green), for different annual emission rates. The values of r and s used are 0.75 and 0.25 respectively, while the initial emission impulse is equal to 1 ton of CH4 / year (adapted from R. A. Cady, 2020, with values recalculated by the authors of this work).*

two terms of the equation in defining the value of ECO_2-e, i.e., the contribution of gas accumulation (s, stock) and the emission rate (r, rate), in a given period of time H. The values of the two coefficients are determined by a linear regression based on an equation (Cain et al., 2019) that takes into account the impact of CH_4, in a given period of time, in terms of CO_2eq, adding the cumulative effect (GWP_{100}) and that of the emission rate (GWP*).*

According to an example of calculation reported in Cain et al. (2019), the graph above compares the different values of total methane emissions over a period of 30 years, in terms of CO_2eq calculated with the GWP_{100} and the GWP (Cain et al., 2019). The example assumes different annual emission rates (from -2% to +2%), starting from 1 ton of CH_4/year. The first observation that can be made concerns the different trend of the trajectories identified by the estimates of GWP_{100} and GWP*; in particular, the GWP* has a much steeper slope and meets the GWP at a point which corresponds to an annual increase of 1.01%. It can be seen that for rates above this value, the GWP_{100} dangerously underestimates CO_2eq; on the other hand, for lower rates, the GWP overestimates the emissions in terms of CO_2eq, and therefore the impact on the warming increase. Another important observation also emerges from the graph: the values calculated with the GWP_{100} always assume positive values, even for negative emission rates; this is because this metric takes into consideration the effect of the total methane emitted in 30 years, as a single pulsed emission of CO_2. Conversely, the GWP* also assumes negative val-*

ues, in particular, in the example, for rates lower than 0.33%, which corresponds to a CO_2eq value equal to zero. In fact, considering that methane is a gas with a short half-life, reducing its emission rate also means reducing its accumulation and, consequently, the increase in global temperature will be reduced (considering all other emissions to be zero). One of the major criticisms addressed to this new approach lies in the fact that even small drops in the methane emission rate would bring great benefits in terms of impact reduction; therefore, different sectors, or different countries with high emissions from agricultural activities, could benefit from it, reaching the so-called net-zero with little effort, despite the fact that they are still emitting GHG (Beacon, 2020; Rogelj et al., 2021). On the other hand, the need to better distinguish the role of the different GHGs in global warming is increasingly shared, in order to better define the responsibilities of the different sectors and the most efficient mitigation strategies (Lynch et al., 2021; Allen et al., 2022).*

- *Allen M.R., Fuglestvedt J.S., Shine K.P., Reisinger A., Pierrehumbert R.T., Forster P.M. (2016), New Use of Global Warming Potentials to Compare Cumulative and Short-lived Climate Pollutants, Nature Climate Change, 6(8), pp. 773-776.*
- *Allen M.R., Peters G.P., Shine K.P., Azar C., Balcombe P., Boucher O., Cain M., Ciais P., Collins W., Forster P.M., Frame D.J., et al. (2022), Indicate Separate Contributions of Long-lived and Short-lived Greenhouse Gases in Emission Targets, NPJ Climate and Atmospheric Science, 5(1), pp.1-4.*
- *Allen M.R., Shine K.P., Fuglestvedt J.S., Millar R.J., Cain M., Frame D.J. and Macey A.H. (2018), A Solution to the Misrepresentations of CO2-equivalent Emissions of Short-lived Climate Pollutants under Ambitious Mitigation. npj Climate and Atmospheric Science, 1(1), pp.1-8.*
- *Beacon B. (2020), GWP* Should Not Be Adopted by the IPCC, Brussels Blog, https://www.brusselsblog.co.uk/gwpstar-should-not-be-adopted-by-the-ipcc/.*
- *Cady R.A. (2020), A Review of GWP*: A proposed Method for Estimating Global Warming Potential (GWP*) of Short-lived Climate Pollutants like Methane, Global Dairy Platform Rosemont, (Il), USA.*
- *Cain M., Lynch J., Allen M.R. et al., Improved Calculation of Warming-equivalent Emissions for Short-lived Climate Pollutants. npj Clim Atmos Sci 2, 29 (2019), https://doi.org/10.1038/s41612-019-0086-4.*
- *Collins W.J., Frame D.J., Fuglestvedt J.S. and Shine K.P. (2020), Stable Climate Metrics for Emissions of Short and Long-lived Species-combining Steps and Pulses, Environmental Research Letters, 15(2), p.024018.*
- *Houghton J.T., Ding Y., Griggs D.J., Noguer M., van der Linden P.J., Dai X., Maskell K. and Johnson C.A. eds. (2001), Climate Change 2001: The Scientific Basis: Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.*
- *Lynch J., Cain M., Frame D. and Pierrehumbert R. (2021), Agriculture's Contribution to Climate Change and Role in Mitigation is Distinct from Predominantly Fossil CO2-emitting Sectors, Frontiers in Sustainable Food Systems, p.300.*
- *Rogelj J., Geden O., Cowie A. and Reisinger A. (2021), Net-zero Emissions Targets are Vague: Three Ways to Fix, Nature, 591, 365-368.*
- *Shine K.P., Fuglestvedt J.S., Hailemariam K. and Stuber N. (2005), Alternatives to the Global Warming Potential for Comparing Climate Impacts of Emissions of Greenhouse Gases, Climatic Change, 68(3), pp.281-302.*
- *United Nations Framework Convention on Climate Change (2015): Adoption of the Paris Agreement, FCCC/CP/2015/L.9/Rev.1.*

THE USE OF THE NEW METRICS

RECALCULATING THE GLOBAL WARMING IMPACT OF ITALIAN LIVESTOCK METHANE EMISSIONS WITH NEW METRICS

The impact of methane (CH_4) emissions on warming, calculated using the metrics proposed by the Intergovernmental Panel on Climate Change (IPCC), which measure the global warming potential for this gas in 100 years (GWP_{100}) expressed in carbon dioxide equivalents (CO_2e), is considered by far the largest for animal production chains, representing for the FAO around 50%.

In a work published by our research group, we used the new metric, illustrated in the previous box, which considers the difference between short-lived climate pollutants (SLCP), such as CH_4, and long-lived ones (LLCP), such as CO_2, to measure the equivalent warming effect (we) over a given period of time. The new metric, indicated with the acronym GWP (Global Warming Potential Star) is expressed not as the cumulative effect of the warming due to CO_2 (CO_2e) but as the equivalent of warming compared to this gas (CO_2we) which takes into account the dynamics of emissions recorded 20 years before the estimation. Briefly, if emissions have increased, they have contributed to atmospheric warming, if they have remained constant, they have not contributed to it, but if they have decreased below a predefined threshold, then they have compensated for those of CO_2 and can be accounted for with a negative sign.*

The GWP was applied to enteric and manure CH_4 emissions from all Italian livestock supply chains and compared with the GWP_{100} for an annual and cumulative assessment from 2010 to 2020 of the impact of this gas on climate change. Based on the official data published by the Italian Institute for Environmental Protection and Research (ISPRA) from 1990 to 2020, almost all species, with the exception of buffalos, showed lower impacts if calculated with the new metric than those estimated by ISPRA. The greatest reduction can be observed for beef (-53,786 Mt of CO_2we calculated with the GWP* compared to +66,437 Mt of CO_2e estimated with the GWP_{100} method), as shown in figure 1. The total cumulative contribution of Italian livestock production to global warming in the years 2010-20 (figure 2), including emissions of nitrous oxide (N_2O) also drawn from the ISPRA historical series, was strongly negative (-48,759 Mt of CO_2we) compared to the data calculated with the GWP_{100} method (+206,091 Mt of CO_2e).*

The application of the GWP metric to the CH_4 emissions of all Italian livestock supply chains has allowed to more accurately assess the role of Italian livestock farming on climate change. In the 2010-2020 period, national livestock supply chains showed a negative trend on the warming linked to their CH_4 emissions, with ruminants (except buffaloes) being the most contributing to this positive effect.*

FIG. 1 - TOTAL CLIMATE IMPACT OF METHANE (CH_4) OF ITALIAN NON-DAIRY CATTLE

from 2010 to 2020

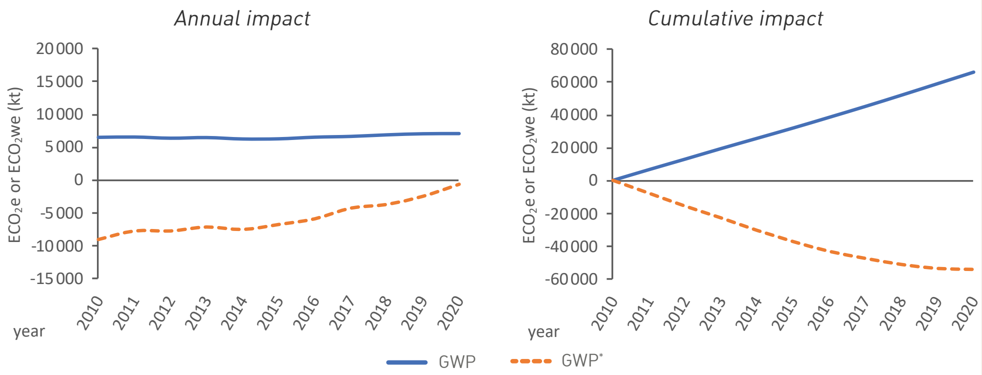
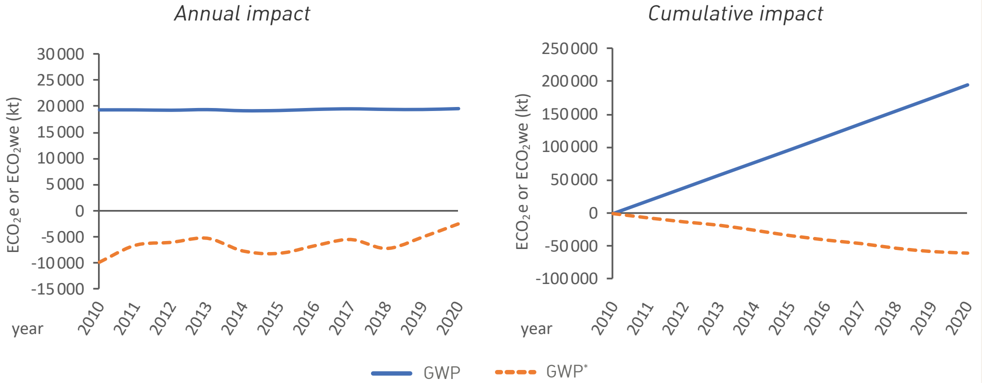


FIG. 2 - TOTAL CLIMATE IMPACT OF METHANE (CH_4) OF ITALIAN LIVESTOCK

from 2010 to 2020



Farms include dairy cattle, beef, buffaloes, sheep, goats, pigs, horses, mules and donkeys, poultry, rabbits.

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[1] *IPCC 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.*

[2] *FAO (2022). Methane Emissions in Livestock and Rice Systems – Sources, Quantification, Mitigation and Metrics (Draft for Public Review). Livestock Environmental Assessment and Performance (LEAP) Partnership. FAO, Rome, Italy.*

[3] *Correddu F., Lunesu M.F., Caratzu M.F., Pulina G. (2023), Recalculating the Global Warming Impact of Italian Livestock Methane Emissions with New Metrics, Italian Journal of Animal Science.*

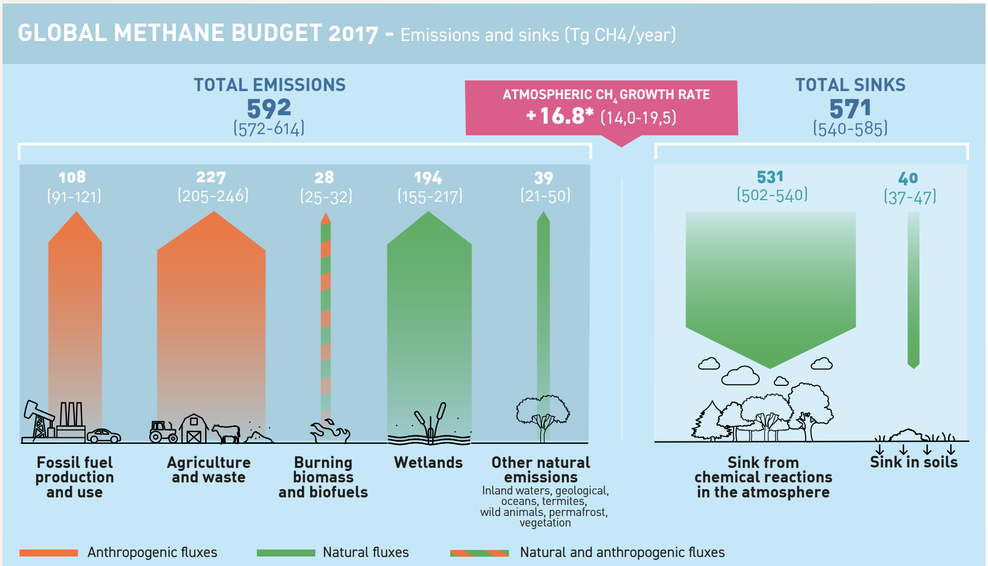
[4] *ISPRA, 2022 [a], National Inventory Report 2022 – Italian Greenhouse Gas Inventory 1990-2020, ISPRA Rapporti 362/2022, ISPRA, 2022.*

CLIMATE CHANGE AND FARMS:
HOW METHANE MANAGEMENT CAN MAKE CATTLE PART OF THE SOLUTION[1]

*METHANE BALANCE AND GWP**

The international community recognises that methane has important consequences on the greenhouse effect. It is therefore ***essential to fully understand the behaviour of this molecule*** *in order to better quantify its impacts and to implement effective strategies to reduce its emissions. To date, in fact, two crucial aspects are still too often overlooked:* ***the balance between emissions and removals;*** *the model with which the presence of methane in the atmosphere is converted into the relative contribution to global warming.*

According to the most recent version of the Global Methane Budget, it is in fact observed that anthropogenic methane emissions essentially derive from three sources – ***production and use of fossil fuels, agriculture and waste, combustion of biomass and biofuels*** *– to which natural ones must be added. The total, according to the top-down method, is 592 million tons/year (592 tera-grams in the figure). While there is clarity on emissions, the aspect that is often overlooked concerns the* ***removal processes*** *(above all through the oxidation of CH_4 into CO_2 directly in the atmosphere, but also through* ***storage in the soil*** *by, for example, of methanotrophic bacteria). These removals, according to the top-*



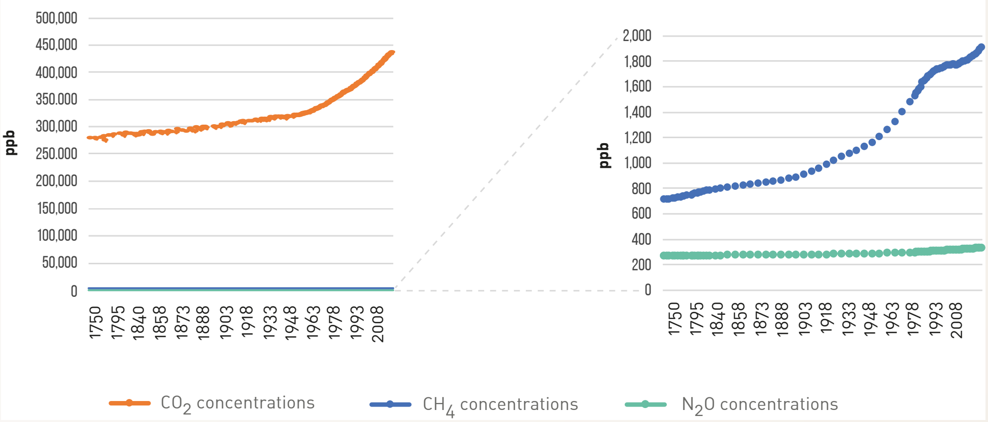
*Global methane gas balance for the year 2017, in tera-grams of CH4 per year, based on the top-down method and considering natural (green), anthropogenic (orange) and mixed emissions and removals (dashed orange-green). *Data shows observed atmospheric growth rate. The budget imbalance of some Tg of CH4 per year reflects the uncertainties of the models in capturing the observed growth rate. Source: Global Carbon Project; Jackson et al., 2020 [2].*

down method, are estimated to be equal to approximately 571 million tons per year. For this reason, the net contribution to global warming of methane must be calculated as the difference between the two values, thus resulting significantly lower than commonly communicated.
*The second crucial point is represented by the mathematical model used to convert methane (and other greenhouse gases) emissios into impacts. The currently used metric is the Global Warming Potential referred to an observation interval of 100 years (**GWP_{100}**) which indicates an effect of CH_4 28 times more powerful than that of CO_2.*
However, this metric has the limitation of not considering the short life of methane in the atmosphere.
*To go beyond this uncertainty, a team of researchers from Oxford has developed an update of the calculation methods by creating the **Global Warming Potential Star (GWP*).** This model takes into account how increasing, constant or decreasing emissions of methane can affect global warming. The results indicate that, in a scenario of constant emissions, the **GWP_{100} metric returns an impact 4 times higher than that obtained with the updated method (GWP*).** Furthermore, the conventional metric neglects the beneficial consequences on the climate when methane emissions stop to be constant and begin to decrease.*
This new approach is attracting the attention of the scientific community – both in terms of the theory's validity and for the consequences that its eventual adoption would have – and it has also been mentioned in the new version of the IPCC[3] report which admits the limit of system currently used. While awaiting a formal position from the international community, the best approach remains that of maximum transparency, combining the GWP with the current metric and balancing the emission sources with those of absorption.*

THE BEHAVIOR OF THE TWO GASES

*To date, **emissions of all major greenhouse gases are increasing,** although huge efforts are already underway to reverse this trend.*
*But what would happen if every year the **emissions***

ATMOSPHERIC CONCENTRATION OF METHANE, NITROUS OXIDE AND CARBON DIOXIDE OVER TIME



The gas concentration is expressed in parts per billion, i.e., one thousandth of the better-known ppm.
Source: Our World in Data[4].

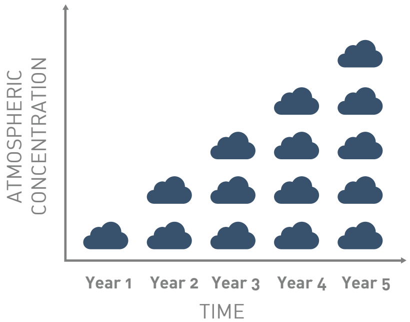
from human activities were equal to those emitted the previous year? In other words, what should happen if it were possible to make the emissions of each gas ***constant over time?***

- ***CO_2*** *is a gas with cumulative behaviour. It means that* ***each new gas emission*** *adds up to the CO_2 emitted in previous years. In other words, even by emitting the same quantity of the previous year, each year (in the image, a new cloud), there would still be an* ***increase in the concentration in the atmosphere.***
- *Conversely,* ***CH_4*** *is a gas subject to oxidation and its concentration halves over the course of about ten years. This means that, simplifying, the quantity emitted in year 1 will be halved in year 10 and will disappear completely within 50 years, that emitted in year 2 will be in year 11 and so on. In other words, in a constant emission scenario, the concentration in the atmosphere would also stabilise.*

What would be happening if annual emissions would even start to fall?

- *If year after year we were able to reduce* ***CO_2****, emissions ever more, every single new contribution, however small, would in any case contribute to the increase in the concentration in the atmosphere and the increase in global warming.*
- *Conversely, if we were able to do the same with* ***methane****, the concentration of this gas would begin to decrease. This would translate into an ever-decreasing contribution of methane to global warming.*

EFFECT OF A CONSTANT EMISSION OVER TIME

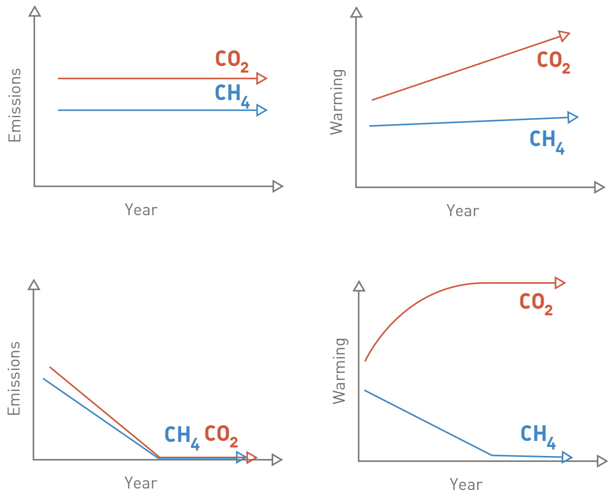


CO_2
(cumulative behaviour)
The CO_2 molecule remains in the atmosphere for a long time: this determines an increase in its concentration over time.

CH_4
(non-cumulative behaviour)
The CH_4 molecule is subject to rapid oxidation: this means that, in a constant emissions scenario, the concentration remains unchanged over time.

Unfortunately, the last scenario (a reduction in global emissions) is still a distant goal. But much can already be done to start undertaking this path and, in this context, ***the agricultural sector is in a privileged position. In fact, despite being an integral part of the problem, it has an advantage compared to other sectors: if it learns to manage methane correctly, it can become an important part of the solution.***

DIFFERENT BEHAVIOR OF CARBON DIOXIDE AND METHANE



CONSTANT EMISSIONS

As in the infographic on the opposite page, CO_2 accumulates in the atmosphere. The result is a growing contribution to global warming.

EMISSIONS IN DECLINE

Every single contribution of CO_2 (however small) remains in the atmosphere adding up to the previous ones. The result, also in this case, is a growing contribution to global warming. For CH_4, on the other hand, the reduction of emissions leads to a reduction in the concentration in the atmosphere and, ultimately, to an ever-decreasing contribution to global warming.

Different behaviour of carbon dioxide and methane in global warming, depending on the size of the emissions: constant or decreasing[5].

[1] The contents of this study are taken from the speech of Professor Frank Mitloehner (Professor and Air Quality Specialist, UC Davis USA) at the International Symposium "Cow is veg - The role of ruminants in a sustainable diet" (Rome, 29 /9/2022) Full video of the intervention: https://www.lastoriadiunerbivoro.it/2022/10/03/simposio-internazionale-cow-is-veg-il-ruolo-dei-ruminanti-in-una-dieta-sostenibile/.

[2] Jackson et al. (2020), Increasing Anthropogenic Methane Emissions Arise Equally from Agricultural and Fossil Fuel Sources, Environmental Research Letters, doi: 10.1088/1748-9326/ab9ed2.

[3] Forster P. & Storelvmo T. (2021), The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity. Chapter 7 of the report "Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the 6° Assessment Report of the Intergovernmental Panel on Climate Change", Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 923–1054, doi:10.1017/9781009157896.009.

[4] https://ourworldindata.org/atmospheric-concentrations.

[5] Oxford Martin Programme on Climate Pollutants, July 2022. Climate Metrics for Ruminant Livestock. Available on the site: https://www.oxfordmartin.ox.ac.uk/downloads/reports/Climate-metrics-for-ruminant-livestock.pdf%C2%A0.

THE REDUCTION OF METHANE IN BOVINE FARMS: FROM PROBLEM TO RESOURCE[1]

The agricultural sector can undoubtedly play a key role in reducing methane emissions. The scientific knowledge and technologies to do so already exist, and they are constantly under imprement. There is therefore only one basic problem: to correctly inform the livestock sectors to manage methane in the best possible way.

So, what can be already done, concretely?

METHANE FROM ENTERIC FERMENTATIONS

The rumen hosts millions of microorganisms, the rumen bacteria, with which it is in perfect symbiosis: the rumen provides a perfect environment for bacteria, while the bacteria break down the plant material into final products that can be used by bovine. This is the aforementioned enteric fermentation process. Methane represents one of the waste products of this process, and it is eliminated by traveling up the animal's airways and out of the mouth. The most effective strategy to reduce methane from enteric fermentations is to modify the animal's diet, essentially in two ways.

The first is to provide the animal with a ***quality ration****. While a feed based on forage implies high digestion times and leads to a considerable production of methane, a feed based on concentrates allows to lower both. In recent decades, beef and dairy cattle livestock farming has recorded substantial improvements in terms of carbon footprint, following the increase in knowledge on the nutritional quality of feeds and their effects on the methane production. For example, a recent analysis of the California dairy industry[2] found that methane emissions associated with the production of 1 kg of milk in 2014 were reduced by about 55% compared to 1964.*

The second way, perhaps less known, is to enrich the ration with ***feed supplements****. It is an effective practice in all farming systems, but which becomes strategic in systems*

with grazing animals (precisely due to the fact that it partially counteracts the emissions given by lower quality feed).

Feed supplements in the ration are divided into two categories:

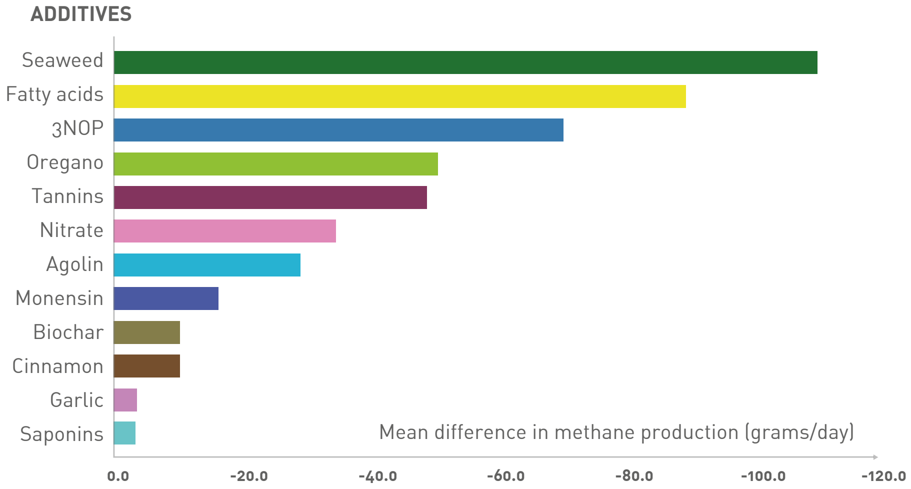
	Additives that act as methane inhibitors	Additives that modify the fermentation process more generally
FUNCTION	Blocking the formation of methane through a change in the structure or function of key molecules involved in the process.	Favourable changes in the rumen environment, thereby affecting the way the rumen processes ingested feed. These additives – in addition to reducing the formation of methane – can also improve productivity and animal health, for example by increasing the amount of dietary protein available to the animal.
EXAMPLES OF PROMISING ADDITIVES	**Red algae** are among the most promising inhibitors, but further investigations are needed for their widespread diffusion, both to fully understand the mechanisms underlying their inhibitory effect, and to identify a method of procurement (harvesting in nature or cultivation) that is environmentally and economically sustainable. Among the species tested, A. taxiformis was the one that aroused the greatest interest. Its presence in the ration is in fact able to reduce methane emissions (kg of methane produced per kg of dry matter eaten), without affecting the digestibility of the forage: in the experimental field, reductions of up to 55% have already been **observed in dairy and up to 98% in beef cattle.**	**Tannins** (secondary metabolites produced by plants to protect themselves from herbivores) are known for their ability to bind and denature proteins. As it is known, the fermented material is processed by the rumen and other forestomach to reach the glandular stomach (the abomasum), where the reactions typical of digestion take place (including the breakdown of proteins) by the gastric juices. When tannins are included in the diet, the proteins are less subject to ruminal bacterial degradation and a greater proportion is therefore able to reach the abomasum where it will be digested.

There are already several effective products on the market. Agolin, for example, is a mix of essential oils, tannins and bioflavonoids specially selected to work in synergy to support and improve rumen function. Numerous international universities – including the Department of Veterinary Medicine and Animal Sciences of Milan – are carrying out in-depth investigations on these types of products, often observing significant reductions in methane emissions accompanied by an increase in meat and milk production and positive implications in terms of animal health. The use of these food supplements is spreading a lot and, considering the numerous positive results, it is destined to grow more and more.

METHANE FROM MANURE

In this case, the quantity and type of gas emitted (methane, but also ammonia and nitrous oxide) are linked both to the type of manure and to the

ADDITIVES AND METHANE REDUCTION



Source: revised by Carrazco, 2021[3].

relative storage methods. As far as the latter is concerned, noteworthy results are being rapidly obtained in California and are therefore reported below as a case study.
The state of California has set an ambitious goal: to reduce CH_4 emissions from manure management in the dairy industry by 40% (compared to 2013 levels). It intends to do so by 2030. To make this goal achievable, California has adopted an intelligent political strategy: not by frightening farmers with the threat of taxes and sanctions, but by encouraging virtuous behaviour through the allocation of specific funds. Even teams of university researchers[4] (CLEAR centre of UC Davis) have already mobilised, working close to farmers to guide them towards the use of food additives (described above) and towards the implementation of effective manure and waste management.

The results? The California dairy industry has already achieved a 22% reduction in emissions by storing manure in covered lagoons and converting the captured biogas into vehicle fuels[5,6]. In addition to an undoubted improvement in terms of environmental sustainability, these strategies also represent an important economic advantage for farmers. Thanks to both obtaining carbon credits and the sale of biogas, converted into fuel for vehicles 7 (in some cases, this sale represents a 50% increase in the farmer's income).

*In conclusion, **methane is only a problem if it is not managed. Otherwise, it becomes not only an important lever in the fight against global warming but also a valuable source of energy and income for farmers.***

[1] The contents of this study are taken from the speech of Professor Frank Mitloehner (Professor and Air Quality Specialist, UC Davis USA) at the International Symposium "Cow is veg - The role of ruminants in a sustainable diet" (Rome, 29 /9/2022). Full video of the intervention: https://www.lastoriadiunerbivoro. it/2022/10/03/simposio-inter-nazionale-cow-is-veg-il-ruo-lo-dei-ruminanti-in-una-die-ta-sostenibile/.

[2] Naranjo et al. (2020), Greenhouse Gas, Water, and Land Footprint per Unit of Production of the California Dairy Industry over 50 Years, Journal of Dairy Science, 103(4): 3760-3773.

[3] Carrazco A. (2021), How can Cattle Feed Additives Reduce Green-house Gas Emissions? Further details available at: https://clear.ucdavis. edu/explainers/how-can-cattle-feed-additives-reduce-green-house-gas-emissions.

[4] CLEAR Center (Clarity and Leadership for Environmental Awareness and Research), University of California (UC Davis). https://clear.ucdavis.edu/.

[5] California Air Resources Board, March 2022, Final report, Analysis of Progress toward achieving the 2030 Dairy and Livestock Sector Methane Emissions Target, https://ww2.arb.ca.gov/sites/default/files/2022-03/final-dairy-live-stock-SB1383-analysis.pdf.

[6] Place et al. (2022), Symposium Review: Defining a Pathway to Climate Neutrality for US Dairy Cattle Production. Vol 105(10), 8558-8568. doi: 10.3168/jds.2021-21413.

[7] Renewable Natural Gas (RNG). https://www.rngcoalition.com/.

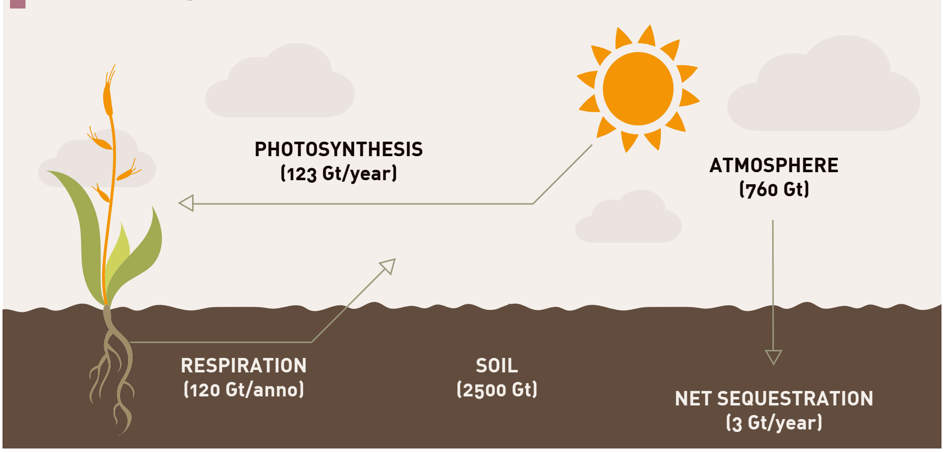
CARBON SEQUESTRATION AND CARBON FARMING

By Mondina Francesca Lunesu

*In recent months, also in the light of the political commitment of the European Green Deal to achieve climate neutrality by 2050, the need to promote and disseminate forms of clean energy and mitigation strategies for atmospheric carbon removal has become increasingly pressing (Bossio et al., 2020). The adoption of these measures also applies to the agricultural sector which will, at the same time, have to improve the efficiency in the use of resources to feed an ever-growing world population. There are essentially five carbon deposits on our planet: **oceans, soil, atmosphere, rocks** (geological carbon) **and living organisms** (biotic carbon) (Pacala & Socolow, 2004). **After the oceans** (38,400 Gt), **the second largest carbon sink is soil** (Stockmann et al., 2013). It is estimated that just over 2,500 Gt of carbon are stored **in the first three meters of soil,** of which about 50% in the first meter (Stockmann et al., 2013). The carbon present in the soil is equal to 3.3 times that present in the atmosphere (760 Gt) and is represented by organic carbon (1,550 Gt) and inorganic carbon (950 Gt) (Jansson et al., 2021).*

*The deposition of organic carbon in the soil derives from the **removal, long-term or permanent (e.g., over 100 years), of CO_2 from the atmosphere and subsequent "storage" in the ground, phenomenon defined as "carbon sequestration"** (Lal, 2004; Stockmann et al., 2013). If reduced to the size of farms actively engaged in carbon conservation and sequestration practices, these assume the denomination of **"carbon farming"** (Sharma et al., 2021).*

CARBON SEQUESTRATION IN THE SOIL



Carbon sinks are expressed in gigatonnes of carbon, the fluxes (arrows) in Gt/year.
By "respiration" we mean the cumulative effect of plant and microbial respiration.
Source: Jansson et al., 2021.

STORAGE IN THE SOIL: A REVERSIBLE PHENOMENON

The ability of soil to capture atmospheric CO_2 plays an essential role in the removal of greenhouse gases and **can represent 25% of natural mitigation solutions** (Bossio et al., 2020). However, this is a reversible phenomenon, so depending on the conditions, the soil can act as a **carbon sink or carbon source.** The overall impact of an agricultural production is therefore given by the balance between emission and carbon removal by animals, plants and soil.

To guarantee the continuity of sequestration over time, it is necessary to adopt a series of "good agricultural practices" that are able to limit the loss of organic matter in the soil: for example, conventional tillage reduces the soil's disposal of organic matter (Lal, 2004), but the operations, also defined respectively as "minimum tillage" and "no tillage" preserve it (Lal, 2004). The presence of cover crops, the use of organic fertilisers and the use of irrigation also favours the deposition of carbon in the soil (Lal, 2004). As highlighted by Jansson et al. (2021), the use of cover crops can on the one hand favour the removal of atmospheric CO_2 and on the other increase soil fertility.

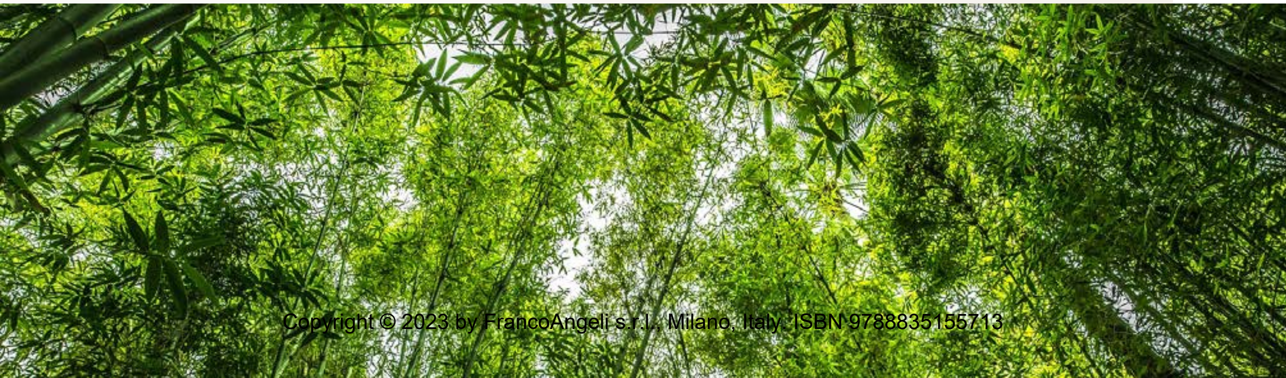
In general, **the carbon stock in the soil increases as average annual temperatures decrease** (Post et al., 1982) so much so that the greatest amount of organic carbon is found in soils located in arctic and boreal ecosystems, particularly in peatlands (Tarnocai et al., 2009) and in moist soils compared to those present in drier environments and in those with a temperate climate (Harrison et al., 2021). Therefore, global warming accelerates the processes of decomposition of organic matter promoting carbon emissions into the atmosphere (Stockmann et al., 2013).

Another factor that affects the ability to sequester CO_2 is the **temporal interval.** As reported by the IPCC (2006), the soil's organic carbon reaches an equilibrium after only 20 years of continuous conservation practices and at least 6-10 years are needed to observe a 15% increase (Smith, 2004).

STORAGE IN THE LIVESTOCK CHAIN

Since livestock farms are a part of agriculture that emits but also absorbs CO_2, the overall impact of a livestock supply chain process is given by the balance of total emissions, and the removals made from plants and soil of farms in the supply chain.

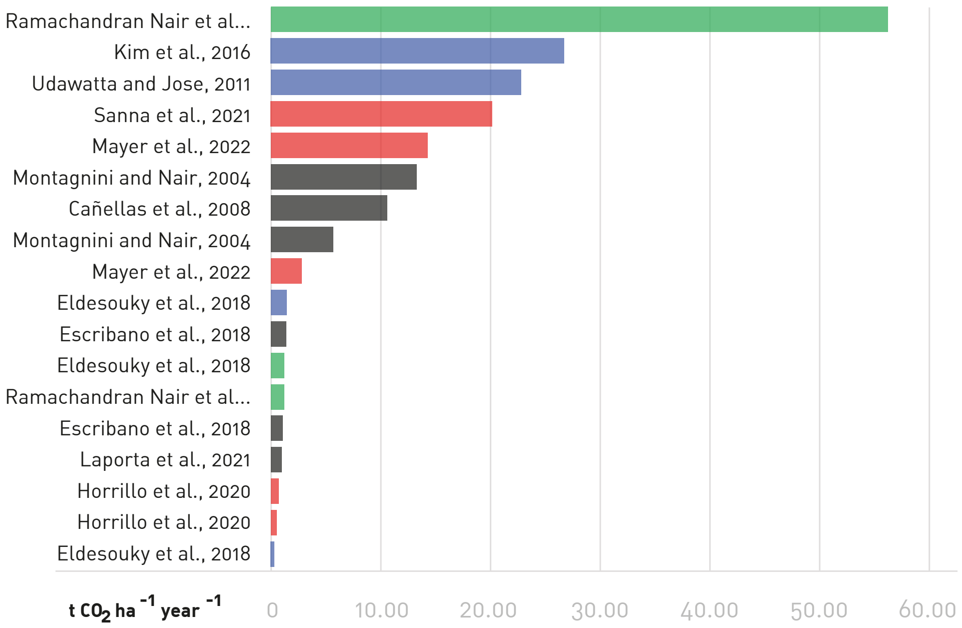
In the case of the meat supply chains of the Mediterranean areas, the presence in the phase of the cow-calf of large pastures and woodlands leads to important absorptions of C, albeit with a high variability as shown in the figure below. A bibliographic survey aimed at quantifying the C balance in agroforestry systems typical of temperate zones and the Mediterranean area (e.g., Meriagos, Montado and Dehesa) demonstrates that the **amount of carbon sequestration** operated by the arboreal component, by the soil or by both varies from



a minimum of 0.18 to a maximum of 55.8 t CO_2 ha[-1] year[-1] reaching an average value of 9.9 ± 14.3 t CO_2 ha[-1] year[-1] (Lunesu et al., 2022).
*Assuming two minimum and maximum sequestration scenarios: A) 1.28 t CO_2 ha[-1] year[-1] (Eldesouky et al., 2018) and B) 19.9 t CO_2 ha[-1] year[-1] (Sanna et al., 2021) it has been estimated that, in the systems considered, **the minimum area per calf sold necessary to reach the condition of carbon neutrality is equal to 2.85 ha for scenario A and 0.19 ha for scenario B** (Lunesu et al., 2022).*

CARBON SEQUESTRATION RATE OF TYPICAL AGROFORESTRY SYSTEMS OF TEMPERATE ZONES AND MEDITERRANEAN AREA

in t CO_2 ha^{-1} year^{-1}



in green: sequestration of C by the tree component; in red: sequestration of C by the soil; in blue: sequestration of C by both the tree component and the soil; in black: not specified.

- *Bossio et al. (2020), The Role of Soil Carbon in Natural Climate Solutions, Nature Sustainability, 3:391-398, doi: 10.1038/s41893-020-0491-z.*
- *Cañellas I., Sánchez-González M., Bogino S.M., Adame P., Herrero C., Roig, S., Tomé M., Paulo J. A., & Bravo, F. (2008), Silviculture and Carbon Sequestration in Mediterranean Oak Forests. Managing Forest Ecosystems: The Challenge of Climate Change, 317-338.*
- *Eldesouky A., Mesias F.J., Elghannam A., Escribano M. (2018), Can Extensification Compensate Livestock Greenhouse Gas Emissions? A Study of the Carbon Footprint in Spanish Agroforestry Systems, J Clean Prod 200:28-38, https://doi.org/10.1016/j.jclepro.2018.07.279.*
- *Escribano M., Díaz-Caro C., & Mesias F.J. (2018), A Participative Approach to Develop Sustainability Indicators for Dehesa Agroforestry Farms, Science of The Total Environment, 640, 89-97.*
- *Harrison M.T., Cullen B.R., Mayberry D.E., Cowie, A.L., Bilotto F., Badgery W.B., Liu K., Davison T., Christie K.M., Muleke A., & Eckard R.J.*

(2021), Carbon Myopia: The Urgent Need for Integrated Social, Economic and Environmental Action in the Livestock Sector, Global Change Biology, 27(22), 5726-5761.

- *Horrillo A., Gaspar P., Mesías F.J., Elghannam A., & Escribano M. (2020), Understanding the Barriers and Exploring the Possibilities of the Organic Livestock Sector in Dehesa Agroforestry Systems: A Multi-actor Approach for Effective Diagnosis, Renewable Agriculture and Food Systems, 35(6), 663-677.*
- *Intergovernmental Panel on Climate Change, IPCC, (2006), Guidelines for National Greenhouse Gas Inventories.*
- *Jansson C., Faiola C., Wingler A., Zhu, X. G., Kravchen-ko A., De Graaff M. A., Ogden A. J., Handakumbura P. P., Werner C., & Beckles D.M. (2021), Crops for Carbon Farming, Frontiers in Plant Science, 12, 636709.*
- *Jansson C., Wullschleger S. D., Udaya C.K., Tuskan G.A. (2010), Phytosequestration: Carbon Biosequestration by Plants and the Prospects of Genetic Engineering, Bioscience 60, 685–696, doi: 10.1525/bio.2010.60.9.6.*
- *Kim D.G., Kirschbaum M.U., & Beedy T.L. (2016), Carbon Sequestration and Net Emissions of CH4 and N2O under Agroforestry: Synthesizing Available Data and Suggestions for Future Studies, Agriculture, Ecosystems & Environment, 226, 65-78.*
- *Lal R. (2004), Soil Carbon Sequestration to Mitigate Climate Change, Geoderm 123(1-2), 1-22.*
- *Lal R. (2010), Managing Soils and Ecosystems for Mitigating Anthropogenic Carbon Emissions and Advancing Global Food Security, BioScience, 60(9), 708-721.*
- *Laporta L., Domingos T., & Marta-Pedroso C. (2021), It's a Keeper: Valuing the Carbon Storage Service of Agroforestry Eecosystems in the Context of CAP Eco-Schemes, Land Use Policy, 109, 105712.*
- *Lunesu M.F., Caratzu M.F., Correddu F., Nudda A, Battacone G., Pulina G. (2022), Meriagos can Contribute to Achieve Net Zero Sardinian Beef Cow-calf System Farms, Proceeding of 6th European Agroforestry Conference (EURAF) "Agroforestry for the Green Deal Transition, Research and Innovation towards the Sustainable Development of Agriculture and Forestry", 16-20 May 2022, Nuoro, Italy.*
- *Mayer S., Wiesmeier M., Sakamoto E., Hübner R., Cardinael R., Kühnel A., & Kögel-Knabner I. (2022), Soil Organic Carbon Sequestration in Temperate Agroforestry Systems–A Meta-analysis, Agriculture, Ecosystems & Environment, 323, 107689.*
- *Montagnini F., & Nair P.K.R. (2004), Carbon Sequestration: An Underexploited Environmental Benefit of Agroforestry Systems, In New Vistas in Agroforestry: A Compendium for 1st World Congress of Agroforestry, 2004 (pp. 281-295), Springer Netherlands.*
- *Pacala S., & Socolow R. (2004), Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies, Science, 305(5686), 968-972.*
- *Post W.M., Emanuel W.R., Zinke P.J., & Stangenberger A.G. (1982), Soil Carbon Pools and World Life Zones, Nature, 298(5870), 156-159.*
- *Ramachandran Nair P.K., Mohan Kumar B., & Nair V. D. (2009), Agroforestry as a Strategy for Carbon Sequestration, Journal of Plant Nutrition and Soil Science, 172(1), 10-23.*
- *Sanna F., Campesi G., Deligios P., Ledda L., Piluzza G., Sulas L., Re GA (2021), Combined Effects of Microenvironment and Land Use on C Fluxes in a Mediterranean Agro-silvopastoral System, Eur J Agron 130:126348, https://doi.org/10.1016/j. eja.2021.126348.*
- *Sharma M., Kaushal R., Kaushik P., & Ramakrishna S. (2021), Carbon Farming: Prospects and Challenges, Sustainability, 13(19), 11122.*
- *Smith P. (2004), How Long before a Change in Soil Organic Carbon can be Detected?, Global Change Biology, 10(11), 1878-1883.*
- *Stockmann U., Adams M.A., Crawford J.W., Field D.J., Henakaarchchi N., Jenkins M., Minasny B., Alex B., McBratney A. B., de Remy de Courcelles V., Singh K., Wheeler I., Abbott L., Angers D. A., Baldock J., Bird M., Brookes P. C., Chenu C., Jastrow J. D., Lal R., Lehmann J., O'Donnell A. G., Parton W. J., Whitehead D., & Zimmermann M. (2013), The Knowns, Known Unknowns and Unknowns of Sequestration of Soil Organic Carbon. Agriculture, Ecosystems & Environment, 164, 80-99.*
- *Tarnocai C., Canadell J.G., Schuur E.A., Kuhry P., Mazhitova G., & Zimov S. (2009), Soil Organic Carbon Pools in the Northern Circumpolar Permafrost Region, Global Biogeochemical Cycles, 23(2).*
- *Udawatta R.P., Jose S. (2011), Carbon Sequestration Potential of Agroforestry Practices in Temperate North America, Carbon Sequestration Potential of Agroforestry Systems: Opportunities and Challenges, 17-42.*

BIOGENIC EMISSIONS IN THE AGRI-FOOD CHAIN
A COMPLEX THEME[14]

It has been said that the farming process is above all directly responsible for methane gas emissions. On the contrary, the cultivation processes cause emissions in terms of nitrous oxide. In both cases, carbon dioxide emissions occur to a lesser extent. As can be understood, quantifying the volumes of gas emitted and converting them into a carbon footprint value is anything but banal. Without going too far into technical details, the intent of this section is again to provide a useful tool for interpreting impacts, which is not easy reading.

The first aspect to consider is the ***temporal relationship*** *between* ***the moment of emission into the atmosphere and the complete reabsorption*** *of that CO_2. On closer inspection, actually, even fossil fuels regenerate: the problem lies in the fact that regeneration time (millions of years) is much shorter than that in which they are released into the atmosphere (years). In order for agricultural systems to be considered "zero impact", the emission/absorption cycle should be as balanced as possible. In this context, a fundamental role is played by the possibility of securing carbon in the ground, effectively slowing down the flow of emissions. Though this is an element that depends very closely on the agricultural practices adopted.*

A second complicating aspect concerns ***the behaviour of the various gases emitted****, determined by complex physical/chemical exchanges. Carbon dioxide, for instance, can persist in the atmosphere and continue to have effects on the climate for thousands of years. Methane, on the other hand, has a much shorter permanence time, around 10 years. However,* ***the carbon footprint is calculated considering a fixed period of time, typically taking into account the contribution to global warming that a molecule emitted today will have over the next 100 years.*** *Obviously, this contribution is calculated evaluating both the extent of the damage and the time interval over which this damage is to be spread: in the case of a methane molecule, the impact over 100 years is greater than that caused by carbon dioxide (about 28 times) and is therefore to be kept under close observation.*

As can be understood, this is an area still under study and, pending further certain considerations (as well as calculation conventions), the two key elements are:

- *the calculation and reporting of emissions, those derived from fossil sources are kept separate from those generated by biological systems (biogenic emissions in fact);*

- *agricultural processes can be a (partial) solution only when it can be demonstrated that the absorption/emission cycle is regulated by timings that allow them to be considered in equilibrium.*

[14] Extract from the book 'Il cibo perfetto' (Marino and Pratesi, 2022).

2.5 Monitoring in Italy[15]

As part of the tools and policies implemented to face climate change, a fundamental role is played by the monitoring of greenhouse gas emissions.

ISPRA (Italian Institute for Environmental Protection and Research) is the Italian body in charge of compiling **the national inventory of greenhouse gas emissions** (National Inventory Report - **NIR**), in accordance with the provisions under the United Nations Framework Convention on Climate Change (UNFCCC). It is a strategic document containing the estimation methodologies used and an explanation of the observed trends which serves as a reference for the planning and implementation of all environmental policies by central and peripheral institutions.

The documentation every year is submitted for examination (review) by a body appointed by the Secretariat of the Convention which analyses all the material presented by the country and verifies in detail the qualities stated. Without these prerequisites, Italy would be excluded from participating in the flexible mechanisms envisaged by the same Protocol, such as the emissions quotas market, the implementation of projects with developing countries (CDM) and the implementation of joint projects with countries with economies in transition (JI).

Alongside the greenhouse gas inventory, every year ISPRA carries out the **national inventory of pollutant emissions into the atmosphere** (Informative Inventory Report - **IIR**), required by the Geneva Convention on Transboundary Air Pollution (UNECE-CLRTAP) and by the European directives on the limitation of emissions. In this case, the object of study is broader: not only the gases which, once in the atmosphere, contribute to the greenhouse effect, but all the substances which alter the normal chemical composition of the air with consequences on human health and the environment. Accordingly, among others, emissions of heavy metals and fine dust emissions (PM10, PM2.5) are also included, i.e., solid and liquid particles of variable size and composition, typically emitted by motorised road traffic (but not only).

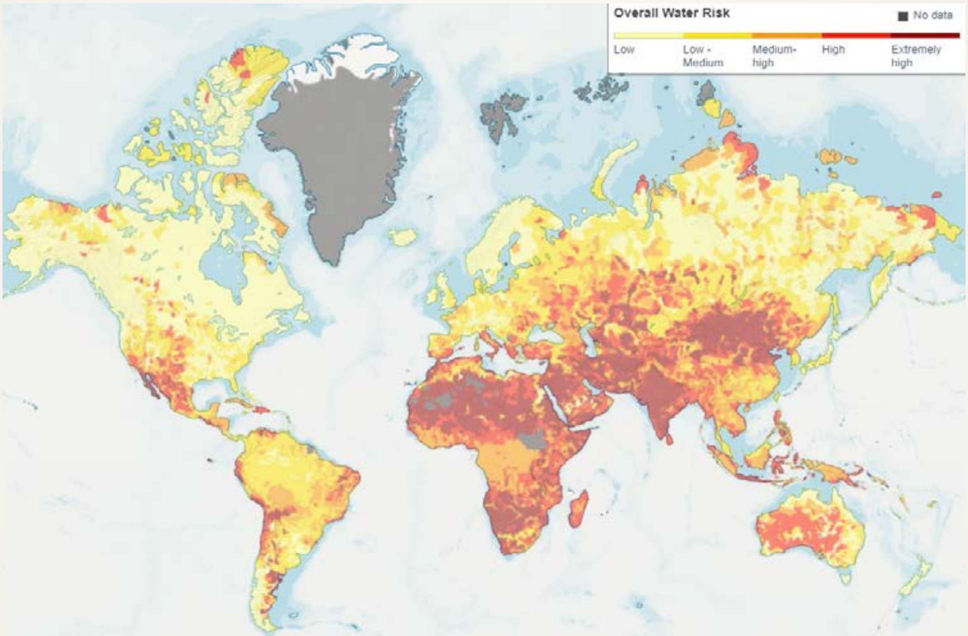
In addition to the reporting activity carried out by ISPRA, the whole Italian territory is currently covered by regional inventories essentially congruent with the Italian inventory, mainly carried out by the Regional and Provincial Agencies for the Protection of the Environment (ARPA).

Despite the progress made, the activity of preparing inventories continually faces new challenges related to the need to consider new sources and new pollutants.

3 IMPACTS ON WATER: WATER FOOTPRINT

One of the most discussed environmental aspects of agricultural and livestock production regards water. This aspect must be analysed from two different points of view: on the one hand, the **volumes used in the production processes** must be considered, and on the other, the level of **contaminants released into the environment.** Each of these two aspects, which should always be analysed combined, is controlled and measured with different evaluation parameters. While water quality has historically been subjected to greater controls (for example, the annual publication of the national plan for the research of residues by the Ministry of Health), the volumes consumed have begun to attract interest and become elements of discussion in more recent times.

AREAS SUBJECT TO WATER RISK



Higher values indicate a higher water risk.
Source: Aqueduct Water Risk Atlas[17].

As with climate change, **calculating the impact of water is also a complex issue, with many variables at stake.** The need to translate this complexity into concise and understandable information - capable of guiding individual consumers in their choices as well as players along the supply chain and even political decision-makers - has led to the definition of **aggregate indicators** (an example of which is shown in the figure in the previous page). In recent years, the calculation of the water footprint has been the subject of lively debate within the scientific community, leading to the parallel development of **two main alternative approaches** of evaluation: the one proposed by the **Water Footprint Network (WFN)** and the one elaborated by the **Life Cycle Assessment** community (which initially contributed to the definition of the concepts underlying the **ISO 14046** standard, and then went on to develop new methods, including **AWARE**). There are also variation proposals in scientific literature to these two procedures, but also very different methods among which it is worth mentioning that of **water scarcity** (water stress or water scarcity which will be discussed later) which links consumption to the possibility of natural regeneration of water bodies, starting from the assumption that a litre of water used in the desert is different from one used in the rainforest.

3.1 The Water Footprint Network

The Water Footprint Network[18] (WFN) method was the first protocol used globally to account for the water footprint of products and processes, until the publication of the ISO 14046 standard and new impact calculation methodologies related to the use of water (Ecological Scarcity, Pfister, AWARE, just to name a few) which, as mentioned, have integrated the approach with the weighing of water consumption based on the real availability in the place of production, providing a more complete and contextualised interpretation.

The **green water** footprint is characteristic of products of agricultural or forestry origin and represents the quantity of rainwater that crops use in their production cycle to live and grow. This quota is the quantity of "evapotranspirated" water, i.e., which passes from the ground to the atmosphere due both to the evaporation of soil moisture and to the plants' own transpiration and which is stored in the surface layer of the soil. Not all rainwater is exploited in this process for reasons related to the particularities of the soil, the needs of plants and the characteristics of root systems. The **green water footprint**, consequently includes exclusively the volumes of rainwater that are retained by the soil and are available to meet the needs of the crops, calculated according to the type of crop, the meteorological-climatic area and the average annual rainfall.

The **blue water** quota represents the quantity of water withdrawn from a body of water (rivers, lakes, aquifers) which is effectively used in the production process and does not return downstream to the same source from which it was withdrawn. Therefore, if the water is withdrawn, e.g., for a hydroelectric plant and immediately re-emitted into the same water course from which it was drawn, the blue water footprint consists only of the part possibly lost through evaporation or micronisation during the plunge and impact with turbines.

Finally, the **grey water** component is defined as the volume of water necessary to dilute the load of contaminants leaving the system (such as fertilisers that percolate in depth underneath a cultivated field or chemical products leaving an industrial process), so that their concentration in the water remains below the maximum values established by current legislation. In practice, the higher the level of pollution generated, the higher the grey footprint value will be. However, on closer inspection, the quantity that **man has consumed or polluted directly** consists of the **blue** component (necessary as an input to the process) and the **grey** component (necessary to reduce the output load of pollutants). **On the contrary, the green component** is simply water that completes its natural hydrogeological cycle, continuously passing from the atmosphere to the ground and to waterways (surface and groundwater). This component **represents over 80% of the total water** footprint of all agri-livestock systems calculated according to the WFN.

3.2 The ISO 14046 standard

The WFN was the most used protocol for accounting for the water footprint of products and processes until the publication of the ISO 14046 standard in 2014.

The ISO standard was created with the aim of defining the guidelines for evaluating the water consumption of a system starting from an LCA-type analysis.

The ISO standard does not refer to the concept of virtual water or to the distinction between green, blue and grey water footprints. However, the protocol suggests taking into consideration **the quantity of pollutants** present in the flows and evaluating them when representing the impacts with environmental indicators.

In addition, this standard introduces the concept of **Water Scarcity**, defined as the impossibility of having adequate quantities of water to make ends meet. In other words, water consumption is weighed on the basis of the real availability of water in the place of production: therefore, unlike what happens for climate change impact, here local characteristics really do count!

3.3 The AWARE model

In the past, a very widespread model used to quantify Water Scarcity was the **Water Resource Depletion**, developed in 2010, by the Joint Research Centre (JRC) of the European Commission and promoted as part of the initiatives for the calculation of the environmental footprint of products (PEF, Product Environmental Footprint) and organisations (OEF, Organisation Environmental Footprint). The Water Resource Depletion was then replaced in 2018, by the **AWARE** model, also based on the concept of Water Scarcity.

The impact indicator AWARE (**A**vailable **WA**ter **RE**maining)[19] measures the "**potential for deprivation**" of water, both for humans and ecosystems, starting from the assumption that the less water remains available per area, the greater the probability that another consumer in the same area is deprived of it[20-21].

The characterisation factors obtained with this method are still used today within the European certification schemes (PEF and OEF), but they are also adopted by the International EPD System® and can be used to calculate the water scarcity water footprint as defined by the ISO 14046 standard.

AWARE
THE MODEL IN DETAIL

The characterisation factors are specific to each geographical macro-area and are essentially based on the relationship between water supply and demand.

*In fact, the calculation of this indicator starts from the difference between the availability and the demand (utilisation) of water, on a monthly basis (m^3/m^2 per month). This signifies taking into account, for example, the fact that in Mediterranean areas the consumption of water for **agricultural purposes** will occur more in the summer months.*

*For consistency, although less accentuated, the monthly variations in consumption for **non-agricultural purposes** (domestic and industrial use) are also considered.*

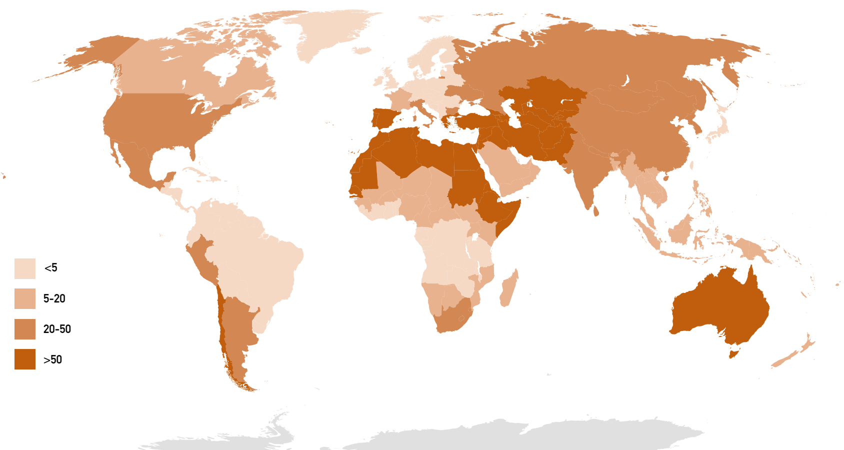
*The value acquired is then normalised with the average result obtained on a global scale, gaining the value of AMD (Available Minus the Demand). In this way, the value for each area is expressed in relation to the average water consumed in the world and can therefore be compared with the result obtained in other geographical areas. The characterisation factor according to the AWARE model is the inverse of ADM, i.e., 1/ADM, and is included **in a range of 0.1-100, with the value of 1 corresponding to the world average.***

Example: agricultural use in Italy

World average	1
Italian value	0.02*
= Characterisation factor	46.40

** The ADM value (0.02) means that the water that remains available in Italy, once the water demand by human and aquatic ecosystems has been satisfied, is 2% of the average world value*

SIMPLIFIED MAP OF CHARACTERISATION FACTORS FOR AGRICULTURAL USES
average over 12 months



The lowest values are observed for tropical rain forests (Amazon area and Central America, Central Africa, South-East Asia), zones characterised by intense rainfall in the face of not very high-water demand.
Source: Boulay et al., 2018[20].

3.4 The Net Waterfootprint (WFP_{NET}) model

As the name suggests, this model is a variation of the aforementioned WFP.
In the WFP method it has already been underlined that the **green component** alone represents over 80% of the water footprint of any agri-livestock system. This value dominates the WFP indicator and originates from the fact that all the consumption of evapotranspiration water from the crops used for animal feed (ET) is attributed to the product. In other words, if there hadn't been that specific cultivation, the ET of that area would have been zero. Which of course doesn't make sense.
The WFPNET[22] model aims to improve this aspect of the calculation, with the quantification of the difference between the ET of the crop under investigation and the ET of a natural reference situation (e.g., forest) that is conceivable for the geographical area in question. In other words, the model assumes that if there were no crops in the fields for the production of feed for livestock, the area in question would still have a vegetation cover with relative evapotranspiration. The value obtained is therefore the amount of water that the crop has consumed (more or less) than in a situation with natural cover. This value is then added to the drinking water and the service water.

This alternative calculation method represents the real impact induced by human action in the choice of cropping systems, returning much lower values than the traditional method (WFP).
For example, feeding an animal with a ration that has a low feed conversion factor but achieved through an efficient use of water during the cultivation phase, we obtain:

WFP AND WFP_{NET} COMPARISON FOR MEAT AND MILK[22]

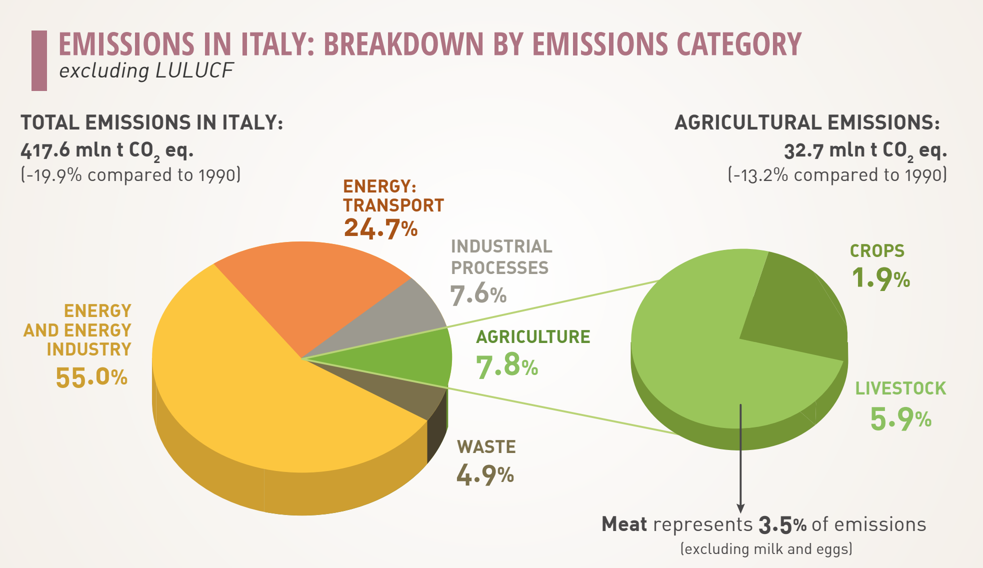
	WFP	WFP_{NET}
Liters of water consumed per kg of meat produced	15,700	790
Liters of water consumed per kg of milk produced	728	27

4 IMPACTS ALONG THE SUPPLY CHAIN

4.1 The Italian scenario

ISPRA data (National Inventory Report 2023 and Informative Inventory report 2023), show that in Italy **only 7.8% of greenhouse gas emissions are attributable to all the agricultural sector.** This is approximately 32.7 million tonnes of CO_2 eq., a sharp decline when compared to that of thirty years ago (-13.2%). As shown in the figure below, about two thirds of these emissions are attributable to livestock activities, one third to crops.

The main input is given by the **energy sector**, which accounts for almost **80% of climate-changing gas emissions**, broken down as follows: 24.7% from transport; 55% from the energy industry – i.e., all the industries involved in the production and sale of energy, including extraction, production, refining and distribution of fuels – and from other activities related to the energy sector (such as use of fuels in industrial plants, fugitive emissions, etc.).



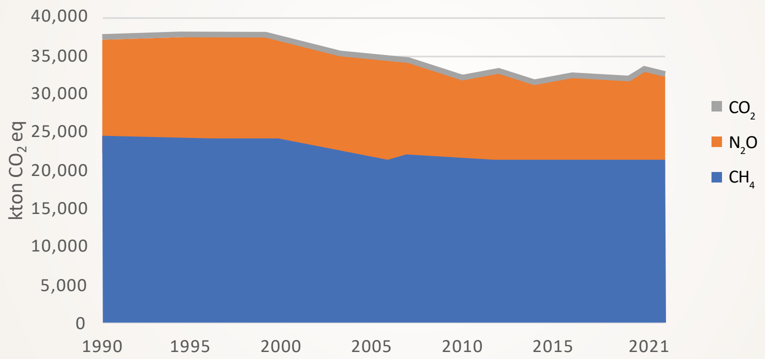
In agricultural emissions, the 'livestock' category includes emissions from the spreading of livestock manure and those deriving from grazing.
Source: ISPRA Report 383-2023. Table ES.2.

There are many types of gases that contribute to the greenhouse effect, but the most relevant for the livestock supply chain are three:

- **nitrous oxide** (N_2O) caused by the cultivation of vegetable sources used in rations, due to the use of nitrogen-based fertilisers (natural or synthetic) and by the volatilisation of nitrogen caused by the treatment of bedding and effluents;
- **methane** (CH_4) from enteric fermentations (gases generated by ruminant digestion) and from manure management;
- **carbon dioxide** (CO_2) generated by the use of fossil fuels.

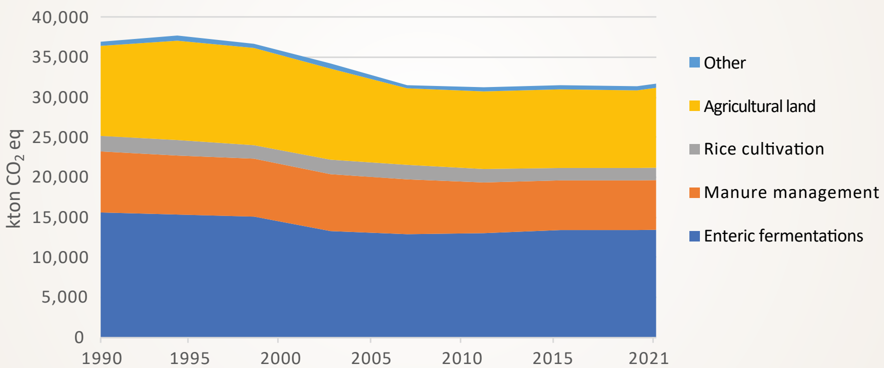
The two graphs below represent the greenhouse gas emissions from the Italian agricultural sector, separated according to type of gas and type of agricultural processes.

GREENHOUSE GAS EMISSIONS IN THE ITALIAN AGRICULTURAL SECTOR



Contribution of carbon dioxide, methane and nitrous oxide to the total (data in kton of CO_2 eq.)
Source: ISPRA Report Ispra 383-2023 . Tab. 5.1.

GREENHOUSE GAS EMISSIONS IN THE ITALIAN AGRICULTURAL SECTOR



Contribution of the various processes to the total impact (data in ktons of CO_2 eq.)
Source: ISPRA Report Ispra 383-2023. Tab. 2.4.

IMPACTS ALONG THE SUPPLY CHAIN

In the following sections, the meat supply chain is presented according to a logical division into 4 consequential phases: feed production (feed ration), livestock farming, transformation and distribution. Each phase is characterised by peculiarities that allow the more or less specific recognition of impact analyses and the actions to reduce them.

Like people have, animals have dieticians as well. They establish the appropriate rations for the various animal species during the various phases of their lives. Soy, corn, sunflowers, alfalfa and hay are the main raw materials grown for making feed for livestock.

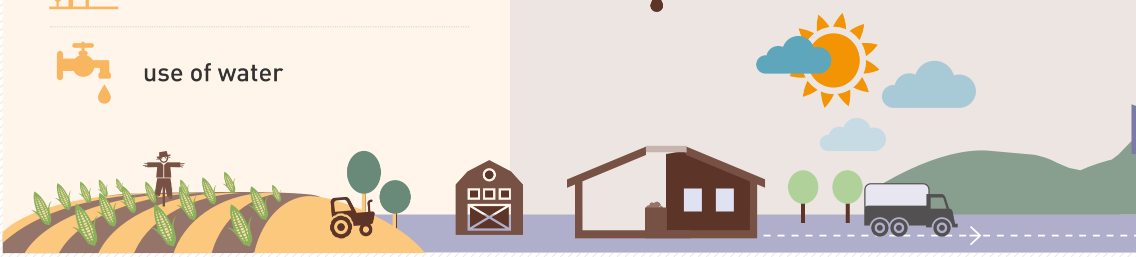
Livestock farming can be managed according to different production models according to both where they are located and the type of animals bred.

PRODUCTION OF FEED

- use of fertilisers and agrochemicals
- use of diesel fuel
- land occupation
- use of water

LIVESTOCK FARMING

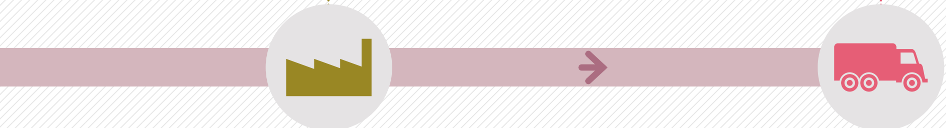
- the manure of animal management
- energy consumption
- use of water



Although it is often believed that the most significant phases are those related to industrial processing or distribution, **more than half the overall impact derives from agricultural production (farm management and feed cultivation) and from land use change, as already mentioned in section 2.1.** Agricultural and livestock farms are therefore the places where it is necessary to work to control and reduce, where possible, the factors of environmental impact.

The transformation phase begins with the slaughtering of the animals and includes, when foreseen, the production of more elaborate products such as meats and cured meats.

Distribution involves all of the production phases up until the retail stores or the meat's consumption.

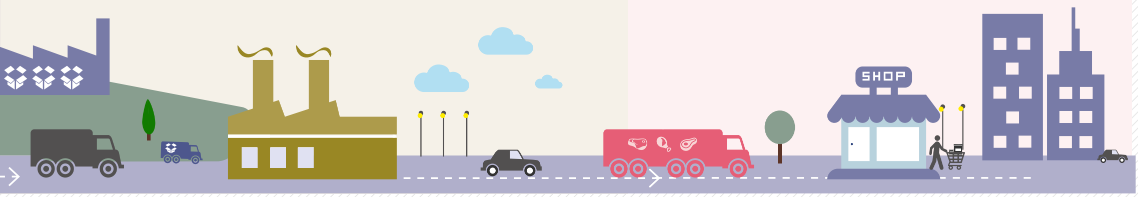


TRANSFORMATION

- energy consumption
- waste production
- use of water

DISTRIBUTION

- transportation
- energy for conservation
- use of packaging



BIOECONOMY
BIOENERGIES

*The European Commission's **Bioeconomy** Strategy defines the latter as that component of the circular economy that uses **"the biological resources of land and sea as raw material for the production of food, animal feed, chemicals, materials and energy"**[1] It represents a fundamental component of the European Commission's Green Deal[2] and a lever for the transformation of the European economy into a resilient and circular system.*

*It is considered a strategic sector that uses **biomass**, i.e., renewable biological resources, as **a material for energy** (bioenergy), **industrial** (biomaterials), **food and feed production.***

*The '**biomass**' category includes any material deriving from **animals, plants and microorganisms.** Therefore, it does not refer to a specific product sector but rather to a "bio-based" production with the use of renewable inputs, and represents a central role in the ecological transition process, as it indicates **the recovery and valorisation of already available biomass** as a priority (second generation resources) **rather than the production of biomass ex-novo** (first generation). In other words, the approach to follow is fully consistent with the principles of circularity.*

VALORISATION OF BIOMASS IN LIVESTOCK

*The bioeconomy is therefore a fundamental element in safeguarding natural resources, but it must be based on renewable biological resources and used defending the **resilience** of ecosystems and not compromise natural capital. The simplest and most natural way to collect and valorise second-generation biomass is the implementation of **integrated supply chains,** strongly connected to the territory and which, if well managed, make it possible to **increase the sustainability of agricultural production.***

*It should be remembered that, in order to optimise the qualitative characteristics of biomass and extract the maximum possible added value, the concept of **bio-cascading**, or sequential use of resources, is applied, for which the direct use of biomass for energy production must be avoided, favouring intermediate uses, with high added value, followed by reuse and recycling to obtain further products, while energy conversion is left as the last step in the chain.*

*This concept is fully respected in the livestock field: animal feed, with the recovery of co-products from other production cycles, is an example of this new paradigm and only the **biomass unusable** for animal consumption (think of winter cover crops or manure collected in the barn) are intended for the **production of energy.***

BIOENERGY AND ANAEROBIC DIGESTION

Since the 1990s, thanks to policies aimed at reducing the causes of climate change, investments have grown in the production of first generation biomass for energy purposes.

These productions, in the absence of explicit criteria to evaluate their sustainability, have had a modest impact on the reduction of *climate-altering emissions and negative environmental consequences. In particular, the most serious accusations are **the competition with food production** and the incentive for deforestation such as, for example, the felling of tropical forests to make space for palm oil plantations to satisfy the growing demand for biodiesel. Realising the error, **the EU has subsequently shifted its attention towards second generation bioenergy** [3], while the cultivation of dedicated species is limited to marginal land unsuitable for food production.*

*The use of biomass for the production of energy is possible through multiple technologies, but **anaerobic digestion** is decidedly the most relevant, as it can **effectively convert organic carbon into biogas,** even on a small scale (> 500,000 l/year of diesel equivalent) and with technologies that are easily useable even in developing countries apply well-known, free biotechnologies, in different agricultural and ecological situations as well as in different climatic zones[4].*

*The main product of anaerobic digestion is **biogas,** a by-product is **digestate.***

BIOGAS

*Biogas originates from the decomposition of organic material by some types of bacteria in the absence of oxygen. The product of the transformation is a gaseous mixture consisting mainly of methane and carbon dioxide. It is a very versatile **energy vector.***

Biomethane** is obtained from biogas through a process called **"upgrading" (removal of CO_2),** which allows the obtainment of a biofuel very similar to **natural gas.

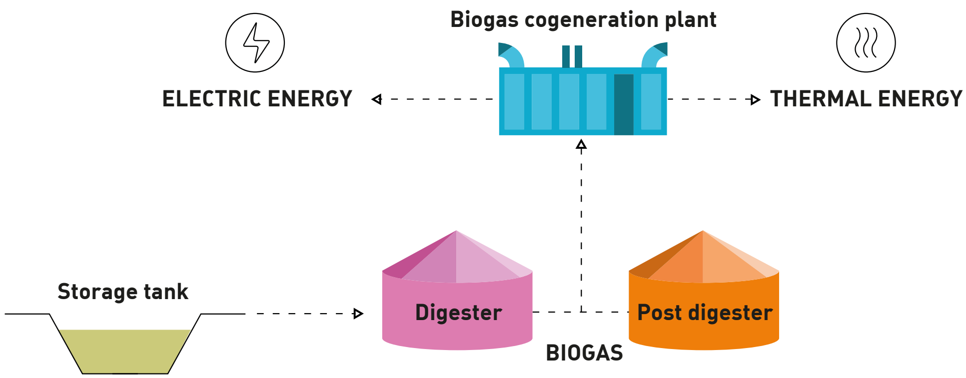
THE DIGESTATE

*The digestate, on the other hand, if produced exclusively from organic agricultural matrices such as effluents, agri-industrial waste, etc., can be used on the farm itself as a **fertiliser,** after an operation of stabilisation. In anaerobic digestion, the life cycle of carbon and nitrogen are therefore closed with the material leaving the plant (digestate) used as a fertiliser, contributing to the circularity of agri-industrial systems.*

*The recent increases in the price of raw materials, caused by the international crisis, have stimulated the adoption of solutions aimed at optimising production cycles and controlling prices. In this context, the introduction of **digestate to replace chemical fertilisers** is recognised as one of the most interesting options, even if the nutrient content varies according to the type of biomass used and the reduction in the use of fertilisers also largely depends on the adoption of **correct distribution techniques.** Several farms with biogas plants, thanks to an advanced and efficient digestate management, have considerably reduced the need for chemical fertilisers with consequent optimisation of crop costs[5].*

*It is no coincidence that **Italy has long been one of the main producers of agricultural biogas,** in 2017, already **fourth in the world after Germany, China and the United States,** with an installed electrical power of over 1000 megawatts (equivalent to 2.4 billion cubic meters of natural gas), as revealed by a study by the Consortium Italian Biogas (CIB)[6]. As far as quality is concerned, the production*

SCHEMATISATION OF A BIOGAS COGENERATION PLANT



From biomass to energy production. Re-elaboration from Intergen S.p.A.

*of biogas and biomethane according to the principles of the Biogasdoneright® platform (Biogas done right, the production specification promoted by the CIB) has **measurable** positive effects not only with the increase in food and fodder production but also with the improvement of levels of biodiversity, quality and nutrients of the soil thanks to the use of digestate[7].*

*The biomass is stored in basins, tanks or silos, and is pre-treated and sterilised to remove pathogens. The material is transferred through special pumps and pipes into the digesters (hermetically sealed and heated tanks), where it is continuously mixed with propeller or hydraulic mixers. The gases accumulate in the upper part of the digesters. Once available, the biogas is conveyed into the cogenerator, consisting of an endothermic engine (internal combustion). The energy exploitation of biogas takes place through CHP (Combined Heat and Power) plants, which guarantee the simultaneous production of **electricity and heat**, with relatively low emissions of polluting molecules.*

*In conclusion, we can state that the Italian Bioeconomy Strategy, precisely because it starts from the involvement of all the players in the supply chain and in particular the **agri-livestock sector, will be able to make an important contribution in overcoming the current criticalities,** but also to design a more sustainable future both from an economic point of view, for the exploitation of materials hitherto considered waste or unprofitable and also from an environmental point of view, in particular for the **reduction of fossil fuel use** and consequent reduction of the impacts of energy production and improvement of levels of biodiversity, soil quality and nutrients.*

[1] European Commission, A Sustainable Bioeconomy for Europe: Strengthening the Link Between Economy, Society and Environment, OM[2018] 673).

[2] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_it.

[3] The EU Directives on Bio-Energy (Renewable Energy Directive): the RED 1 of 2009 and the RED 2 of 2018.

[4] BIOGASDONERIGHT® ANAEROBIC DIGESTION AND CARBON SEIZURE IN THE SOIL, https://www.consorziobiogas.it/wp-content/uploads/2016/12/biogasdoneright_-ITA.pdf.

[5] BIOGAS INFORMS – Magazine of the Italian Biogas Consortium No.38/2022.

[6] THE DAWN OF AN AGRICULTURAL REVOLUTION: ITALIAN BIOGAS AND BIOMETHANE SET EXAMPLES IN THE WORLD. Press release of the Consortium Italian Biogas (CIB) of 10th March 2017. Available at the link: https://www.consorziobiogas.it/lalba-rivoluzione-agricola-biogas-biometano-italiano-fanno-scuola-nel-mondo/.

[7] BIOGASDONERIGHT® ANAEROBIC DIGESTION AND CARBON SEQUESTRATION IN THE SOIL, https://www.consorziobiogas.it/wp-content/uploads/2016/12/biogasdoneright_-ITA.pdf.

[8] ACTION PLAN (2020-2025) FOR THE IMPLEMENTATION OF THE ITALIAN STRATEGY FOR THE BIOECONOMY BIT II (January 2021), https://cnbbsv.palazzochigi.it/media/2426/actionplanbioeconomy_it.pdf.

LIVESTOCK BIODIVERSITY: KNOW IT, CONSERVE IT, VALORISE IT

WHY IT IS IMPORTANT TO PROTECT BIODIVERSITY

*Biodiversity is **the variety of life forms that coexist in a given ecosystem.***

Livestock biodiversity is therefore the set of species and breeds of domestic animals, to which are added the wild animals that coexist with the former (birds, amphibians, reptiles, insects, worms, etc.) and the coexisting plant species and microbial varieties in a given livestock system. The millenary selection carried out by breeders has given us, according to the FAO, over 11,000 breeds of mammals and about 4,000 of birds, all descended from one or a few wild progenitors.

GENETIC VALUE AND AESTHETIC VALUE

*Biodiversity is a natural and man-made heritage of public utility which is in everyone's interest to conserve. The importance of biodiversity lies in the **enormous heritage of genetic variability, essential for the natural processes of evolution and very useful for the selection of genotypes used in agriculture and animal husbandry.** Think of the genetic pool represented by animals and plants adapted to particularly difficult local conditions on occasions: in times of climatic transitions, this constitutes an invaluable heritage of adaptation and resilience of entire supply chains, as well as the possibility of creating new varieties and breeds that can derive from the vigour of the hybrid's specific resistance to parasites and meteorological adversities (heat stress, water salinisation, etc.).*
*Finally, agri-livestock biodiversity contributes decisively to the **aesthetic quality** of a region, composing its landscape mosaic. The same abandoned areas covered by woods would be home to few species and no production, so much so that there are those who speak of **"green deserts".***

TERRITORIAL MANAGEMENT: THE RIGHT BALANCE BETWEEN PRODUCTION AND ENVIRONMENTAL PROTECTION

*The methods for the protection of biodiversity are very different, from the establishment of protected areas to the safeguarding of threatened species or restocking, but a decisive role in this sense is played by **farmers and breeders, who represent the true custodians of agri-livestock biodiversity** and contribute decisively to the preservation of the natural one. A **balanced development of the territory** must therefore, on the one hand, **favour agricultural and livestock practices** capable of safeguarding biodiversity in suitable areas and, on the other hand, **allocate the marginal ones to "cultivated" woods** (where **active forestry is practiced** and not the abandonment harbinger of disorder and risk of fires, considered by some erroneously as "useful renaturalisation") to guarantee its productivity and bio-systemic dynamism.*

*In conclusion, biodiversity is an identity theme, so important that alongside the indispensable **incentives** for the livestock farmers to exercise its conservation in the public interest, **certification systems** must be developed which allow the citizen-consumer to contribute, with its purchasing choices, to preserving it for the benefit of present and future generations.*

4.2 The feed ration

The starting point of any livestock supply chain is the production of the feed ration, administered daily to the animals raised. Therefore, the first step in investigating the sustainability of the supply chain is to understand the composition of the ration, the characteristics of the raw materials needed to produce it and the main sources of impact. As far as environmental impacts are concerned, **the ration always represents a considerable share of the overall impact of the entire livestock farming process.** It is therefore clear that the challenge of sustainability in livestock production can only be won by systematically and far-sightedly involving all the players in the supply chain, including farms.

4.2.1 What do the animals we raise eat?

Excluding fish, not covered in this volume, the other main categories of farm animals are bovine (for meat and milk), pigs and poultry (for meat and eggs). As can easily be understood, these are very different animals under many aspects and feed is certainly one of these.

Ruminants

Bovines, for example, are ruminants, i.e., animals characterised by a very complex digestive system, made up of three pre-stomachs and a real stomach. Unlike monogastric (pigs and poultry), in ruminants digestion begins in the rumen through a complex phase of microbial fermentation by a complex, and in part still unknown, microbial flora. An out-and-out natural system of bio-fermentation of fibre, starches and proteins contained in feeds which makes available nutrients already absorbed in the rumen (volatile fatty acids), which provide energy and fat precursors to animals. Thanks to this process, the animal is able to convert poor vegetable material (indigestible to many other species, including humans) into noble animal proteins, such as milk and meat.

Monogastric

Pigs and chickens, on the other hand, are not able to process and exploit the high quantity of fibres present in the forage and their daily ration is mainly composed of a mixture of cereals (corn, wheat, barley) and legumes (such as soy). Over time, the attention of the livestock sector has been

AVERAGE RATIONS (QUANTITY AS IS) BY USING DRY FORAGES OF SOME SPECIES STABLE-RAISED IN ITALY

FARM	BEEF CATTLE	DAIRY CATTLE	BROILER CHICKEN	PORK
OVERALL RATION	15-20 KG/DAY	25-30 KG/DAY	0,15 KG/DAY	1,35 KG/DAY
CORN IN VARIOUS FORMS	65-70%	60%	25-30%	45-50%
SUNFLOWER	8-10%	< 5%	–	-
BEET	5-10%	< 5%	–	-
WHEAT AND OTHER CEREALS	5-10%	10%	20%	30-35%
SOY	< 5%	< 5%	40%	15-20%
GRASS AND HAY	< 5%	20%	15%	-
SUPPLEMENTS	< 5%	< 5%	-	< 5%

progressively attracted by unconventional resources, which can be used in more or less variable quantities as substitutes for traditional feed ingredients. This change was dictated not only by economic reasons (lower cost of new resources) or regulatory reasons (impositions to use or not use certain ingredients), but also by the intrinsic characteristics of the new ingredients, whose performance has sometimes proved to be even superior to those of traditional ingredients.

CATTLE: HERBIVORES THAT TRANSFORM CELLULOSE INTO PROTEINS

The complexity of bovine metabolism and the specific characteristics of emissions are the expression of a complex process of conversion.
In fact, ruminants have a real natural system of bio-fermentation made up of the rumen and the large intestine. These organs allow the transformation of the cellulose contained in plants, i.e., ***the fraction that is not digestible for humans.***
The digestion of cellulose in ruminants is carried out by a complex and partly still unknown ***microbiome*** *that develops in these organs. It is only thanks to this system that the animal is able to convert vegetable products (otherwise indigestible)* ***into noble proteins, such as milk and meat.*** *In fact, the biological process of rumination determines the transition from the* ***vegetable to the animal world.*** *This is the reason why ruminants were the first animals that, since prehistoric times, have coexisted with the human species, guaranteeing them* ***the supply of proteins with a high biological value, starting from poor plants with no bioavailability for humans.***

WHAT WOULD HAPPEN
IF THERE WERE NO MORE LIVESTOCK ON EARTH?

Ruminants contribute to food security: from only 600 g of vegetable protein, they provide 1 kg of animal protein.

*Worldwide, **86% of animal feed intake is represented by products that are inedible for humans,** such as fodder, crop residues and various by-products/co-products of the food industry.*

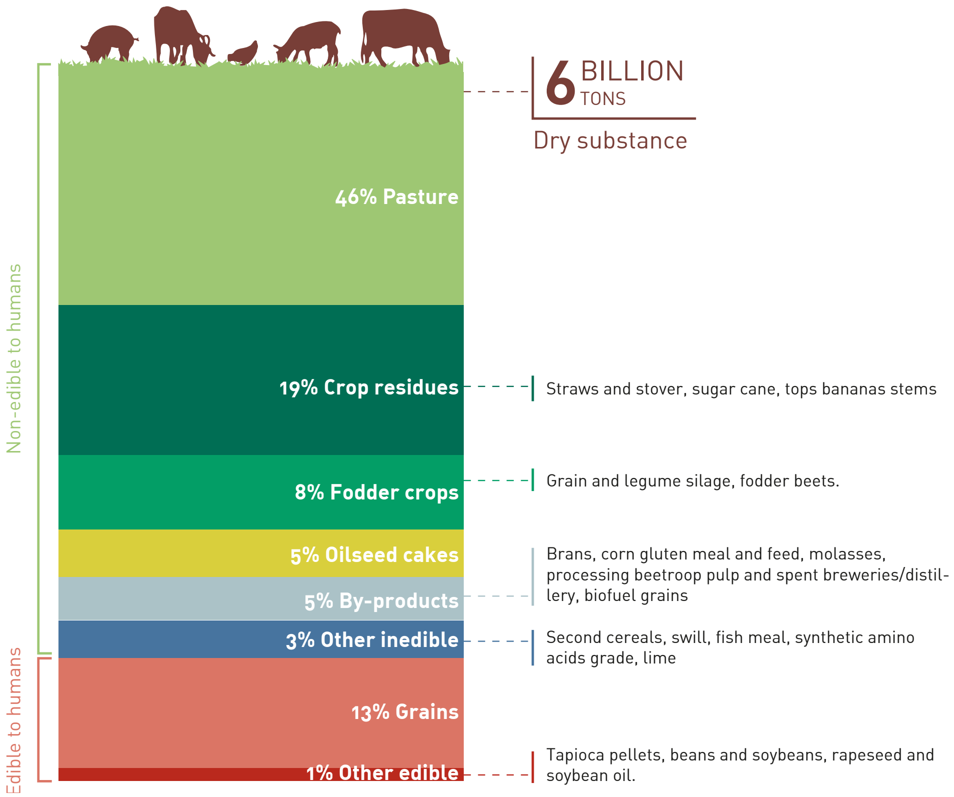
Feeding these products to livestock means reusing/recycling them within the food chain, with a clear advantage for society and the environment (circular economy). In fact, with this choice not only are non-edible products transformed into foods of high nutritional quality (meat, milk, eggs), but also food waste, costs and impacts of waste disposal are reduced.

Seeing as how, despite everything, the competition between animal feed and food for humans continues to be the subject of debate, FAO has conducted an in-depth study on the subject[23]. The results showed that globally livestock consume about 6 billion tons (in terms of dry matter) of feed per year. Of these foods, 86% are not suitable for direct human consumption. The remaining fraction, edible for humans, consists almost entirely of cereals.

*This means that, **to produce 1 kg of meat, only 3 kg of edible feedstuffs are potentially needed for humans** (2.8 kg for ruminants and 3.2 kg for monogastric), much less than the 6-20 kg of cereals which one often hears about.*

*In particular, to produce 1 kg of high biological value proteins (i.e., rich in essential amino acids for humans) present in milk and meat, bovine consume only **0.6 kg** of low biological value proteins coming from feed sources potentially intended for humans (see table on next page). Even if monogastric register a slight imbalance in the conversion factor (2 kg of vegetable proteins to obtain 1 kg of animal proteins), since the average biological value of the first is about 60% of the second, the nutritional balance remains however very positive.*

OVERALL AVERAGE COMPOSITION OF THE ADMINISTERED RATION ON THE FARM



Source: www.fao.org/3/cc3134en/cc3134en.pdf.

TRANSFORMATION VALUES OF VEGETABLE PROTEINS INTO ANIMAL PROTEINS

	Protein	FCR 1	FCR 2	Meat FCR 2	FCR 3	Protein FCR 2
	Mt/year	Kg DM /Kg protein	Kg dry edible DM /Kg protein	Kg edible DM /Kg meat	Kg compete DM /Kg protein	Kg edible protein /Kg protein
Ruminants	36 355	133	6	2.8	6.7	0.6
Monogastrics	38 246	30	16	3.2	20.3	2.0
All	74 601	80	12	3.1	13.7	1.3

FCR1 = Kg of dry matter (DM) intake/ kg of proteins in the products (meat, milk and eggs);
FCR2 = Kg of human edible DM/ kg of protein in the products;
FCR3 = Kg of DM intake from human-edible feed and soybean cakes/ kg of protein in the products.

Source: Mottet et al., 2017. Global Food Security[23].

THE USE OF LAND FOR LIVESTOCK FARMING

By Susanna Bramante

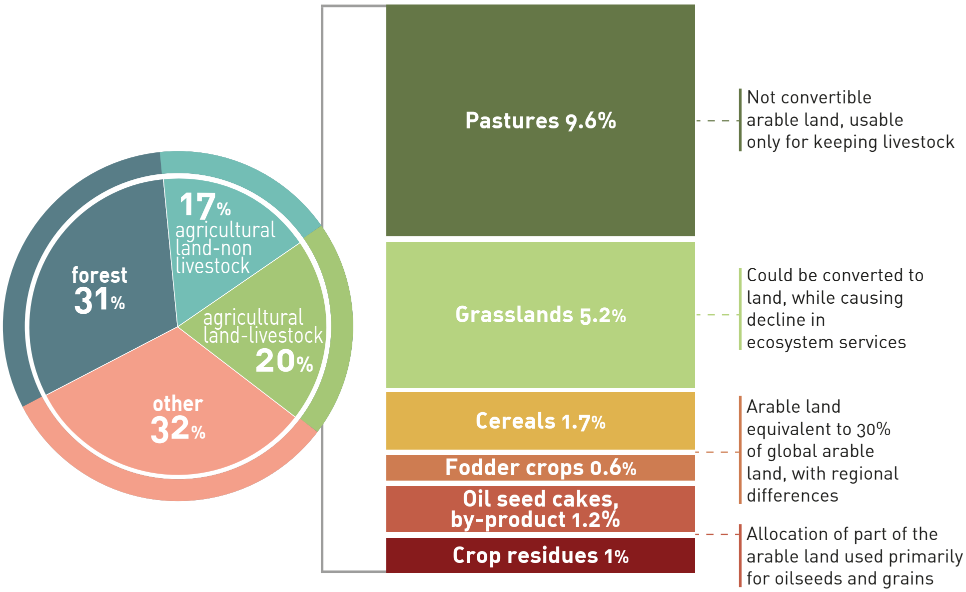
When livestock farming is accused of exploiting or subtracting land from the cultivation of food for human, it is necessary to know that a large part of the land used to feed livestock cannot be directly used to produce food.
The livestock farming takes place on large areas of land, mainly used for grazing and for the cultivation of fodder.

The total area of agricultural land currently used globally for livestock is 2.5 billion hectares, which corresponds to about 50% of the world's agricultural area and about 20% of the land surface. The most considerable part of this surface, i.e., 2 billion hectares, is made up of grasslands used by animals; beyond these, 1.2 billion hectares of vegetated surfaces are not grazed because they are very poor or at high altitudes, or because they consist of steppes and shrubby ecosystems.
However, the lands that are not suitable for grazing play an active role as carbon reserves and therefore for its sequestration from the atmosphere. Of the 2 billion hectares of grassland currently used by livestock, only about 0.7 billion hectares could be converted to arable land for crops. The remaining 1.3 billion hectares, on the other hand, are not convertible, due to various limiting factors, such as excessive steepness, soils of limited depth or due to the limited number of vegetative cycles. Therefore, the only way to use these areas for the production of food for human is precisely through livestock farming, especially ruminants (bovine, buffalo, sheep and goats).
In addition to pastures, livestock farming relies on arable land for the production of forage and feed. The total arable land used for animal feed is approximately 0.55 billion hectares, corresponding to 40% of global arable land.
Most of these are used for the cultivation of cereals, two thirds of which are consumed by chickens and pigs. Livestock is also able to obtain feed from co-products deriving from the processing of oilseeds or residues from the harvest of cereals, such as feed cake and straw, which cover approximately 0.13 billion hectares of land each (but whose primary destination is human nutrition). Only 0.06 billion hectares of land are destined for the production of silage, hay and beet fodder and could effectively be used to obtain food for humans. In short, the competition for land use between animal feed and human food is limited and can be further reduced by optimising the use of co-products deriving from the processing and residues of seeds and cereals in animal feed.

Annual animal feed consumes 20% of global biomass, i.e., 6 billion tons of dry matter.
Livestock consume only one third of the world cereal production as feed, i.e., 11% of the total amount of food ingested. The rest, i.e., 86%, is mainly composed of cellulose-rich plant materials, which cannot be used directly as food by humans, in particular grass, hays, crop residues and crop by-products. By the way, ruminants carry out a paramount labour of transformation in their complex specialised digestive system: making it possible to convert these non-edible fibrous plant materials, indigestible

to humans, into noble proteins of high nutritional quality, as they are endowed with all the essential amino acids necessary to mankind. A last, little-known aspect, relates to the use of animals as a driving and transport force in agriculture: more than half of the power supplied in the world's rural system derives from herbivorous animals, especially bovine and buffaloes, whose diet is exclusively made up of fodder and by-products.

LAND USE AT GLOBAL LEVEL



Global land use totalling 13 billion hectares and detail of convertible and non-convertible grassland into arable land. The "other" section includes bare, sols, snow, and glaciers.

Source: Beal T., Gardner C., Herrero M., Iannotti L. L., Merbold L., Nordhagen S., Mottet A. (2023). Friend or Foe? The Role of Animal-Source Foods in Healthy and Environmentally Sustainable Diets, The Journal of Nutrition, 10.1016/j.tjnut.2022.10.016.

GENOMIC SELECTION
AND NEW BREEDING TECHNIQUES (NBT)

By Alberto Cesarani

*The cosmopolitan breeds, characterised by high productivity, currently bred in modern livestock are the result of **years of genetic improvement (GI)** in which the best animals have been chosen as parents for subsequent generations. Genetic improvement, which has always made use of the most recent discoveries in quantitative genetics and the most modern and performing statistical models, has produced, and still produces, a **permanent improvement that can be transmitted** from one generation to the next. In the past, GI was based exclusively on phenotypic and genealogical information with the aim of extracting, from the total phenotypic variability, a portion of variability of an additive genetic nature and, therefore, transmissible to the progeny. In the last two decades, there has been a shift from genetic to **genomic selection** (Meuwissen et al., 2001), to which genomic information has been added. This was possible thanks to the whole sequencing of the genome of many species – such as chicken (International Chicken Genome Sequencing Consortium, 2004), cattle (The Bovine genome Sequencing and Analysis Consortium, 2009), pigs (Groenen et al., 2012), goats (Dong et al., 2013) and sheep (Jiang et al., 2014) – which allowed the construction of reference genomes. As sequencing technologies advanced, many animals have been sequenced at low resolution, and the subsequent alignment of these sequences with reference sequences has identified several genomic differences among animals. In particular, single nucleotide polymorphisms (Single Nucleotide Polymorphisms, SNP) allowed the creation of commercial genotyping platforms that allow to have hundreds of thousands of SNP for each animal at now reasonable prices. The inclusion of genomic information within the breeding programs has allowed to considerably reduce the generational interval (thus speeding up the process) and to obtain much more accurate animal evaluations. The new genomic evaluation methods make it possible to analyse phenotypes, genealogies and genotypes in a single model thanks to a single-step genomic BLUP technique (ssGBLUP; Legarra et al. 2009), of which the most modern updates allow to include genomic information of millions of animals (Mäntysaari et al., 2020; Cesarani et al., 2022).*

*More recently, the attention of researchers has focused not only on genomic selection, but also on the so-called "**New breeding techniques**" (NBT), genetic "manipulation" techniques that promise to further accelerate the improvement of livestock animals. Among these new biotechnologies applicable to animal husbandry, we can mention "**transgenesis**", "**cisgenesis**", and "**gene editing**". By transgenic animals we mean individuals who, from birth, have a genome modified through the insertion of genetic material of exogenous origin; the term cisgenesis, on the other hand, identifies the transfer of single genes from one animal to another* *within the same species. Finally, gene editing (GE) is a molecular biology technique that allows for the modification of a single nitrogenous base within an individual without the introduction of new genetic material. More precisely, gene editing can be viewed as a precise change in the DNA sequence. GE is a very different biotechnology from cisgenesis and transgenesis, as these techniques involve the use of exogenous genetic material, while GE exclusively modifies genes already present in the individual. With GE, the final result is the same as it would be obtained through genetic and/or genomic improvement, but much faster. With this technique the intensity and control of the entire improvement process could be improved: from genetic selection, characterised by low control and a slow response over the years, to genomic selection, with medium control and a more rapid over the years, to the possible use of gene editing, with high control and an immediate response.*

*The use of the GE technique would open the door to a new phase of genetic improvement, identifiable with the term "**precision breeding**". In fact, it must be remembered that in the current schemes of genetic or genomic selection, the selected progeny is a mix of the genetic material of the previous generation plus a series of possible new mutations (outside of human control).*
Currently, therefore, we try to improve a feature but it is possible to have repercussions, positive or negative, also on other features of interest. In fact, an important difference between genetic/genomic improvement and GE is the fact that traditional selection involves the whole genome of animals, while the more recent technique allows working on a few, or even on a single gene.
This aspect would have significant repercussions on the selection of animals and, in particular, on the improvement of qualitative traits (e.g., appearance/absence of horns, coat colour...) or in any case on traits controlled by a single gene or a few genes. Research in the GE field has explored the possibility of modifying several monogenic controlled Mendelian traits – including heat tolerance, resistance to tuberculosis and thigh muscle hyperplasia – in which the change of a single DNA base would lead to a different phenotypic expression. Thigh muscle hyperplasia, also known as double muscling, is of considerable importance for meat production as animals with this particular mutation in the gene coding for myostatin (Kambadur et al., 1997) are characterised by a greater muscle growth due to a higher number of muscle fibres. Therefore, by applying the GE technique on the myostatin gene alone, it would be possible to have animals with much higher meat production, as it already happens for animals that "naturally" show this mutation.

*The **application of NBT** on a commercial scale is, however, **not yet uniformly possible in various countries.** In fact, these biotechnologies, which make it possible to directly modify the DNA of animals which will then be destined for human consumption, are a source of more or less veiled concern on behalf of a certain section of consumers.*
While in the United States there is a clear distinction between genetically modified organisms (GMO), obtainable through cisgenesis and transgenesis, and organisms obtainable through GE, the situation in Europe is less clear. In Europe, the European Food Safety Authority (EFSA) has the task of carrying out independent assessments and providing scientific advice on the potential risks of GMOs for human health, animal health and the environment, and to propose appropriate measures to mitigate the risks. Currently in the European Union it is not possible to produce GMO animals, nor food or feed deriving from

them. However, as described above, GMO animals and those obtained from GE are different; in fact, **EFSA** had initially declared that **GE** produces animals comparable to those obtained through the normal crossbreeding envisaged in the genetic/genomic breeding programs and, therefore, are not considered as **dangerous for humans.** The European Court of Justice has the opposite opinion, deeming animals obtained through gene editing genetically modified products and, therefore, to be regulated according to the strict rules of GMO. Given the rapid development of these biotechnologies, the **opinions of the authorities** that regulate animal production are also **constantly adjourned.** The fact remains clear that these techniques, and in particular gene editing, can represent enormous **potential** for the **Italian animal husbandry sector,** even if not without possible undesirable effects; most of the features of livestock interest are polygenic, i.e., governed by a large number of genes each with a small effect, and present a genetic correlation between them. For this reason, in-depth studies are needed to evaluate the repercussions of the change in the functionality of a single gene on all other genes and the possible negative effects that this change could entail.

- Cesarani A., Lourenco D., Tsuruta S., Legarra A., Nicolazzi E.L., VanRaden P.M., Misztal I. (2022), Multibreed Genomic Evaluation for Production Traits of Dairy Cattle in the United States Using Single-Step Genomic Best Linear Unbiased Predictor, Journal of Dairy Science, https://doi.org/10.3168/jds.2021-21505.
- Dong Y., Xie M., Jiang Y., Xiao N., Du X., Zhang W. et al. (2013), Sequencing and Automated Whole-genome Optical Mapping of the Genome of a Domestic Goat (Capra Hircus), Nature Biotechnology.
- Groenen M.A.M., Archibald A.L., Uenishi H., Tuggle C.K., Takeuchi Y., Rothschild M.F. et al. (2012), Analyses of Pig Genomes Provide Insight into Porcine Demography and Evolution, Nature.
- International Chicken Genome Sequencing Consortium (2004), Sequence and Comparative Analysis of the Chicken Genome Provide Unique Perspectives on Vertebrate Evolution, Nature.
- Jiang Y., Xie M., Chen W., Talbot R., Maddox J., Faraut T. et al (2014), The Sheep Genome Illuminates Biology of the Rumen and Lipid Metabolism, Science.
- Kambadur R., Sharma M., Smith T.P., Bass J.J. (1997), Mutations in Myostatin (GDF8) in Double-muscled Belgian Blue and Piedmontese Cattle. Genome research, https://doi.org/10.1101/gr.7.9.910.
- Legarra A., Aguilar I., Misztal I. (2009), A Relationship Matrix Including Full Pedigree and Genomic Information, Journal of Dairy Science, https://doi.org/10.3168/jds.2009-2061.
- Mäntysaari E.A., Koivula M., Strandén I. (2020), Symposium Review: Single-step Genomic Evaluations in Dairy Cattle, Journal of Dairy Science, https://doi. org/10.3168/jds.2019-17754.
- Meuwissen T.H., Hayes B.J., Goddard M. (2001), Prediction of Total Genetic Value Using Genome-wide Dense Marker Maps, Genetics, https://doi.org/10.1093/genetics/157.4.1819.
- The Bovine Genome Sequencing and Analysis Consortium (2009), The Genome Sequence of Taurine Cattle: A Window to Ruminant Biology and Evolution, Science.

4.2.2 Impacts on ration production

Use of fertilisers, irrigation and tillage, use of agri-pharmaceuticals: in most cases the agricultural phase is the one in which the greatest impacts of the entire food production chain are found.

Fertilisers are compounds that supply the soil with **nitrogen, phosphorus and potassium**, the nutrients necessary for plant growth. However, they are also **one of the first sources of environmental impact of agricultural production**, both for the methods of use and for the production processes, especially when it comes to **synthetic fertilisers.** Among all, the greatest impacts come from nitrogen, due to the generation of nitrous oxide which significantly influences the greenhouse effect, but also indirectly, as the synthesis of synthetic nitrogen starting from atmospheric nitrogen (the Haber-Bosh process) is energy-intensive and, if powered by low-cost fossil fuels such as coal, causes high emissions of climate-altering gases. Furthermore, when the fertiliser is supplied in excess, the residues not consumed by the plants can reach surface watercourses or first underground aquifers, leading to an anomalous rise in the nitrogen concentration which favours an exaggerated growth of flora: the so-called phenomenon of **eutrophication.**

As an alternative to synthetic fertilisers there are **organic fertilisers** (also known as organic or natural fertilisers), very often used in **organic farming** and generally characterised by a **lower production impact.** As far as the emissions generated in the field are concerned, the effects of synthetic and organic fertilisers are different and in any case variable, as they are influenced by their different nature in biochemical terms and by local pedoclimatic

conditions. A final aspect to underline is the fact that the use of natural fertilisers such as manure hinders the adoption of "evolved" cultivation practices, which aim at reducing impacts thanks to the use of innovative techniques and technologies.

In addition to nutrients, agricultural crops need to be **defended against diseases**, insects and weeds.

Then there are the operational choices, which require **decisions in a very short time**, also based on contingent situations: the weather, the risk of infection, etc.
Since they can have significant environmental and economic impacts, these choices require ever more tools and information that often the "traditional" farmer does not have. For this reason, various **Decision Support Systems (DSS)** are gradually spreading which automatically collect, organise, interpret and integrate key information, thus providing operators with a full picture of the situation and supporting them in deciding the most appropriate actions to respond to the most diverse cultivation needs, whether they are strategic long-term decisions or operational ones to be taken quickly.

4.2.3 Process control and efficiency: Decision Support Systems

Decision Support Systems (DSS) are digital management systems that use data from various sources, with the aim of providing farmers with information that supports their decision-making process in different circumstances. They are used in particular in precision agriculture and precision feeding.
Precision agriculture uses DSS to increase crop productivity, optimise resource consumption and receive accurate, real-time information to make the best decisions in every situation. The DSS for precision agriculture are based on a series of field installed sensors which monitor in real time a vast series of variables such as atmospheric conditions, quality and state of soil health, its nutrient content, plants' water requirement and the presence of diseases. With this information, the DSS supports the farmer in operational management decisions, allowing him to intervene in a targeted and timely manner.

Some examples of the decisions supported by a DSS can be:

- optimal dose by dose distribution of fertilisers based on the specific conditions of the single field (soil type, nutrient content, need, etc.);
- irrigation of plants with quantities of water optimised on the basis of soil humidity and the specific requirements of the plant;
- targeted treatments with pesticides only where disease is actually present, avoiding distributing them on healthy areas of cultivation;
- planning work based on optimal weather and soil conditions.

In addition to agriculture, there is naturally **also precision livestock**, **within which a pre-eminent place belongs to precision feeding.** In this case it is about the use of DSS to optimise the ration administered to farmed animals through the use of sensors and cameras that make it possible to administer specific rations to single animals or groups of animals with the reduction of waste and the guarantee of the high quality of ingredients used (thanks to sensors that carry out chemical analyses of forage and feed in real time).

GFLI (GLOBAL FEED LCA INSTITUTE), FOR THE ENVIRONMENTAL IMPACT OF FEED

The purpose of the Global Feed LCA Institute (GFLI) is to measure the environmental impact of feed production. This is a project launched in 2015, in the United States and promoted by various international associations such as FEFAC (European Feed Manufacturers' Federation), IFIF (International Federation of Feed Manufacturers), AFIA (American Feed Industry Association) and ANAC (Animal Nutrition Association of Canada), as well as a consortium of international companies.

The objective of the GFLI[28] is:

- *adopt on an international scale a standard method for the assessment and analysis of the environmental impact linked to the production of feed;*
- *ensure the creation and use of a free and transparent database that collects all the information relating to the life cycle of the ingredients used in the production of animal feed;*
- *create a method of comparative analysis of the effects that the production of feed has on the environment.*

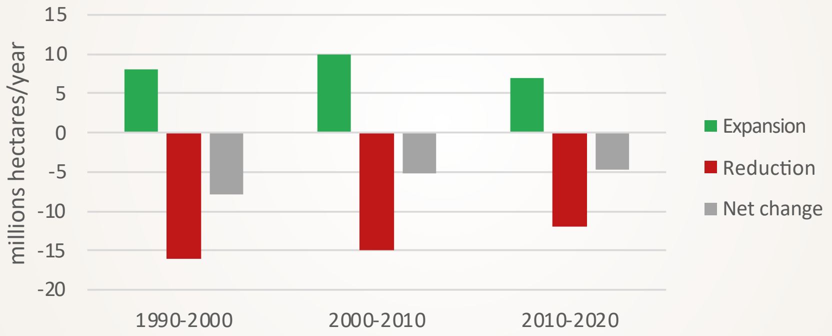
The GFLI has also partnered with FAO and the Livestock Environmental Assessment and Performance Partnership (LEAP) to ensure that its activities are compatible with the methodological requirements defined by the two organisations. The GLFI technical program was designed to comply also with the PEF (Product Environmental Footprint) scheme, aimed at detecting the environmental footprint of products and coordinated by the European Commission.

The greater control over the processes guaranteed by the use of DSS makes it possible to optimise the use of inputs (and therefore the reduction of waste), maximise productivity and, consequently, reduce both costs and environmental impact.

4.2.4 Abandonment and deforestation, two sides of the same coin

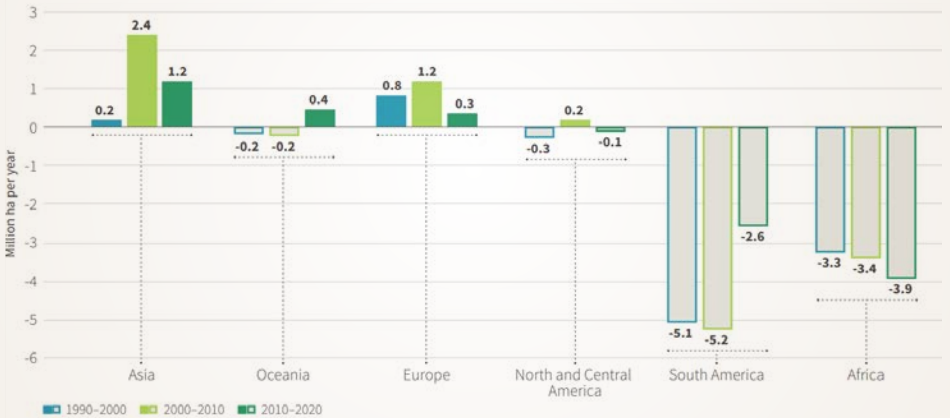
When it comes to territory, one of the most debated environmental aspects concerns the **use of land** which leads, paradoxically, to **opposite problems** according to the regions of the world to which it refers: sometimes the main risk is the abandonment of agricultural territories, in other cases, however, the problem is deforestation, i.e., the excessive aggression of the natural environment by human activities.
The latest monitoring on a global scale carried out by FAO shows that, **between 1990 and 2020, around 420 million hectares of forest were lost worldwide** due to deforestation[29]. As shown in the figure above, the global trend appears to be improving[30], but on a macro-regional scale the situation is very heterogeneous.
In fact, most forest losses occur in developing countries, such as sub-Saharan Africa and Latin America following population increases. It is often an uncontrolled deforestation, linked to the exploitation of precious wood, followed by the creation

VARIATION IN THE EXTENT OF FOREST AREA
global average



Source: FAO, 2020. Global Forest Resources Assessment 2020[30].

NET ANNUAL CHANGE OF FOREST AREA
by decade and region



Source: FAO, 2020. Global Forest Resources Assessment 2020[30].

of plantations for food or energy purposes (mainly palm and/or soybean oil), and finally pastures for livestock farming. **In other parts of the world (such as Europe and North America), the forest area has instead increased**, partly thanks to protection programs put in place by the various countries and partly due to the abandonment of marginal agricultural lands with low productivity, which turn back into wooded areas.

However, the situation is even more complex. Europe, for example, although not directly affected by the phenomenon of deforestation, is responsible for the reduction of forests in other areas of the world due to its continuous and growing demand for raw materials (phenomenon of **induced deforestation**, or embodied deforestation)[31].

Forests that are cut and/or burned emit CO_2 rather than absorb it, contributing to around 15% of all greenhouse gas emissions[32].

Italy: never so green since the post-war period

As far as Italy is concerned, the main problem is represented by the conspicuous transition from agricultural land to urbanised land, with the consequent general abandonment of territories by farmers. According to the most recent data published by ISPRA[33], at national level, soil consumption has increased from an estimated 2.7% in the 1950s to 7.6% in 2016, equal to over 23,000 km^2. At the same time, since the WWII, **the abandonment of marginal agricultural areas, hills and mountains** has resulted in an **increase in forest areas which have increased from 5.6 to 11.1 million hectares.** The percentage of land covered by woods has reached 38% of the Italian territory, a value higher than that of two "traditionally" forest-based countries such as Germany (31%) and Switzerland (31%).

4.2.5 Improper use of agricultural land for energy purposes

One of the lesser-known causes of soil consumption is **that linked to the incentives for renewable energies**, which often prompted farmers to convert the land into "photovoltaic power plants", or to convert "food" crops into the production of resources used for energy purposes (the so-called bioenergy).
This phenomenon involves various economic and social impacts (for example, it involves a loss of productivity with the consequent need to purchase raw materials from abroad) and environmental losses.
The presence of farms is in fact extremely useful for the protection of the territory, as continuous maintenance makes it possible to reduce, among other things, the risk of landslides, especially in those districts characterised by substantial hydrogeological risk. Support, including economical, for agriculture and animal husbandry is for that reason essential to avoid the progressive impoverishment of the "countryside".

These data show a very articulated phenomenon, the management of which is extremely complex and must certainly take into account the ever-increasing demand for food by the world population. The containment of meat consumption can be a solution only where these are very high; however, a global vision must also aim at production efficiency. One of the aspects of intervention is represented by the adoption of specific policies for the acquisition of raw materials by the pro-

ducers, in order to permit a control of the supply chain and the complete **traceability of raw materials.**

4.3 The protein ingredients of the ration

The proteins in the feed ration represent one of the most critical aspects. In fact, the protein sources used have a dominant role both in determining the overall performance of the feed (as they are necessary for many vital functions of the body, for example the development and maintenance of muscles) and in defining their degree of environmental sustainability. It is thus important to understand what the advantages and disadvantages are underlying their production and use. Among the conventional sources, i.e., amid the protein ingredients that have always been used in animal husbandry, the most relevant is **soy** (in particular the extraction flour that derives from the production process of the soy oil), **sunflower, rapeseed, protein pea and processed animal protein (PAPs).** Among the so-called 'innovative' sources, i.e., little or no widespread in Europe and to date not yet produced on an industrial scale, is found instead **algae, insects and proteins from microorganisms.**

4.3.1 Conventional sources

Soy

The production of soybeans - a herbaceous plant of the legume family - is constantly increasing, quintupling over the last 40 years and exceeding 350 million tons in 2020[34].

Its value is contained in the seeds, widely used as a protein source in feed for livestock animals. In fact, only a quarter of the soya produced is destined directly for human consumption: the rest ends up in the livestock feeders (bovine, pigs, poultry, but also farmed fish). If used integrally, the seeds can be transformed into flakes or extruded and used as an energy and protein source. The seeds can also be used for the production of oil, generally intended for human consumption: in this case, it is the **by-product of mechanical pressing (soy cake) or de-oiling (soy flour extraction)** that is destined for animal feed.

Among the main European producers of soy, we find Italy, from which almost half of European production comes, followed by France and Romania. But the European soybean **requirement**, equal to about 37 million tons, **cannot be satisfied with self-production alone**, and most of the soybean used in Europe is necessarily imported. Restricting the field to the Italian context, to date over 80% of demand is satisfied through imported soybeans: of the 3.6 million tons used in animal husbandry in 2020, over 1 million tons of seeds were imported from Brazil and over 1.3 million tons of flour from Argentina. Two other important suppliers are the United States and Canada (0.4 million tons of seeds imported in 2020)[35].

Unfortunately, the areas of importation are often characterised by an exponential growth of production, made possible only at the price of an increasing over-exploitation of the territory, with monoculture cultivations often on surfaces obtained by deforesting precious natural ecosystems (frequently the case especially for South American productions). To deal with the problems that the intensive cultivation of soy nowadays implies, operators in the European feed sector are progressively moving towards the **selection of more responsible suppliers**, compliant in their agricultural practices with the dictates of European Feed Manufacturers' Federation's

(FEFAC) guidelines. The document – born with the specific intention of guiding the choices of those involved in the selection of raw materials – lists the base criteria in order to define a supplier as more or less sustainable and indicates which, among the certifications attainable by a soy producer, truly certify the sustainability of the product and therefore are worthy of trust. Already in 2019, in Europe 77% of soybean flour for feed was produced in compliance with FEFAC guidelines; the percentages are increasing, with some countries even reaching 100%.

If on the one hand it is undoubtedly strategic to pay more attention to the selection of suppliers and to the traceability of soy along the supply chain, an effective alternative strategy consists in working on the (even partial) replacement of soy with alternative protein sources, that perform adequately but at the same time with a reduced environmental impact.

Sunflower, rapeseed, protein pea

Sunflower and rapeseed are oilseeds and therefore their use is similar to that of soy (production of oil for human consumption). As in the case of soybeans, protein flour is the by-product of the oil production process and differs in **extraction flour** and **feed cake.** In the period 2014-2018, their volumes represented 60% (soy), 12% (rapeseed) and 9% (sunflower) of the total oilseeds grown. As far as sunflower is concerned, over half of this production comes from Russia and Ukraine, while in the case of rapeseed the main producers are Canada, China and India.

Unlike the previous vegetable sources, the **protein pea** has a dual nutritional aptitude, i.e., the supply of proteins (24%), but above all of starch (50%). On the market it is available in the form of **grains**, but it can also be processed and sold in the form of **extruded or protein concentrate.** In the latter case, the finished product acquires a very high protein content (from 50 to 90% of dry matter), depending on the type of processing. World production is one tenth of that of soybeans (about 40 million tons) and comes mainly from Canada, Russia and China.

As regards the carbon footprint value, these alternative vegetable sources to soy are increasingly sustainable, with values generally below 1 kg CO_2 eq. per kg of product if we exclude any negative transformations of the soil.

PAPs (processed animal protein)

PAPs is obtained from by-products of animal origin. These are materials obtained from the slaughtering process side by side with the main material (meat for human consumption), they are wholesome and safe and represent a real resource, intended for commercial reasons as feed only. The most valuable PAPs in the feed sector are fishmeal and meat meal, very attractive for monogastric animals (chickens and pigs) and forbidden for ruminants.

In the case of meat flour, as they are fewer common ingredients in animal feed compared to vegetable proteins, an exact quantification of the relative market volumes and costs is not currently available. At European level, however, a production of PAPs of pig and poultry origin has been estimated at around 1.3 million tonnes. Regarding fishmeal, which has always been widely used in aquaculture, but also with applications in the breeding of monogastric species, the volumes of fish caught for this purpose are around 20 million tons per year.

USE OF MEAT FLOURS IN THE FEED SECTOR: FROM THE BSE HEALTH CRISIS TO ITS PROGRESSIVE READMISSION

By Giovanni Sorlini

The rigorous BSE control measures adopted by the Community for over twenty years have made it possible to drastically reduce the health risk and to face the reintroduction of PAPs into the feed sector in complete safety, thanks to new scientific findings and the effectiveness of prevention measures towards the adopted risk.

The reintegration of PAPs, far from being lived with fear or worse with ideological foreclosure, represents a concrete opportunity to make farming a more sustainable practice from an environmental point of view. How? Thanks to the reduction of the carbon footprint associated with the production of feed and less competition over agricultural land between crop production intended for human and animal nutrition. This can lead to improved environmental sustainability both locally and globally, as this valuable source of protein can reduce the dependence of the European livestock sector on imports of soya or other vegetable protein sources from countries at risk of deforestation.

The use of PAPs is consistent with an animal husbandry that can make the most of the principles of circularity of its productions, valorising at best some types of by-products obtained during the slaughtering and meat processing phases, thanks to the technical-scientific knowledge acquired in over twenty years of health prevention and a particularly rigorous regulatory approach, based on the precautionary principle which places consumer health protection at the centre.

FROM THE HEALTHCARE CRISIS TO ITS PROGRESSIVE READMISSION

Following the healthcare crisis produced by Transmissible Spongiform Encephalopathies (TSE) in the early 2000s, the European Union ordered in 2001, a complete ban on the use of meat flour, more properly defined as Processed Animal Proteins (PAPs), in feed intended for all food-producing animals, as well as further prevention measures based on the sanitary control of ruminants and on the elimination of certain tissues with greater disease transmission risk, applied in farms and processing meat plants. The cornerstone of the prevention strategy is constituted by Regulation (EC) 999/2001, which was added to the pre-existing ban on the use of meat flour in the feed of ruminants in force in Italy since 1994.

The health risk prevention measures progressively implemented have proved to be effective and have already made it possible **since 2005,** to develop a **health risk assessment activity** aimed at their progressive reintroduction into the livestock food chain. Indeed in 2005, the Commission had produced a first guidance document[36] concerning the period 2005-2009.

Since 2010, due to the constant favourable trend of epidemiological and health risk data on a European scale, the European Commission has launched progressive measures to loosen the ban on

PAPs obtained from non-ruminant animals intended for food production. In parallel, a series of less restrictive BSE control measures[37] were introduced respect to previous decade. In reality, the Commission went beyond those same suggestions, on the strength of a decidedly positive BSE epidemiological situation.

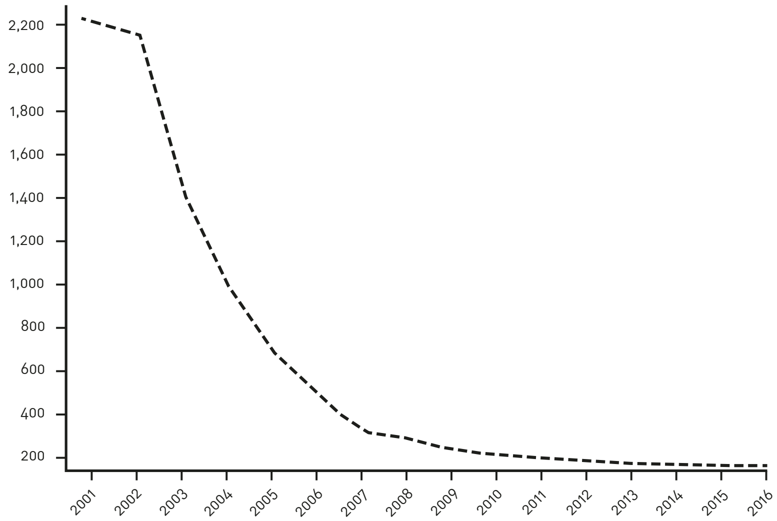
Currently, in fact, the administration to non-ruminants of PAPs obtained from milk and derivatives, eggs and derivatives, protein hydrolysates, collagen and gelatine from non-ruminants is permitted; also permitted the use of fishmeal, processed animal proteins (PAPs) obtained from poultry and pigs with prohibition of intra-specific use, products based on non-ruminant blood (e.g., haemoglobin, plasma) and insect PAPs (only for pigs and birds), calcium and tricalcium phosphate of animal origin. A summary diagram is shown below.

USE OF PROCESSED ANIMAL PROTEINS (PAPs) IN FEED

	Farm animals other than fur animals			Pets and fur animals
	Ruminants	Non-ruminants (except fish)	Fish	
Ruminant PAPs, including ruminant blood meal	NA	NA	NA	A
Non-ruminant PAPs, including non-ruminant blood meal but excluding fishmeal	NA	NA	A	A
Insect PAPs	NA	NA	A	A
Blood products from ruminants	NA	NA	NA	A
Gelatine and collagen from ruminants	NA	NA	NA	A
Hydrolysed proteins other than those derived from non-ruminant or from ruminant hides and skins	NA	NA	NA	A
Fishmeal	NA[38]	A	A	A
Blood products from non-ruminants	NA	A	A	A
Di and tricalcium phosphate of animal origin	NA	A	A	A
Hydrolysed protein from non-ruminant or from ruminant hides and skins	A	A	A	A
Gelatine and collagen from non-ruminants	A	A	A	A
Egg, egg products, milk, milk products, colostrum	A	A	A	A
Animal proteins other than the above mentioned ones	NA	A	A	A

Legend: A= authorised; NA= not authorised.

CASES OF CLASSICAL BSE (C-BSE) IN THE EU FROM 2001 TO 2016



Source: EFSA, 2018.

During 2020, on the basis of EFSA[39] opinion, the use of ruminant collagen and gelatine was also allowed in the feed of non-ruminant food-producing animals, including aquaculture fish. In addition to the use of ruminant collagen and gelatine in non-ruminant food-producing animals, the use of ruminant proteins is also permitted in pet food lines in feed mills that have separate facilities and logistics to avoid cross-contamination risk.
In 2018, EFSA[40] expressed itself definitively on the health risk generated by PAPs. The same document also reports the number of BSE cases detected in bovine through surveillance activities, highlighting a constantly decreasing trend. The model adopted in that point of view demonstrates a total BSE infectivity risk four times lower than that assessed in 2011.

HEALTH CONDITIONS EXPECTED FOR THE REINTRODUCTION OF RUMINANT PAPs

In the light of the favourable BSE epidemiological trend in the EU and the scientific findings in the field of risk assessment, a progressive safe reintroduction of additional types of PAPs obtained from ruminants into the feed of non-ruminant food-producing animals is expected shortly (pigs, poultry, fish). The progressive reintroduction of PAPs will be restricted to following health conditions by the companies producing PAPs, of complete feed, as well as by all operators in the supply chain, including phases of transport, storage and administering on farms.

1. For both bovines and small ruminants, the current list of specified risk materials (SRM) must not undergo any modifications.

2. The use of slaughtering waste from small ruminants cannot be subject to authorisation; scrapie, when present, is also distributed in tissues not present in the list of SRM. Allowing their use could favour the circulation of scrapie and potentially also of BSE if the latter were present in small ruminants, with no measures in place to identify it.

3. The by-products of animal origin that can be used for the production of PAPs must originate only from category 3 materials and, as a precaution, the material deriving from emergency slaughtering (MSU) must also be excluded.

4. Only negligible risk countries (according to the OIE classification) can be authorised for the production of ruminant PAPs and only animals born and raised in negligible risk countries can enter the chain.

5. The collection of category 3 by-products must take place in slaughterhouses authorised for the exclusive slaughter of bovine, or in any case on physically separate slaughter lines.

6. Category 3 by-products intended for the production of ruminant PAPs that can be used in animal feed for livestock use must be treated in accordance with the provisions of Regulation (EC) 142/2011, Annex IV, and must be transformed in dedicated lines, physically separated from the PAPs production lines of other animal species. The PAPs must be transported and stored in vehicles, containers and premises used exclusively for this purpose.

7. Feed containing PAPs of ruminants and intended for farmed species of non-ruminants must be produced and canalised on completely separate lines, transported on vehicles used exclusively for this purpose, as is the case for feed intended for pets.

8. The same conditions (as at point 6) must be used for the production and use of ruminant blood products (e.g., haemoglobin and plasma).

9. The administration of feed containing ruminant PAPs in livestock farms where there is a mix of ruminant and non-ruminant farming cannot be allowed to avoid any possibility of exposure downstream of the production process.

10. It is important that the National Animal Feed Plan remains active, in the section concerning PAPs, according to the provisions of Reg. CE/2017/625 and that the control of feed ingredients intended for ruminants and non-ruminant herbivores is strengthened.

11. The self-control plans of feed mills that produce feed for ruminants (and related inspection audits) must be maintained, giving particular emphasis to the objective of continuous verification of the prevention and absence of cross-contamination.

4.3.2 Innovative sources

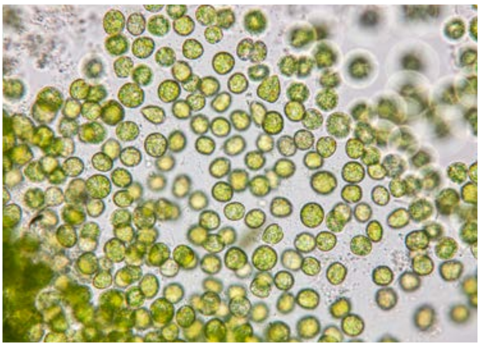
As mentioned, innovative sources are very promising resources under various aspects, both in terms of nutritional properties and for various advantages linked to their production process. These are resources that have only recently been taken into consideration by Western markets and are therefore still produced on a small scale and at non-competitive prices. However, the attention paid to these products by the scientific community and the world of industry is ever higher, and the technologies for their production are rapidly progressing.

Insects

Insects are the most promising option to date. In fact, at European level, more than half of the insects farmed are now used in the feed/livestock sector; followed by usage in pet feed and, marginally, use for human consumption. The selling price for feed derived from insects varies according to the considered species, but at the moment it is still not very competitive due to the low volumes produced. The **breeding of insects for food use** has several advantages from an environmental point of view. First of all, these are animals capable of feeding on the most disparate substrates and this allows the recovery and bio-conversion of organic material of little commercial value (for example many agricultural by-products) into high quality proteins. Furthermore, their production has a low carbon footprint (higher than that of vegetable sources but in any case, on average between 1 and 4 kg CO_2 eq. per kg of product, therefore decidedly low for an animal source) and requires small surfaces.

Microalgae

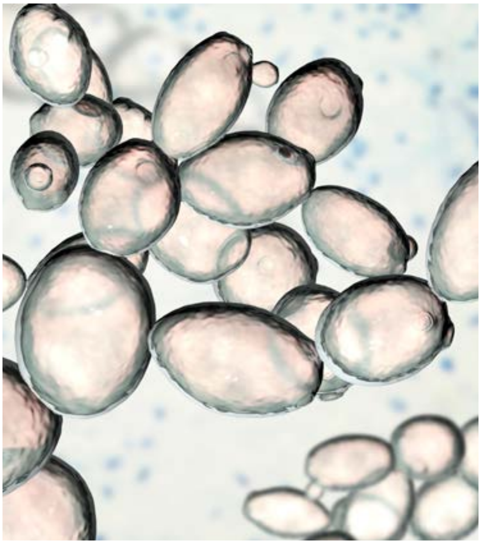
As for **microalgae** (i.e., unicellular algae), these are organisms with an interesting protein content – for example, the crude protein content (referring to algae in dried form) for **Chlorella** is 32-65%, for **Spirulina**[41] 38-80% - but whose overall quality can vary considerably, depending on the digestibility and availability of essential amino acids. The cultivation of various species is well established in many countries, but their market availability is uncertain: unlike what happens for algae, their production is poorly monitored at a national level and FAO statistics[42] indicate a probably underestimated value of about 56 thousand tons in 2019. The main problem related to their production is their low growth rate (less than 400 g/m_3/day), which prevents their use on a large scale. The low yields lead to rather high carbon footprint values (high consumption of resources against low volumes produced) and obviously a high market price, de-



pending on the type of microalgae and the methods of conservation (refrigerated, frozen or simply dehydrated product).

Single cell protein (SCP)

Single cell proteins (SCP) are also derived from microorganisms (fungi, yeast, bacteria[43]). The process for their production is essentially fermentation, after which the biomass is collected and subjected to further transformational processes. The protein content is variable (from 10 to 80%), depending both on the species and on the culture medium in which it is grown. Their production offers many advantages, such as short production times, constant growth rates regardless of the season and no need for arable land. In terms of environmental impact[44], studies conducted on the bacterium *Methylococcus capsulatus* show about 20 times lower consumption of fresh water than that for the production of fishmeal and 140 times lower than that for the production of soybean meal. The same trend can be observed for land use.



4.4 Feed and circular economy

4.4.1 The enhancement of by-products

To increase efficiency and reduce as far as possible the use of edible ingredients for humans as livestock feed, it is important that farming and animal feed increasingly optimise the use of crop residues and **agri-industrial by-products**, trying new combinations that keep conversion efficiency and animal welfare equally high[45]. As the world population continues to grow, so does the demand for food and **farm animals will play an essential role in converting non-edible human foods into high-quality foods.**

On closer inspection, the reuse and recovery of resources is also part of the feed manufacturer's DNA since the production of feed has always been based on the valorisation of co-products of the milling industry, such as bran and proteaginous flours, oil with protein flour and dairy products with whey. The starting point was therefore **tradition**, to which was added an ever greater **technical-scientific competence** in the management of "precision" formulations for each type of animal and in the specific breeding phase.

The environmental advantage of using these materials is multiple: the dependence on **foreign feed materials is reduced, agricultural land is saved** for the benefit of production for human consumption and **food waste is reduced by recovering resources which would otherwise be disposed of**[46].

4.4.2 The case of former food products

An ingredient that is less talked about, at least for now, and which still represents

ORIGIN OF ITALIAN FEED INGREDIENTS

INGREDIENT	ORIGIN
Forage: grasses, alfalfa, clover, hay, silage	**Primary products**
Cereals: grain maize, wheat, barley, millet, sorghum, triticale, oats	**Primary products**
Vegetable proteins: soy (feed cake and flour), cotton (seeds and flour), rapeseed and peanut meal	**Primary products**
Trace elements: vitamins, minerals, probiotics, yeasts, enzymes, preservatives	**Primary products**
Cereal derivatives: corn gluten, wheat bran, straw, crop residues	**By-products**
Apple peels, citrus pulp, almond shells, fruit/vegetable scraps	**By-products**
Ex-foods deriving both from the production process and from the distribution phase but no longer intended for human consumption	**Ex-food products (vegetable and animal)**
By-products of sugar beet processing: molasses and exhausted pulps	**By-products**
By-products of meat processing	**By-products**
Milk, whey, casein	**By-products**
Fish processing by-products, fish oil, algae	**By-products**

Source: Assalzoo 2020 report

an excellent example of circularity is that of ex-food products, other than catering residues, manufactured in full compliance with the Community legislation on food for human consumption, but which are no longer intended for it for practical, logistical reasons or related to manufacturing, packaging or other defects, without presenting any health risk when used as feed (EU Regulation 68/ 2013).
There can be various types of ex-food products. The most common are derivatives from the food processing and marketing process (such as **biscuits**, **pasta**, **snacks**, **bread**, **snacks**, **sweets**) and can be packaged or loose; following appropriate processing (unpacking and mixing), they become excellent raw materials that **replace cereals**, **sugars and fats** in animal diets. This procedure ensures maximum safety and traceability, if carried out following protocols. Most of these **former food products** have already undergone a cooking process, which greatly improves the digestibility of starches and therefore increases the digestible energy of the ration, to which must be added the presence of high-quality lipids and sugars, as well as a reduced risk of mycotoxin contamination.
The inclusion of ingredients based on ex-food products in animal feed was **promoted by the European Commission** for two reasons: on the one hand, it **reduces** involuntary and unpredictable "**food waste**"

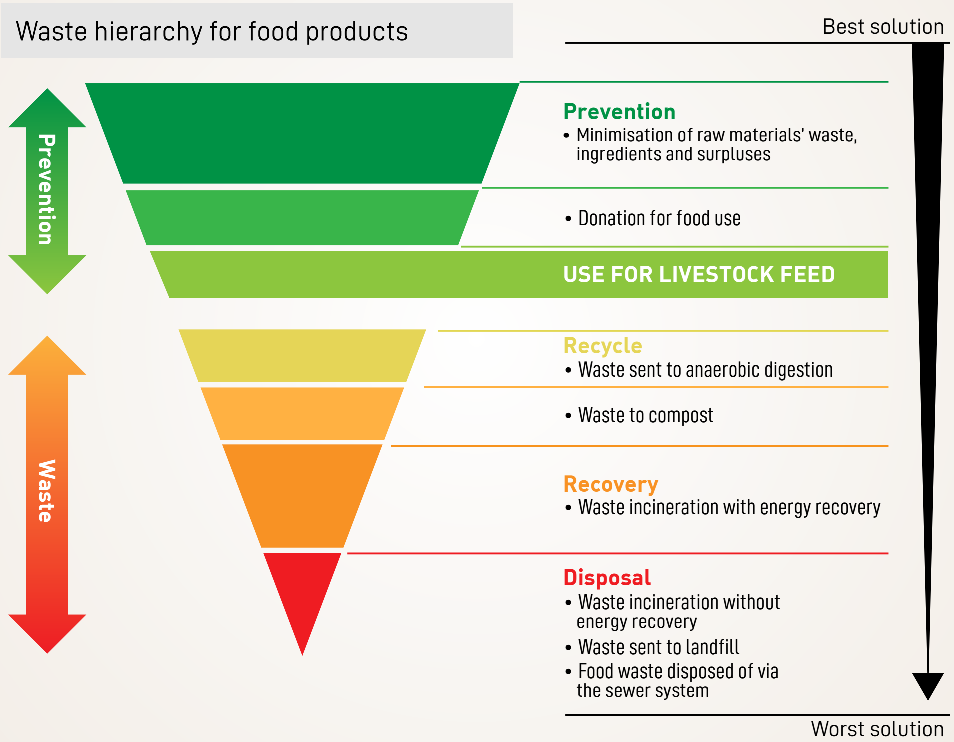
and, on the other, it reduces the use of soil, energy, water, fertilisers and sometimes even pesticides.

4.5 Sourcing and traceability of ingredients

4.5.1 Self-production, integrated supply chain or bought on the market?

In Italy, there are farms that **self-produce** a large part of the livestock feed they need. This practice, which represents an indisputable strong point, is widespread **above all in the case of ruminants** as they are able to valorise vegetable biomasses rich in fibre (fodder). Having forage crops on the farm ensures a high degree of control over both the type and quality of resources cultivated and on production methods. Actually, it is possible to introduce good agricultural practices (e.g., precision farming techniques) and monitor their effects over time, substantially affecting the overall sustainability of agricultural production.
In the case of **pig and poultry production**, the correlation between self-production of feed and feeding quality is less strict than for ruminants. In these cases, **integrated supply chains** have developed, i.e., systems in which there is coordination between **farms and feed industries** to achieve common objectives and create positive synergies. Compared to the purchase of

WASTE HIERARCHY FOR FOOD PRODUCTS



Source: www.wrap.org.uk/content/why-take-action-legalpolicy-case.

feed on the market, **the integrated supply chain allows for greater consistency in the quality of production and above all, a better control capacity**, both in terms of food safety and sustainability aspects.

4.5.2 Traceability

Purchasing on the market a complete feed or even individual raw materials means having little (or sometimes even zero) knowledge about the geographical origin and production methods of the concentrate. In general, the vegetable raw materials intended for feed processing are purchased on national and foreign markets and, depending on the type of agricultural raw material and in particular its convenient price, **the degree of self-sufficiency of Italian production varies.**

In the case of soy, for example, Italy, despite being the largest European producer together with France[47], is not self-sufficient (the degree of self-sufficiency is approximately 20%) and must necessarily source from more suitable territories, such as some areas of the South American continent. In these cases, the EU legislation provides for a complex system of rules concerning health safety and traceability along the entire food chain. Although in the context of international trade it is more complex to activate projects to improve sustainability, it is important to point out that, even in the case of globalised agricultural commodity markets, voluntary control and certification circuits of sustainable production are available. An example in this sense is represented by the **sustainable soy production and certification systems**, the most important of which is represented by RTRS - Round Table on Responsible Soy (www.responsiblesoy.org).

4.6 Farming systems

Farms are the section in the supply chain where most of the emissions with potential environmental impacts are generated. Normally, "intensive" farming is contrasted with "extensive" farming, a term associated with grazing, i.e., a condition that creates in man an impression of less

exploitation and greater well-being for the animals. On the other hand, when it comes to intensive farming, the collective imagination immediately focuses on the idea of animals piled on top of each other, smelly barns, places of suffering. But the reality is quite different.

In particular, there is a threefold reason behind the attention to well-being: an ethical nature, a normative nature (the rare cases of ill-treatment are reportable and punishable by law), but also of an economic nature. Because **a poorly maintained animal produces little and badly. Attention to animal welfare can therefore only be a constant throughout the supply chain**, not a prerogative of extensive and organic systems alone.

Intensive and extensive farming: meaning what?

The word "intensive" is a generic term that is normally used to define a **farming method carried out in protected environments** (such as closed or open barns, enclosures, etc.). These are environments capable of allowing **greater animal health control** and above all the application of an adequate diet, such as to allow **a balanced growth rate** and a good animal daily weight **gain.** The intensive ones are therefore protected, digital, precision systems. Farms that guarantee high standards of animal welfare, safety and production quality.

It goes without saying that the term "extensive" indicates, on the contrary, those farming systems conducted outdoors, at pasture. In these systems the animals certainly have more space available, but this is not always the case and **it is not possible to establish a priori whether they are better off than those reared in barns.** In fact, the advantage of the greater space contrasts with other disadvantages connected to a lesser control over the animal: for example, **lesser possibility of cure from diseases and parasites**, **exposure to bad weather and predators**, the possible **inadequate availability of food and water** in quantitative and qualitative terms.

Where is intensive farming mainly carried out?

Countries with large territories and low fertility or high slopes have developed predominantly extensive systems, while countries with limited plains and high fertility have opted for intensive systems, following the same logic whereby cities and industries occupy the best land (high housing and production intensity), while rural systems are present in the most difficult areas (low housing and production intensity).

Bovinefarming: coexistence of intensive and extensive systems

In reality, the **two farming systems**, which are experienced by the consumer as antithetical, are in reality often **integrated and complementary** to each other. In the case of **bovine**, for example, extensive rearing is aimed above all at young animals (**cow-calf line**), especially during the farming season. The **intensive** system is instead applied in the more advanced stages of the production cycle, when the animal needs a richer diet to support its growth.

THE BOVINE SUPPLY CHAIN IN EUROPE: AMONG TRUTHS AND MYTHS TO DISPEL[48]

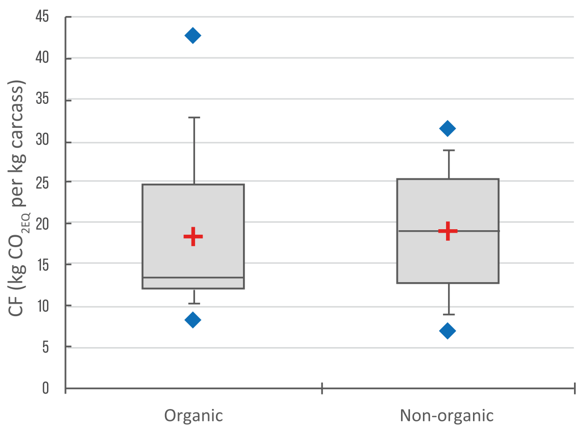
Indeed, studies conducted on European supply chains show that the difference between organic and non-organic farms is not statically relevant in terms of greenhouse gas emissions.

*All farmed species represent a precious resource from many points of view. But above all, the **bovine** appears as the most relevant, and for this reason the most debated.*
*The study of the sustainability of this supply chain is complex, as it is a system interconnected to many others and absolutely not standardised in terms of production process. **The variables that influence the sustainability of the supply chain (and therefore the greenhouse effect) are in fact very many,** some biological (breed, age, sex, etc.) others environmental (local climatic conditions), others managerial, others related to the calculation method. Precisely these last two, have been and continue to be, the subject of heated debates and will therefore be briefly addressed below.*

BIOLOGICAL OR CONVENTIONAL SYSTEMS?

*The first myth to dispel concerns the differences in terms of environmental impacts between **organic** and **conventional** livestock systems.*

VARIABILITY IN THE CARBON FOOTPRINT FOR THE ORGANIC AND CONVENTIONAL SUPPLY CHAIN



Source: Pishgar-Komleh and Beldman, 2022[48].

*In fact, studies conducted on European supply chains show how the difference between organic and non-organic farms is **not statically relevant in terms of greenhouse gas emissions.** This is because some aspects of biological systems increase their impact, other aspects reduce it. In other words, there are organic farms that actually impact much less than traditional farms… but this is not always true. The lower weight of the animals sold and the longer growth period represent two points against organic farming, as well as the transition from high-productivity meadows (intensive agriculture) to low-productivity meadows (the high proportion of roughage in the rations leads to increased enteric methane production). Conversely, the lower use of synthetic fertilisers and pesticides in the production of organic feed leads on average to lower CO_2 and N_2O emissions.*

RATION: IS FORAGE OR CONCENTRATE BETTER?

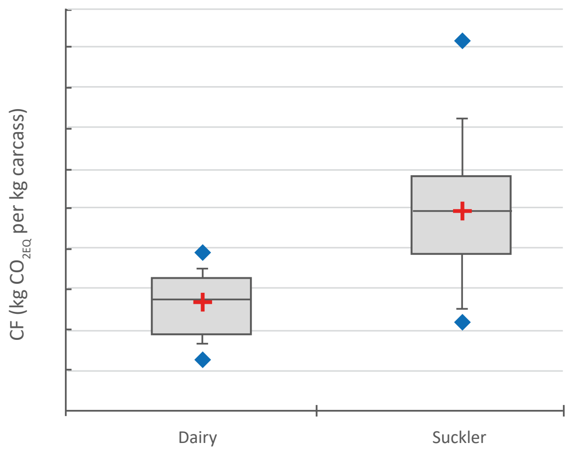
Emissions from enteric fermentation (kg CH_4 emitted by an animal) are strictly linked to the digestibility of the feed, i.e., to that amount of energy in the feed which has actually been absorbed by the animal's digestive system. It follows that a bovine ration based on forage (poorly digestible) leads on average to higher impacts than those of a ration based on concentrates.

MEAT AND MILK SUPPLY CHAIN

Bovine farming is made up of two supply chains distinguished by production aptitude - **meat and milk** - genetically selected over the centuries to maximize the efficiency of the farming process and the quality of the product. The **bullocks** and **heifers** of the supply chain, with specialised breeds for the production of meat, have a high capacity for converting the feed ration into muscle mass and produce meat with better organoleptic, nutritional and texture characteristics. On the contrary, the selection of the **dairy cows** has favoured animals capable of obtaining high milk production in terms of quantity, nutrition and dairy farming aptitude.

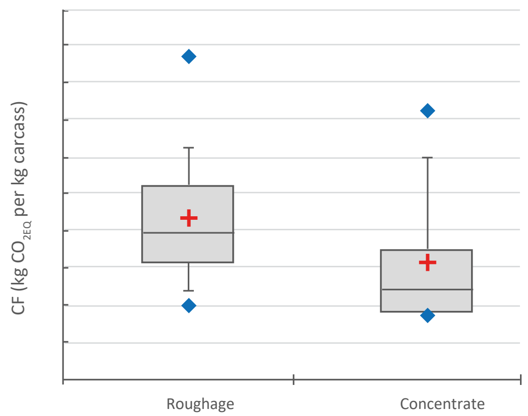
However, although not its primary objective, the milk supply chain inevitably also generates meat, albeit less esteemed. These are male calves (destined from birth to the supply chain of the so-called white veal) and older dairy cows (led to slaughter due to a subsequent decrease in performance in milk production). However, if the genetically fewer valuable females, i.e., not destined to generate the replacement of the herd (the calves that will replace the no longer productive cows), are crossed with beef bulls, the crossbred obtained (technically indicated with the acronym F1) is a

VARIABILITY IN THE CARBON FOOTPRINT FOR THE MILK AND MEAT SUPPLY CHAIN



Source: Pishgar-Komleh and Beldman, 2022[48].

VARIABILITY IN THE CARBON FOOTPRINT FOR THE SUPPLY CHAIN FED WITH FORAGE AND THAT FED WITH CONCENTRATES



Source: Pishgar-Komleh and Beldman, 2022[48].

good subject for barns with the aim of meat production. Furthermore, these calves have a limited environmental impact since, by economically allocating the largest share of emissions from farming to milk production (normally 90%[49]), their CFP entering the fattening centre is very low. In fact, as shown in the figure at the top of the previous page, the meat supply chain has an average impact higher than that of the milk supply chain: respectively, 25.5 and 13.5 kg CO_2eq per kg of carcass.

However, on closer inspection, the main reason for this gap between the two supply chains is not of a managerial nature, but of a ***methodological*** *nature. Indeed, in the meat supply chain, the 'blame' of the impacts generated (both for the farming of animals destined for slaughter and for the maintenance of the brood cows) is attributed to the only product leaving the system: the bovine adult ready for slaughter.*
Conversely, in the milk supply chain the overall impacts are divided between two distinct products: a high share is attributed to milk (the main product), a marginal share to beef.

Another aspect worth reflecting on is the wide range of variations within the meat supply chain, a clear demonstration of how, for the same product obtained, there are systems with a high impact and others that are very virtuous: from the study of the latter, useful indications can be drawn for the former.

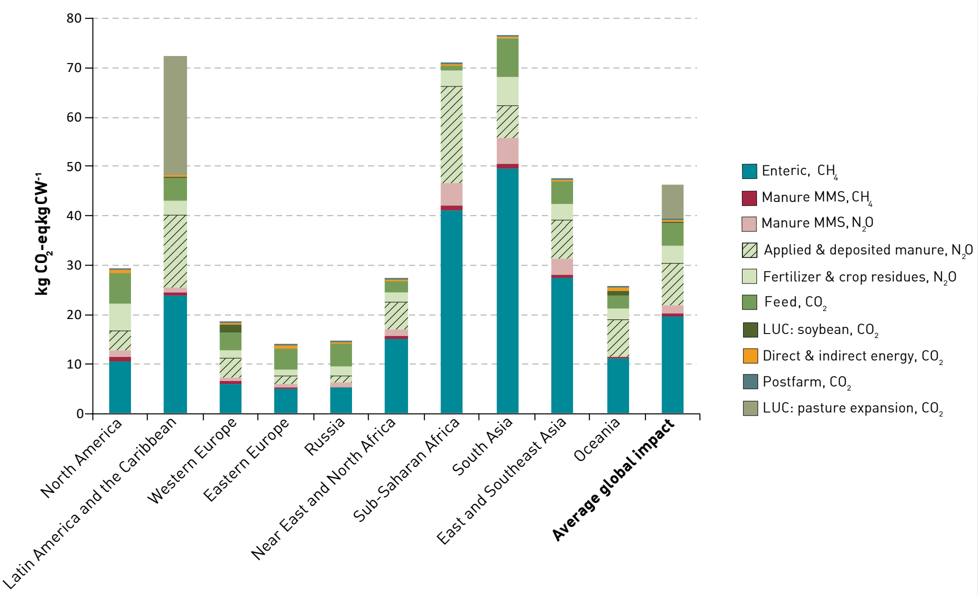
AN OVERVIEW
OF THE BEEF SUPPLY CHAIN IMPACT IN THE WORLD[50]

Europe is the continent with one of the most efficient livestock production systems in the world, characterised by lower greenhouse gas emissions per kg of meat compared to production in other areas of the world.

European production represents excellence worldwide. The graph below shows the climate-altering emissions of the beef supply chain according to the geographical area of production. Note how the value fluctuates between 14 kg CO_2-eq/kg of carcass in Eastern Europe and the Russian Federation and 76 kg CO_2-eq/kg in Southern Asia. Again, the highest emissions are found in developing regions – South Asia, Sub-Saharan Africa, LAC and East/South-East Asia – this time due to low forage digestibility, lower slaughter weights and the highest age at slaughter.

Furthermore, the emissions linked to land use change in Latin America stand out, due to the expansion of pastures at the expense of wooded areas.

IMPACT OF THE BEEF SUPPLY CHAIN ACCORDING TO THE GEOGRAPHICAL AREA OF PRODUCTION



Impacts are expressed in CW (carcass weight)[50]. Source: GLEAM.

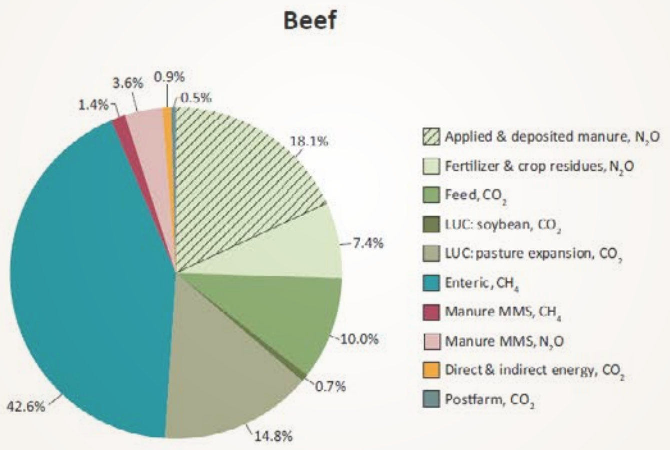
4.7 Enteric fermentations

Enteric fermentation is one of the results of the food digestion process; it becomes particularly relevant in the case of herbivorous **ruminant** animals (bovine, sheep, buffalo, etc.), as it involves the production of a large quantity of methane (CH_4). The quantity of methane produced mainly depends on the **characteristics of the animal** (breed, age, weight), **but also on the type and quantity of the feed fed.**

The IPCC organisation dealt in detail with the calculation of enteric emissions in the guidelines updated in 2019[51], defining a phased approach in order to evaluate them with a different level of detail and depth.

- **Phase 1** is the least precise, but the simplest, as it provides an estimation of emissions solely on the basis of the type of animal (for example beef or dairy cattle) and the geographical area of origin.
- **Phase 2** involves a more complex approach to calculation and a more in-depth knowledge of the farm in question; it should be used when the contribution to emissions from animals is significant, as in the case of bovine.
- **Phase 3**, finally, is the most precise, but requires an even more in-depth knowledge of the farm examined. For its application it is in fact necessary to have various primary information, such as the composition of the ration, the seasonal variation in the animal population, the quality and quantity of feed administered and the possible strategies for mitigating the impacts generated. Often this is information deriving from direct experimental measurements.

CONTRIBUTION OF PRODUCTION PROCESSES AND GAS EMISSIONS TO THE TOTAL IMPACT IN RUMINANTS



The contribution of enteric fermentation is particularly high.
Source: Opio et al., 2013[50].

4.7.1 How emissions vary: an example of calculation

The phase 2 is the most used approach and the analysis of the formula leads to understanding how methane emissions can vary significantly with animals' diet, both in terms of the quantity of feed and the type. The calculation is based on specific emission factors which are a function of the diet administered according to the following formula, where:

$$EF = \left[\frac{GE * \left(\frac{Y_m}{100} \right)}{55{,}65} \right] * d$$

- EF (emission factor) = emission factor expressed in kilograms of CH_4 per head over period d;
- d is the number of days of administration of the reference ration;
- GE (gross energy intake) = total caloric intake per head per day in Mj;
- Y_m (methane conversion factor) = conversion factor of the energy contained in food into energy lost in the form of methane. It depends on the type of farming and is mainly linked to the digestible fibre content of the ration;
- the factor 55.65 (MJ/kg CH_4) is the energy content of methane.

At pasture, emissions are double those in barns

As far as the Y_m factor is concerned, its value depends on the type of farming and is mainly linked to the digestible fibre content of the ration administered. Remaining in the scope of **bovine**, the IPCC values are **3% for animals in fattening barns** and **6.5% for grazing animals** (or for dairy cows). This means that, for the same caloric intake (constant GE), **the methane emissions generated by a ruminant in the pastured meat supply chain are double those of a barn animal** due to the greater ingestion of fibre, directly linked to rumen production of methane.

4.8 Manure management

The impact linked to the management of animal manure is due both to the emissions into the atmosphere of the volatile substances present (ammonia, methane and nitrous oxide) and to the release of nitrogen into the soil. As with enteric fermentations, emissions can be estimated using the equations contained in the IPCC guidelines[48] with one of three possible approaches. The two extremes are the tabular approach and the experimental one; the intermediate scenario, phase 2, is the one used for environmental impact calculations because it allows for sufficient precision starting from data that is normally easy to collect.

In extensive farms (grazing animals) neither the emissions of volatile substances nor the release of nitrogen into the soil can be controlled, as the manure is not collected but left in place (in the best case spread with the aid of mechanical means). On the other hand, targeted management is possible in **farms**, divided into three distinct phases: **farming (type of livestock and housing methods), storage of manure and disposal, or better still, reuse for energy and fertiliser purposes.**

In this case, the first aspect to take into consideration concerns the **management methods of the farm**, which can give rise to:

- **manure (bovine) or chicken droppings (poultry)** in the case of bedding with straw or other absorbent material;
- **sewage (bovine or pig)** in the case of organised rearing on a slatted floor.

Being almost solid materials, manure and poultry manure are easier to manage than slurry. They are therefore to be preferred, because they make more alternatives possible for the subsequent stages of **storage** and **disposal.** In addition to this, it should be kept in mind that they are generated by farms that provide **bedding**, consequently they are also better in animal welfare terms.

After collection, the manure is stored to ensure that treatment takes place in the most appropriate times, ways and places possible. There are many typical **storage** systems, but they can be characterised by a fundamental aspect which is **cover**: especially in the case of sewage, in fact, one can find **open or closed tanks**, with very different effects from an environmental point of view. The uncovered structures obviously lead to higher emissions, both due to the direct release of volatile substances and due to the occurrence of spontaneous fermentation phenomena which lead to a further dispersion of methane, CO_2 and other substances. To improve its own sustainability, the livestock sector should therefore direct investments towards more rational manure management systems, preferring, where possible, **the production of solid material and therefore livestock on bedding.** In addition to the quantity of manure, its type and the storage system, another factor to take into consideration is the geographical area in which the storage takes place, as the climate can be extremely influential in the biological degradation processes responsible for the emissions.

After storage, manure must be disposed of. The **disposal** possibilities are different and the choice depends both on the animal species from which they derive (they may have a different substance content) and on the storage methods used. In principle, their spreading in agriculture can be seen as a "**closing the cycle**", because it allows **the nutrients** (mainly nitrogen and phosphorus) **to be returned to the crops, reducing or eliminating the use of chemical fertilisers.** In this case, however, correct management is essential, in order to avoid spreading an excessive quantity and the consequent uncontrolled release of polluting substances, first of all nitrogen. For this evaluation, in addition to the quantity, it is also important to consider the quality of the material used, because the organoleptic characteristics can be highly variable. In the case of **chicken manure**, for example, the low humidity content (30% against 90% of that of bovine or pig manure) makes it highly concentrated in nitrogen and therefore its spreading must take place with extreme caution.

To limit the impacts, the agronomic use of livestock effluents is governed by specific action programs (first of all the **Nitrates Directive**[52]) which vary from region to region, in order to protect vulnerable areas from nitrates of agricultural origin. The fundamental principle is to have **available a quantity of land proportional to the animals raised**, in order to be able to manage manure directly on the farm. Consequently, intensive farms need to have agricultural areas with a lower livestock density in which to transport manure. The transport of manure is rather complex, but technological innovation has made it possible

Biomethane plant Spilamberto (MO)

to develop various processes to simplify this phase such as, for example, the **drying of digestates** - which will be discussed later - using the heat obtained from **combustion of the biogas produced by anaerobic digestion.** Spreading has also seen a notable revolution, with the introduction of machines that release the sewage into the soil with precision systems and limit or cancel the emission of nitrous oxide into the atmosphere and the leaching of nitrates into the groundwater. Lastly, the management of the bedding and the under-grid led to some technical solutions such as the use of **microorganisms which block the action of urease** (enzyme which transforms urea in urine into ammonia) **greatly reducing the volatilization of nitrogen in the form of ammonia.**

4.8.1 Manure treatment: from problem to resource

The manure treatment systems are generally aimed at the **concentration of nutrients** (nitrogen and phosphorus), in order to make it easy to both transport and use by farmers. One of the best known is **composting** which, through a controlled process of aerobic degradation, allows the material (generally manure or chicken droppings) to be transformed into organic fertiliser. The process takes place by mixing different types of organic material, to provide the microorganisms involved in the biological process with a constant substrate: the manure can therefore be

Composting plant Nonantola (MO).

mixed with purification sludge, grass clippings and organic waste deriving from separate collection. The case of chicken manure is also interesting, through **drying**, it can become an excellent fertiliser used also in organic production.

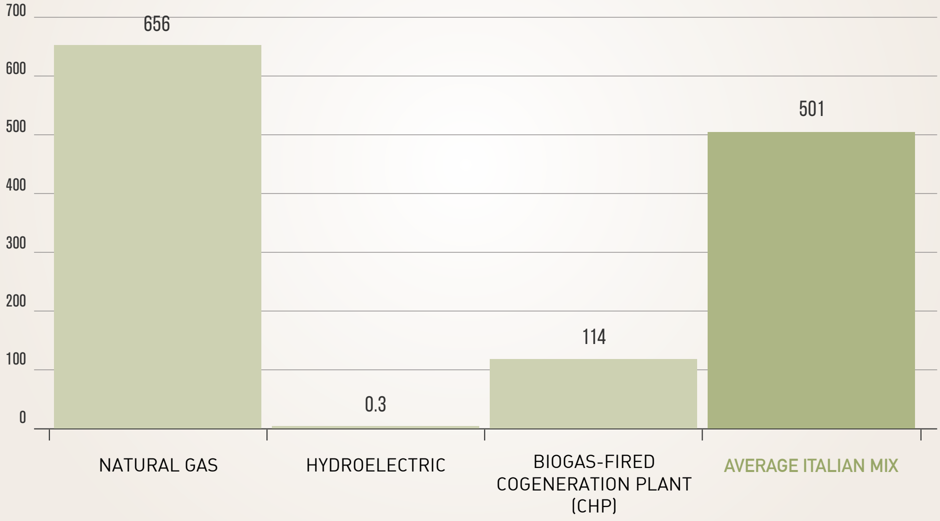
AVERAGE CHARACTERISTICS OF MANURE EXCRETED DAILY ACCORDING TO ANIMAL TYPE

	UNIT OF MEASURE	DAIRY COWS	BOVINE BEEF	POULTRY MEAT	PIGS
Total solids	**kg/ton of live weight**	12	8.5	22	11
Volatile solids	**kg/ton of live weight**	10	7.2	17	8.5
TKN (Total Kjeldahl Nitrogen)	**kg/ton of live weight**	0.45	0.34	1.1	0.52
NH_3N	**kg/ton of live weight**	0.079	0.086	NP	0.29
P	**kg/ton of live weight**	0.094	0.092	0.3	0.18

The values can vary considerably according to the diet, the age of the animals and the management of the farm.
TKN = total Kjeldahl nitrogen, defined as the sum of ammonia nitrogen and organic nitrogen[53].

BIOGAS: A RENEWABLE SOURCE

When farms are structured and of adequate size, the investments necessary for the construction of a biogas production plant are sustainable. The environmental advantage of energy conversion, when compared to traditional energy production, is significant. The operations chosen for comparison derive from the Ecoinvent[54] database.



Comparison of 1 kWh of electricity produced with different systems - g CO_2/kWh.

Of all the processes, however, one most worthy of note is that of **anaerobic digestion** which, in addition to the treatment of manure, **also allows the production of energy from non-fossil sources.** The process consists in the anaerobic degradation of mixtures of organic compounds (manure, plant remains, whey, etc.) and generates a mixture of CH_4 and CO_2. In this case the biological process is rather delicate: the treated material must be sufficiently balanced between dry biomass (manure, agri-food waste, plant residues) and wet biomass (sewage, whey, blood, etc.), and a very well organised management of the facilities is required.

4.9 Water and energy in farms

4.9.1 Energy consumption

Energy consumption in livestock farms is due to the use of electricity for machinery and thermal energy to heat the stables, food and water for washing. In order to reduce the impacts relating to the use of en-

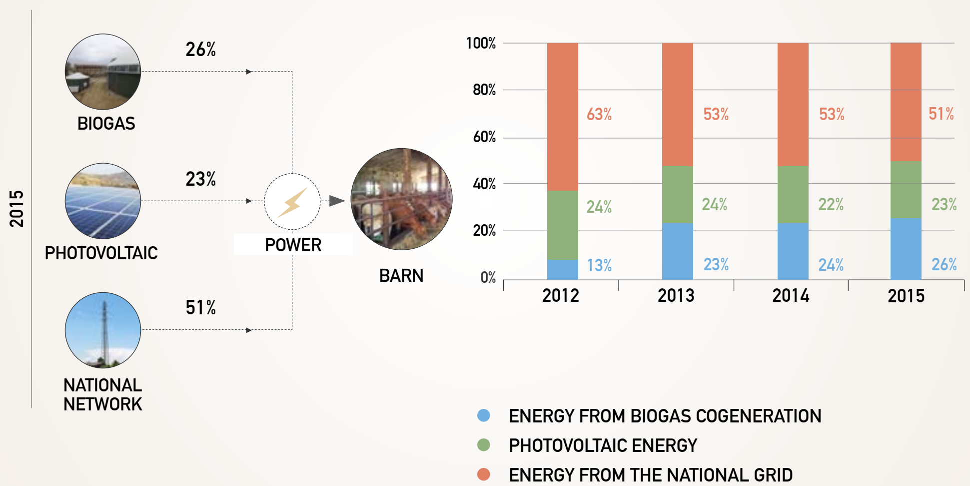
Agricultural biogas plant.

ergy, beyond the obvious practices of limiting consumption, it is possible to resort to production from renewable sources.

In addition to the case of biogas already discussed, the large availability of space makes it possible to generate interest for solar energy. The improvement in the efficiency of solar panels, as well as the duration and low need for system maintenance, have made some applications in the livestock/agricultural sector very interesting (for example on the roof of shelters, barns and sheds). The main applications of the production of energy from solar sources are the exploitation for thermal uses and for the production of electricity. These systems, as well as the production of biogas through anaerobic digestion, make it possible to reduce direct energy consumption relating to the rearing phase (usually modest). The use of these systems is quite widespread, thanks also to economic support interventions by the Italian government that have taken place over the years. Renewable sources consisting of **agri-solar** and **agri-wind power** have recently been brought to the attention of livestock operators. If in the

Photovoltaic plants in Ospedaletto.

AVERAGE ENERGY MIX USED IN ITALIAN BARNS OF ADULT BOVINE



Source: COOP-branded adult bovine environmental product declaration, S-P-00495 (Rev. 4 of 2016).

second case we are dealing with a modern re-proposition of a historical driving force (think of the wind mills that dot many rural landscapes of our continent), in the first it is necessary to carefully evaluate the agronomic (**competition for light and water with crops**) and landscaping implications of the dissemination of photovoltaics in the Italian countryside.

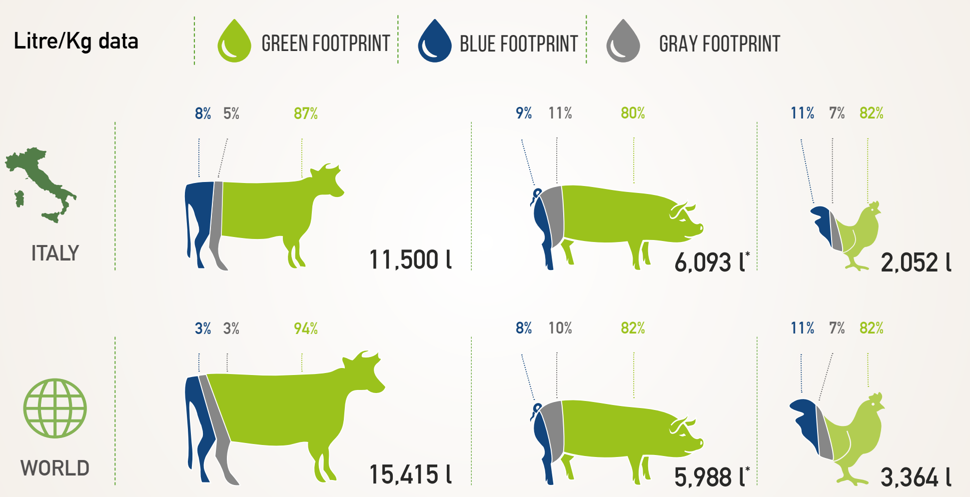
4.9.2 Water consumption

As better explained in the section of the chapter dedicated to water impact, according to the Water Footprint Network (WFN) method, the water footprint is given by the sum of three contributions: partly **real (blue)** and partly **virtual (green and grey)**.

- **blue footprint**, i.e., the quantity of water withdrawn from a body of water to be used in the production process;
- **green footprint**, characteristic of products of agricultural or forestry origin (quantity of rainwater that crops use in their production cycle to live and grow);
- **grey footprint**, i.e., the volume of water necessary to dilute the contaminant load leaving the system.

In livestock supply chains, over 80% of the water footprint is made up of the green component, i.e., rainwater that has been retained by the soil and which becomes available to meet the needs of the crops. It is therefore water that is not actually consumed by livestock, but which simply completes its natural hydrogeological cycle, passing continuously from the atmosphere to the ground and to water (surface and groundwater).
The water consumption directly attributable to a farm, on the contrary, is above all linked to washing (grey water) and drinking water (blue water). As far as washing is

WFP VALUES FOR THE THREE MAIN TYPES OF FARM ANIMALS



** The figure refers to heavy pigs (160 kg, 9/11 months of age) while the most common pig abroad weighs 80/100 kg (5/7 months of age).*

Source: Mekonnen and Hoekstra, 2010.

concerned, the reduction in consumption is linked to barn management and specifically to the implementation of procedures that prevent the generation of dirt. The volumes consumed with drinking troughs, on the other hand, depend on many factors such as, for example, health status, the microclimatic conditions, the type of feed and the drinking system. Also in this case, technology can limit consumption, allowing waste to be reduced to a minimum without influencing animal welfare.

4.10 Meat processing

The "industrial" phase in the meat supply chain **starts from slaughtering and ends with the creation of products that are placed on the market.** As with all processes, the environmental aspects concern the use of energy and water, as well as the generation of waste.

However, it should be noted that out of the entire lifecycle of food products, the transformation part is the **least problematic** from an environmental point of view, both because the impacts are quantitatively less than in the other phases, and because they are collected in a few points with a high technological concentration, which makes it possible to maximise efficiency: the reduction of consumption and best waste management are in fact indispensable requirements for reducing costs.

4.10.1 Waste or by-products?

The transformation of meat involves the generation of a large quantity of materials which, **although not intended for human consumption, are a secondary resource that is very useful for other destinations.** The management of these materials is quite complex, because it is necessary to distinguish between **by-products, co-products and waste**, in a context in which legislation is rather careful to avoid practices that constitute a risk to human health. The by-products are in fact divided into three classes:

- **category 1**, which includes parts of regularly slaughtered bovine such as skulls, entrails or carcasses of sick animals, etc., intended for incineration;
- **category 2**, which includes manure, stomach contents of ruminants or dead animals in general;
- **category 3**, which includes materials with characteristics that would also make them suitable for human consumption (for example fat or bones), but are intended for other uses (such as the production of feed for pets).

Without prejudice to compliance with the law and focusing attention on by-products destined for a second use in other production systems, the industry is trying to exploit as much as possible the research and innovation achieved in the scientific field to give added value to by-products of animal origin, going well beyond the usual profitability. In fact, there are many possible uses: **human or animal nutrition, animal feed, pharmaceutical products, fertilisers and by-products to generate biodiesel.** The organic material that cannot be recovered in other productions can conveniently be sent to anaerobic digestion for the **production of biogas**, and therefore of **renewable energy and digestate that can be used for agronomic fertilisation**, with environmental and economic advantages already discussed in the section relating to manure management.

MAIN USES
OF SLAUGHTER BY-PRODUCTS

BONES

are used for producing pet food, animal fodder, fertilisers and gelatine used for food and pharmaceuticals.

CATTLE AND PIG SKIN

are used for producing leather products: veal leather is used for luxury articles (shoes, handbags, belts etc.), steer leather is used in the automotive sector (car seats), cow leather is used for making sofas and leather goods while pig leather is used to line shoes internally.

FAT

is used in the cosmetic and chemical industries (soaps) as well as in the livestock sector (to produce animal fodder).

PORK RIND AND CARTILAGE

are used for producing food thickening agents as well as pet food.

PORK RIND AND OTHER SINUOUS PARTS

are used for producing gelatine, both for food preparation (mainly pork) and pharmaceuticals (mainly bovine) for preparing films required for encapsulating medicines.

BLOOD AND ENTRAILS

pig entrails are used for producing cured meats, while bovine blood is used for producing fertilisers and animal proteins, while chicken blood is used for pet food.

PERICARDIUM

taken from both bovine and pork, are used for making medical devices (heart valves).

FAT LIQUIDS AND RUMEN CONTENT

along with other wastes are used for producing green energy (biogas cogeneration).

ABOMASUM

(the last cavity of the four stomach chambers of ruminants) is used for making rennet (for example it is the only coagulant that can be used for making PDO cheeses such as Grana Padano or Parmigiano Reggiano).

PORK BRISTLES

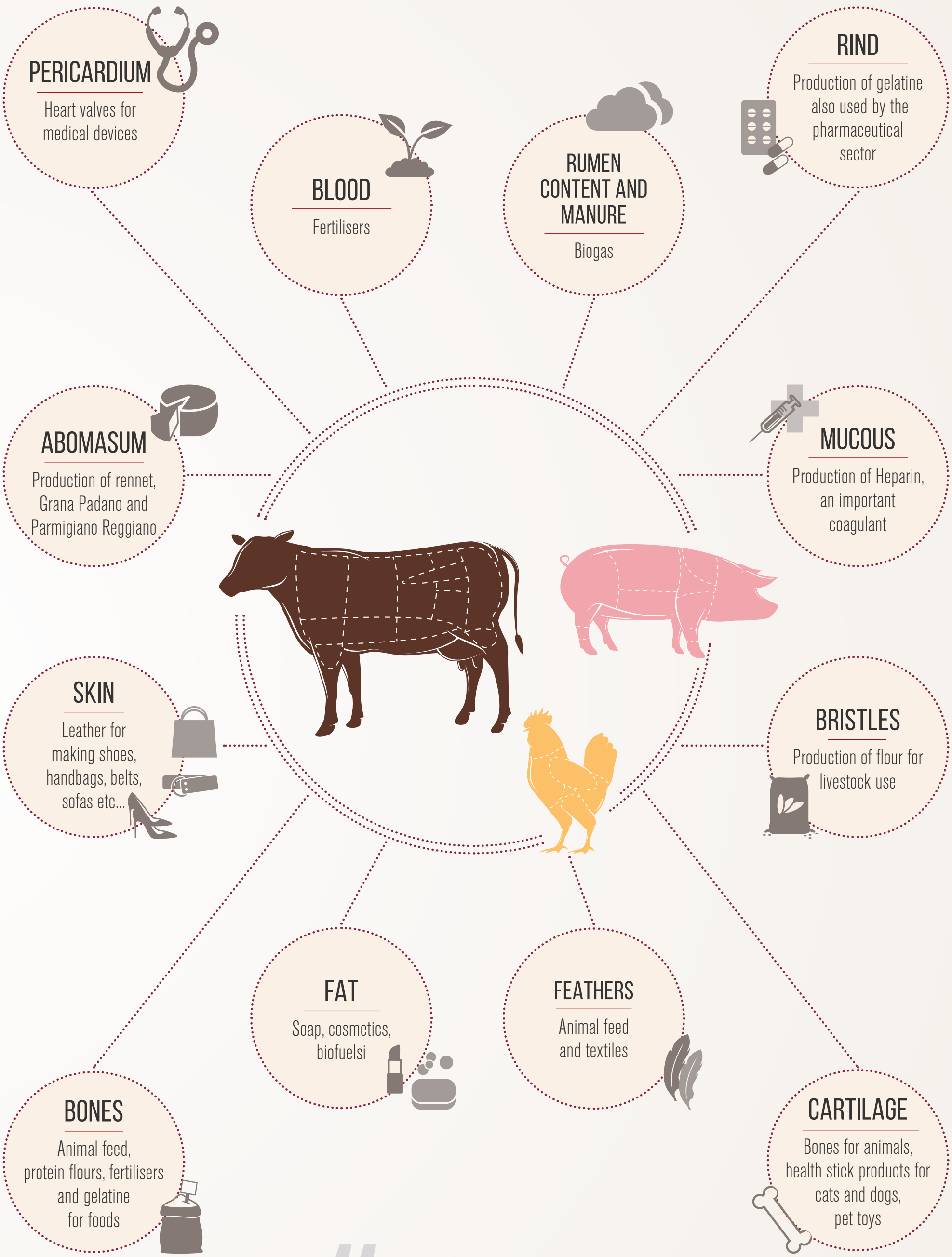
once used for making paintbrushes and brushes, today they are mainly used for making flours for livestock use.

PORK MUCOUS

(extracted during the preparation of pork entails) is used by pharmaceutical companies for making Heparin, which is an important anticoagulant medicine.

THE FEATHERS

are used in the production of animal feed and in the textile industry.



"NOT ONLY MEAT IS OBTAINED FROM AN ANIMAL"

4.11 Distribution

The lifecycle analysis approach allows you to examine processes with a complete system logic, sometimes with non-intuitive results and considerations.

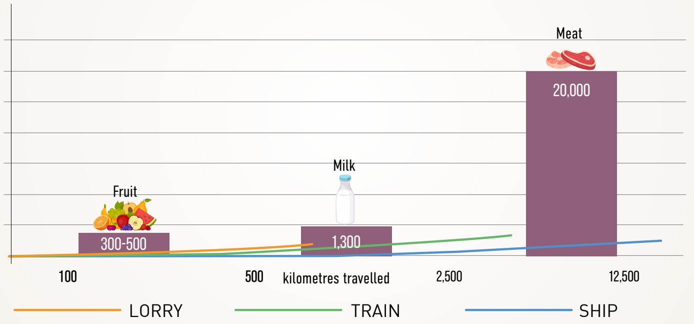
By way of example, local products are generally considered "sustainable", meaning those that travel as few kilometres as possible from the place of production to the place of sale and consumption.

The basic idea of this deeply rooted conviction is to reduce the environmental impact that the transport of a product entails, by reducing its carbon dioxide emissions. However, **it is not obvious that consuming local products leads to a reduction in the overall CO_2 emissions of food, as it has been demonstrated that transport has an almost negligible impact on the overall cycle.** In fact, comparing the impact of the production and distribution of different agri-food goods, it is evident that transport affects, albeit limitedly, only those characterised by a "simple" supply chain, such as fruit and vegetables. In the case of more complex products, such as meat or cheese, the environmental load associated with distribution is almost irrelevant, considered throughout the whole supply chain. In this case it is therefore much more important to aim for efficient and low-impact processes, rather than "nearby" products.

The advantage of local products can be seen from other points of view, such as the promotion of the local agri-food heritage and the drive to rediscover territorial and cultural identity. The Figure below clearly shows that the impacts related to the transport phase are always very low compared to those related to the production phase. With the exception of fruit, for which transport over long distances (approximately over 5,000 km) can have a significant impact on the total.

IMPACTS RELATED TO TRANSPORT

in grams of CO_2 eq. per kg of product



Comparison between the impact of transport (by lorry, train or ship) and that of some of the most commonly consumed products.
Source: Marino and Pratesi, 2022.

5 INITIATIVES TO IMPROVE THE SUSTAINABILITY OF FARMS

5.1 The role of FAO for sustainable farming

The Food and Agriculture Organisation of the United Nations (FAO) supports the sustainable development of livestock farming in various ways. Among the many initiatives undertaken, two partnerships on a global scale are certainly worthy of note (http://www.fao.org/policy-support/mechanisms/en/) which have allowed governments, public sector entities and private individuals, producers, civil society and the academic world to sit around a common table.

The Global Agenda for Sustainable Livestock[55] was created by FAO, which today plays a facilitating role and is actively involved in the partnership. The latter is composed of 7 typologies – governments, civil society, organisations, private sector, donors, research/academia, NGOs, intergovernmental and multilateral organisations – and aims to catalyse the action of stakeholders on the following issues:

1. **Global Food Security and Health** – The Agenda promotes an inclusive approach to the management of infectious diseases at the animal-human-environmental interface, involving all industry stakeholders in the development and implementation of programs for animal disease management and food safety.

DIGITISATION AND DIGITAL TRANSFORMATION IN MEAT SUPPLY CHAINS

By Stefano Epifani

The meat supply chains, today, are amongst those that could benefit most from the ongoing digitisation process but which, however, are developing the least. The lack of pervasive infrastructures, the scarce diffusion of a digital-oriented culture in the sector and the difficulty of managing a change process which, in order to be effective, must touch all the links of a complex and multiform value chain in an ecosystem perspective, however have slowed down - but not blocked - the development of experiences, models and cases of excellence that demonstrate ***how these supply chains can be not only made more efficient, but sometimes revolutionised by digital transformation with*** *a view to ever greater environmental, economic and social sustainability.*

To understand the reasons, still it is necessary to understand what is meant by digitisation and digital transformation[1]*.*

• ***The first concept,*** *that of* ***digitisation,*** *concerns the automation of information and related processes: it pertains to a dimension that is related to "how" people or companies act in the management of their activities. In other words, thanks to digitisation and technologies, it is possible to improve what is done in terms of process efficiency. The concept of digital transition, therefore, expresses the path of those organisations that are passing from an analogical approach to a digital one: automating processes and as a result optimising them.*

• ***The second concept,*** *that of* ***digital transformation****, instead concerns the way in which the pervasive diffusion of information technology in all segments of the population (think of the diffusion of smartphones to understand how widespread the phenomenon is) generates a societal change that does not only have an impact on the way things are done - typical of digitisation - but on the very meaning of the things that are done. In other words, if digitisation concerns process automation, digital transformation concerns the impacts of digitisation on society. Impacts that generate a widespread change in people's behaviour that have, as a result, a change in their habits.*

The digital transformation, by changing the way people meet, inform each other, decide what to buy as well as who to vote and, ultimately, manage all aspects of their lives, has profound and irreversible impacts on the value chain of each company, often redefining its meaning. ***Digitisation and digital transformation act in a combined way on the meat supply chain.***

• ***Digitisation*** *has impacts on all supply chain processes, both in the agricultural, industrial and commercial phases. Digital technology makes it possible to monitor the behaviour of the animals in the barn as well as at pasture*[2]*, to intelligently manage the nutrition process by revolutionising the unifeed model*[3]*, to control the growth and fattening of the animals through widespread sensors*[4]*, to develop analyses useful for the prediction of diseases*[5]*, even to increase the level of quality animal welfare monitoring through artificial intelligence systems used to recognise any expressions of livestock suffering*[6]*. The use of digital tools and technologies, therefore, makes it possible to effec-*

tively manage tracking processes[7] which, when properly implemented, guarantee all the actors, from the producer to the consumer, throughout the commercial supply chain.

*• **The digital transformation**, the effects of which will be seen above all in the coming years, acts on the business models of the players in the supply chain and on the consumption models of customers. On the one hand it allows the development of disintermediation models which, especially in the case of smaller players, allow the consumer to be reached directly, on the other - with the platform economy - it creates new intermediaries among the actors in the supply chain which interpose differently respect to the past, requiring them to develop new skills to avoid suffering the negative externalities of these actors.*

To manage the impacts of digitisation and digital transformation, maximising the benefits and minimising the risks, a joint commitment of institutions, producers and companies is required which:

*• **understand that the digitisation of processes is the most important innovation tool** available to the sector, both with a view to implementing new tools and new business models;*

*• promote the **development of distributed digital infrastructures,** to enable all players in the supply chain to act in an increasingly digitised context;*

*• develop such a system of skills so as to seize the transformative opportunities that digital brings with it, favouring the emergence of **new professionals** who know how to apply both digital skills and specific sector skills in a combined and synergistic way;*

*• enable the necessary conditions for the creation of **digital ecosystems of innovation**[8], to ensure that the profitability of the individual links in the value chain is also maximised through the ability to build value from data.*

In this process of change, a central role is that of the citizen-consumer, who will be increasingly informed and aware only to the extent that the actors in the supply chain will succeed in making them so, even beyond the fake news that too often pollutes the sector.

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[1] Epifani S. (2020), "Sostenibilità Digitale: perché la sostenibilità non può fare a meno della trasformazione digitale", Digital Transformation Institute.

[2] Imaz J.A., García S., González L.A. (2019), Real-Time Monitoring of Self-Fed Supplement Intake, Feeding Behaviour, and Growth Rate as Affected by Forage Quantity and Quality of Rotationally Grazed Beef Cattle.

[3] Simanungkalit G., Bremner G., Cowley F., Barwick J., Dawson B., Dobos R., Hegarty R. (2021), Automatic Supplement Weighing Units for Monitoring the Time of Accessing Mineral Block Supplements by Rangeland Cattle in Northern Queensland, Australia.

[4] Gokul V., Tadepalli S. (2017), Implementation of Smart Infrastructure and Noninvasive Wearable for Real Time Tracking and Early Identification of Diseases in Cattle Farming Using IoT; Y. Feng et al. (2021), SocialCattle IoT-based Mastitis Detection and Control through Social Cattle Behavior Sensing in Smart Farms (Preprint).

[5] Suresh A., Sarath T. V. (2019), An IoT Solution for Cattle Health Monitoring.

[6] Neethirajan S. (2021), Happy Cow or Thinking Pig?.

[7] Cui X., Iftekhar A. (2021), Blockchain-Based Traceability System That Ensures Food Safety Measures to Protect Consumer Safety and COVID-19 Free Supply Chain.

[8] Briscoe G., De Wilde P. (2006), Digital Ecosystems: Evolving Service-Oriented Architectures, BIONETICS, Proceeding of the 1st International Conference on Bio inspired Models of Network, Information and Computing System, ACM Press.

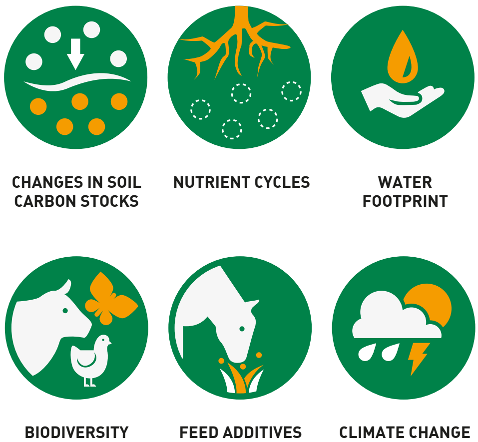
2. **Equity and growth** – The Agenda supports sustainable growth of supply chains, in which the indigent have access to all necessary resources and services and can also participate actively in growing markets
3. **Resources and climate** – The Agenda pushes the sector towards an ever more efficient use of resources and towards a greater contribution to the mitigation of climate change, both by promoting farming systems focused on the use of forage resources that cannot be used for human nutrition and through a system of incentives and rewards for those who start a more conscious management of their business from an environmental point of view.

Farmers, consumers and other stakeholders along the supply chain increasingly need information on environmental performance and sustainability. This need has led, over time, to the development of a wide range of alternative valuation methods. However, calculating environmental performance through different metrics makes it impossible to compare results. The **standardisation of the method has therefore become indispensable**: this would allow the attention to shift from theory (methodological issues) to practice (improvement measures).

The Partnership on Environmental Assessment and Livestock Performance (LEAP)[56], founded in 2012, was created precisely to meet this need.

LEAP is the result of a consultation process between FAO's Animal Production and Health Department and a group of representatives from the food and agriculture sectors. FAO hosts the LEAP secretariat and ensures that its work is based on international best practices.

The purpose of LEAP is therefore to review the existing methodologies and guidelines for the assessment of environmental impacts and validate/improve them in order to allow a correct **measurement, monitoring and improvement of the environmental performance** of the livestock supply chain, keeping in consideration at the same time the possible consequences in the social and economic sphere. LEAP's approach is based on continuous improvement: therefore, it does not limit itself to issuing guidelines[55] but also provides indications on the future work necessary to further improve them. The thematic areas on which LEAP is focusing are six.



FAO is committed to providing comprehensive and reliable assessments of the environmental impacts of the livestock sector, the potential for decreases and the concomitant effects on food security and poverty reduction. This is essential to be able to stimulate political dialogue and take the right strategic direction to follow.

5.2 ERBS, the European project of the Sustainable Agriculture Initiative[57]

Founded in 2002, the platform brings together (as members or external partners) over 100 agricultural businesses, companies and organisations around the world who are literally leading the way in the field of agricultural and livestock innovation. To protect the earth's resources, the platform constantly encourages the **exchange of information** and knowledge among its members, favouring the search for **solutions to common challenges** and thus promoting sustainable agriculture globally in a **pre-competitive environment.**

The platform is also developing several calculation tools and operational protocols, with a particular focus on beef, dairy products and crops.

The Spotlight collaboration tool acts as an aggregator and fosters dialogue between companies through a very simple procedure. The farm fills in its essential characteristics (e.g., main product, country of origin, topic to be investigated), after which it is guided in the search for other companies that share the same interest/concern and can choose whether to get in touch with them.

At European level, the ERBS (European Roundtable for Beef Sustainability) project was launched in 2018, focused on the sustainability of **beef** and addressing all the key aspects along the value chain. ERBS has identified 4 priority areas on which to act, for a total of 8 concrete objectives to pursue.
Each of the nations that has currently joined ERBS (Italy, France, Germany, Ireland, Poland and the United Kingdom) has

ERBS: PRIORITY AREAS AND OBJECTIVES TO PURSUE

PRIORITY AREAS	ENVIRONMENT	ANIMAL WELFARE	ANTIBIOTICS	FARM MANAGEMENT
GOALS	By 2025, 15% reduction in greenhouse gas emissions (measured and monitored through the Carbon Footprint indicator).	Reduction of mortality below 1.5% By 2030, freedom of movement must be guaranteed for all animals (i.e., animals should never be kept chained continuously) Administration of analgesics whenever the animal undergoes surgery.	By 2023, reduce the use of antibiotics below 10mg/kg PCU By 2030, reduce the use of P-CIAs[58] by 50%.	Regarding occupational safety, reduction of accident rates and elimination of fatalities. In terms of economic sustainability, implementation of a Decision Support System (DSS) to support farmers[59].

created its own national platform and is required to submit to ERBS a periodic report of all the activities implemented to achieve the set objectives. Therefore, the national platforms report their work to the European platform which in turn connects to the global platform (the Global Roundtable for Sustainable Beef - GRSB).

5.3 Development lines for the definition of the new Common Agricultural Policy (CAP) post 2020

Launched in 1962, the Common Agricultural Policy (CAP)[60] is one of the most important EU policies, with a significant share of the EU budget. Although the CAP reform is expected to be implemented from 2023, the provisional political agreement reached in the summer of 2021, by the European Parliament and Council, has already started to outline a fairer, greener, more flexible and more respectful of animal well-being. The agreement provides for a more equitable distribution of support, especially to small and medium-sized family farms and young farmers.

In the field of **climate, environment and animal welfare**, more ambitious policies will be implemented, aligned with the objectives of the Green Deal and therefore also with those of the 'from producer to consumer' strategy (Farm to Fork, F2F, strategy), such as:

- the minimum requirements that a farm must meet in order to have access to funds will be more stringent (e.g., at least 3% of arable land destined for biodiversity and non-productive elements);
- Member States will have to offer eco-schemes, assigning at least 25% of their income support funds. These funds will reward farmers who adopt practices that respect the climate and the environment (organic farming, agroecology, integrated phytosanitary defence, etc.) and promote animal welfare;
- at least 35% of rural development funds will be allocated to agri-environmental commitments that promote practices that respect the environment, the climate and animal welfare.

5.4 Agenda 2030 United Nations

Between 2000 and 2015, the United Nations identified 17 Sustainable Development Goals (SDG) divided into 169 Targets to be achieved by 2030, in the environmental, economic, social and institutional fields. The Goals address, amongst other things, environmental impact, employment and economic growth, workers' rights and communities. The European Community is promoter of Agenda 2030 (UN) and based on it defined the 10 priorities of the Commission in subjects such as: employment, energy, climate and trade policy.
The SDG constitute the development of the objectives initially defined in the context of the "Millennium Development Goals" (MDG) and certainly represent one of the most effective results of the inclusive and summary work carried out by the United Nations which has actively involved, among other, over 1,500 businesses.

The SDG are universally applicable in developed and developing countries, form the basis for operational plans, legislative actions and other policy initiatives and as a necessary condition for their pursuit, have placed the economic activities of companies at the centre.

5.5 The policies of the European Commission

5.5.1 European Green Deal[61]

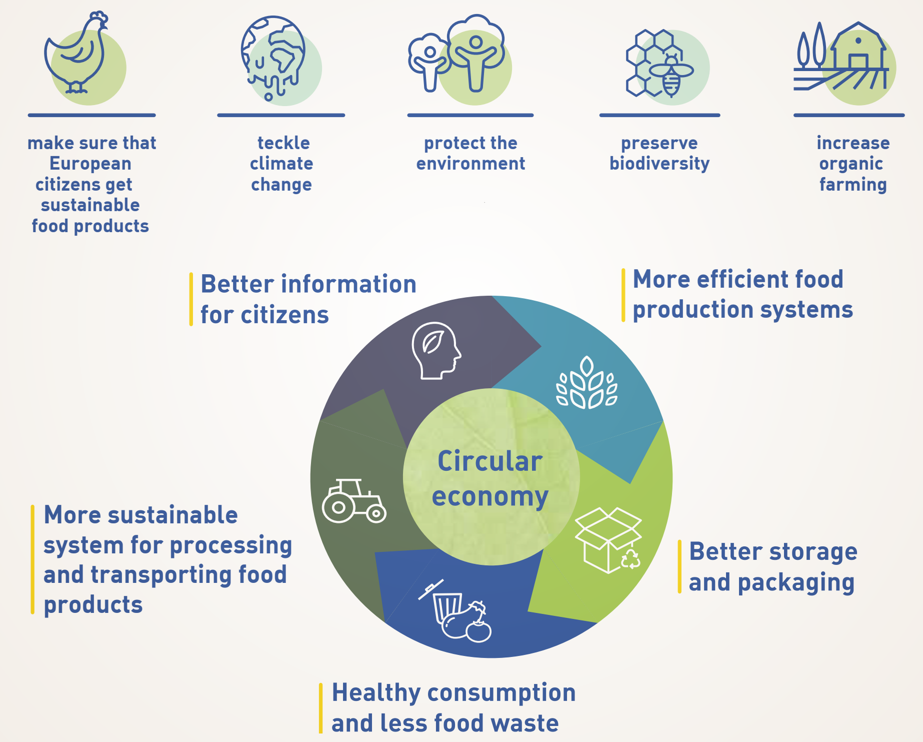
Be the first continent in the world with zero climate impact: this is the goal that we, as the European Union, have set ourselves to achieve[62].
The benefits expected from this transformation are many. Not just a drastic reduction in emissions, but the creation of many new jobs, an increase in the competitiveness of our businesses, a reduction in energy dependence outside the EU and a greater degree of security for its supply. All of this will have undoubtedly positive effects on our health and degree of well-being, both ours and the planet.

The first major milestone of this ambitious roadmap will be a dramatic reduction in net greenhouse gas emissions **by 2030: at least 55% below** 1990 levels.
To implement the European Green Deal, on 14th July 2021, the European Commission presented various operational proposals. The package of proposals aims to **ensure that all sectors of the EU economy are placed in a position to take up this challenge** and that they can take the path towards a rapid reduction in emissions in ways that are **fair, competitive and efficient in terms of costs.**

5.5.2 The Farm to Fork strategy[63]

The goal of climate neutrality by 2050, is both the greatest challenge and the greatest opportunity of our time.
Through the "From farm to fork" strategy (approved by the European Parliament in October 2021), the agri-food sector will also contribute to achieving this goal. The activities to be implemented will be aimed at building a **fair, healthy and environmentally friendly food system**, thus ensuring the production of healthy, nutritious and high-quality food, produced with respect for the environment and following the principles of the circular economy.

THE "FARM TO FORM" STRATEGY



Source: European Commission, December 2019. From farm to fork: the European Green Deal. ISBN 978-92-76-14003-0 doi:10.2775/3630.

5.5.3 The risks of the Farm to Fork strategy

On paper it seems like an idyllic scenario... but several critical issues have already emerged. In fact, so far, the European Commission has not yet made public any impact assessment studies of the Farm to Fork strategy.

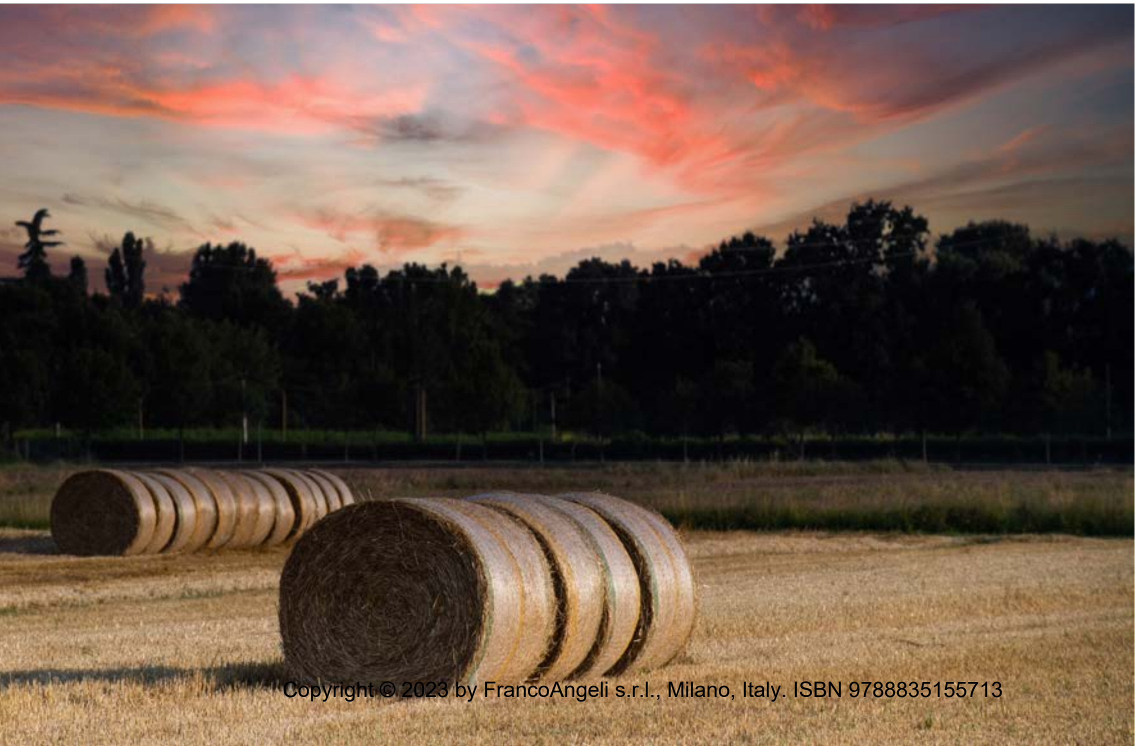
Meanwhile, various independent and academic studies have been published. Surely none is exhaustive and capable of capturing all the complexity of the theme on its own. Below are some impact studies that highlight the risks to which this process could lead. First of all, the technical report produced by the Commission's science and knowledge service, the **JRC**[64], which takes into consideration various possible scenarios with respect to the application of the new strategy. The document comes to the conclusion that whatever the scenario considered, in all sectors of agricultural production and livestock, production **decreases of between 5% and 15%** are expected, with the worst results for the livestock sector (bovine, chicken, pigs) as well as for the cultivation of cereals, oilseeds and fruit and vegetables. Against this decrease in production, the report expects a net **increase in the prices of agricultural products of about 10%** and a drop in exports, with a **worsening of Europe's trade deficit.** However, the most controversial point raised by the report concerns the hypothesis of the effects of this strategy on emissions. In fact, the report underlines how the F2F strategy could help r**educe greenhouse gas emissions** from the agricultural sector **by 28.4%** by 2030, but the report also highlights how over half of the greenhouse

gases that the Europe will save, will be produced instead by equivalent **increases in greenhouse gases in third countries, due precisely to the increase in agricultural production of those countries, aimed at making up for the decline expected in Europe.**

Alarming data partially confirmed by the impact study of the USDA (the United States Department of Agriculture). According to the American analysis[65], in fact, the introduction of the new strategy would cause a **12% drop in agricultural production against a 17% increase** in prices. As far as foreign trade is concerned, **exports would drop by 20%** while imports would increase by 2% with a drop off in GDP of about 58 billion Euro and greater **food insecurity for another 22 million people.** This scenario was confirmed by a subsequent independent study[66].

A worrying scenario that the war in Ukraine has made tangible, showing the extreme fragility of short-sighted supply systems even for developed countries like ours. Completely deferring the production of essential food goods to third countries represents a real risk for agri-food self-sufficiency and the dismantling of the European meat production could lead to emergencies similar to those such as Europe has recently had to face for wheat.

From what has been said, it follows **that sustainability is a path to take together with, and not against, the meat production sector.** The strategy to pursue, consequently, cannot be to penalize a sector that is worth around **170 billion Euro and directly employs more than 4 million people,** making the food necessary for a healthy diet inaccessible to millions of individuals. Indiscriminately reducing meat production would also lead to the need to import it from abroad, from countries that have a higher environmental footprint than Italy and Europe. Seeing as how Europe today is a model in terms of sustainability for the rest of the world, importing meat with a high environmental impact goes against one of the primary purposes of applying the Farm to Fork strategy itself, the reduction of emissions.



6 THE ENVIRONMENTAL IMPACTS OF THE DIET: **THE ENVIRONMENTAL HOURGLASS**

Meat and cured meats are among the foods with the greatest impacts per kilogram. **This consideration becomes less clear if the comparison is made considering the quantities consumed in a diet consistent with nutritional advice.** Trying to graphically represent this concept starting from the weekly consumption suggested by the nutritional guidelines and multiplying them by the average environmental impacts of the various food categories, an innovative graphic representation is obtained, similar to an **hourglass.**

A first edition of this presentation was published in 2013, by COOP Italy with a Book on the sustainability of branded beef[47]: the hourglass, which was intended to propose a different reading of the **relationship between diet and environmental impact**, was reviewed and updated by the Sustainable Meat Project and in 2016 its scientific validity was recognized by the scientific environmental journal "Science of the total environment"[68]. The most important aspect that emerges from this representation is that, in a balanced weekly diet, the environmental impact of protein rich foods (meat, fish, eggs, legumes, cured meats) is comparable with the impact generated by foods of plant origin (fruit, vegetables). If taken in the right quantities, the various food categories have in fact a similar "environmental weight", homogeneously distributed along the hourglass.

This reading allows to reinforce the consideration that **a balanced diet is not only useful for the interests of one's own health, but also for the environment.**

6.1 The construction of the hourglass

Conceptually, the process required to build the hourglass is very simple: **the environmental impacts (per kg) of food are multiplied by the quantity consumed in a week, obtaining the environmental impact.** The criticality in the calculation lies in the data, both of impact and quantity of food, that are chosen. When it comes to fruit, for example, people's food choices can be very different (from pineapple to apple) and with them the related environmental impacts. The same is true for the quantities of food, which obviously cannot be net and precise because, while remaining in the context of a balanced diet, people's choices can be very different. For these reasons the hourglass calculation was made by hypothesizing different possible food selections, with the awareness that what is presented in this document is not the only possible representation: the combinations between consumption frequencies and favourite foods are almost endless.

6.1.1 Environmental impact data

The hourglass setting is made taking into account the global impacts of food, then calculated using the life cycle methodology. For this reason, the impact indicator taken into consideration is that of the carbon footprint that must be read with the limitations evidenced in the previous pages.

6.1.2 How to calculate the weekly consumption: portions and consumption frequencies

The amount of food consumed weekly can be calculated from two pieces of information: **portions** (amount of food) and **frequency** (how many portions). As for the portions, it was decided to adopt what was suggested by the Italian Society of Human Nutrition (SINU) with the LARN published in 2012[69] these portions were then also reconfirmed in the larns (2014)[70]. The aim is to provide operators in the nutritional surveillance sector with a practical, shared reference, useful to define diets for the various age groups or groups with specific nutritional needs (pregnancy, lactation etc.). In the hypothesis of keeping portions constant, the frequency of consumption may vary according to food choices, but also to people's characteristics (gender, age, activities, etc.). To evaluate the variability of these options, **three scenarios** based on a different methodological approach were analysed: two of these (Scenario B and C), similar to last year, are based on INRAN's nutritional guidelines (now CREA - Food and Nutrition)[71]; and the third on the Mediterranean Diet (Scenario A) suggested by the International Mediterranean Diet Foundation[72]. In the elaborations related to the INRAN guidelines, the foods belonging to the first category (meat, fish, eggs, legumes) have been organised in various ways, maintaining the suggested constant frequency of 14 weekly portions.

Regardless of the hypotheses adopted, it should be remembered that a balanced diet should not exclude any food; for this reason, alternative food models, such as the vegetarian one, have not been taken into consideration, as this elaboration does not fall within the scope of the document and would require medical skills that go beyond those of the authors involved.

SCENARIO A LOW

The Mediterranean Diet scenario involves a very low consumption of meat and cured meats (350 grams weekly) and greater consumption of fruit and vegetables.

SCENARIO B INTERMEDIATE

The intermediate scenario takes into account a moderate consumption of meat and cured meats, which reaches 450 grams weekly.

SCENARIO C HIGH

Always in compliance with the nutritional indications, this scenario foresees a greater frequency in the consumption of food of animal origin, reaching 550 grams of meat and cured meats per week.

			WEEKLY CONSUMPTION FREQUENCIES			ENVIRONMENTAL IMPACT
FOODS		g per portion (from LARN 2014)	A	B	C	Data (g CO_2/g food)
MEAT. FISH. EGGS. LEGUMES	Fresh meat poultry/pork	100	2	3	3	4.6
	Fresh beef	100	1	1	1	23.4
	Fresh beef - hamburger	100	0	0	1	10.5
	Cured meats	50	1	1	1	15.1
	Fish and shellfish	150	3	2	2	4.4
	Preserved fish	50	0	0	0	4.4
	Eggs	50	3	3	3	3.8
	Legumes (Fresh or in cans)	150	0	0	0	1.7
	Dry legumes	50	4	4	3	1.7
MILK. YOGURT. CHEESE	Milk/Yoghurt	125	10	21	21	1.5
	Fresh cheese	100	2	1	1	9.3
	Seasoned cheese	50	2	2	2	9.3
DRESSINGS	Butter	10	7	7	10	8.3
	Oil	10	14	14	11	3.1
CEREALS	Bread	50	35	35	35	1.1
	Bakery products	30	7	7	7	1.6
	Pasta	80	5	3	4	1.9
	Rice	80	2	4	3	3.8
	Potatoes	200	2	2	2	1.2
FRUIT. VEGETABLES	Vegetables	200	14	13	12	1.7
	Salad	80	7	1	2	0.6
	Fruit	150	21	21	21	0.5
	Total meat and cured meats		350	450	550	

CARBON FOOTPRINT - Data Source

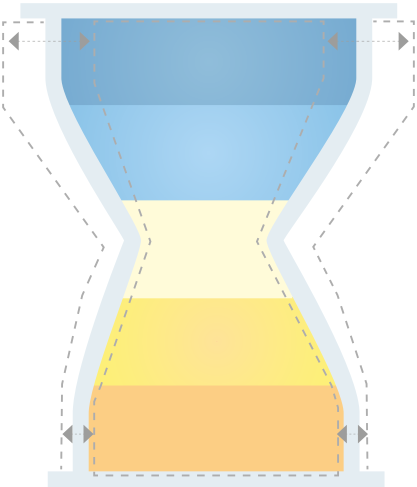
***Fresh beef**: Environmental product declaration for "Adult beef" and "White meat veal " Coop branded. The value is the average of the two types of meat, including cooking. Available at www.environdec.com*

***Fresh beef - hamburgers**: Environmental product declaration for Montana-branded "Frozen hamburgers." Available at www.environdec.com*

***Cold cuts**: Confidential LCA studies.*

***Preserved fish**: The same impact was assumed for fresh and preserved fish.*

***Legumes (fresh or canned)**: Fresh, canned and dried legumes were assumed to have the same impact.*



"DESPITE MEAT BEING AMONG FOODS WITH THE HIGHEST IMPACT, BY UNIT WEIGHT, A BALANCED CONSUMPTION DOES NOT INFLUENCE SUBSTANTIALLY THE WEEKLY IMPACTS"

CARBON FOOTPRINT

HOURGLASS

THE THREE SCENARIOS
kg CO_2 person/week

CATEGORY	A	B	C
MEAT, FISH, EGGS, LEGUMES	6.9	6.7	7.7
MILK, YOGURT, CHEESES	4.6	5.8	5.8
DRESSINGS	1.0	1.0	1.2
CEREALS	4.2	4.5	4.3
FRUIT, VEGETABLES	6.6	6.0	5.7
TOTAL	**23.3**	**24.0**	**24.6**

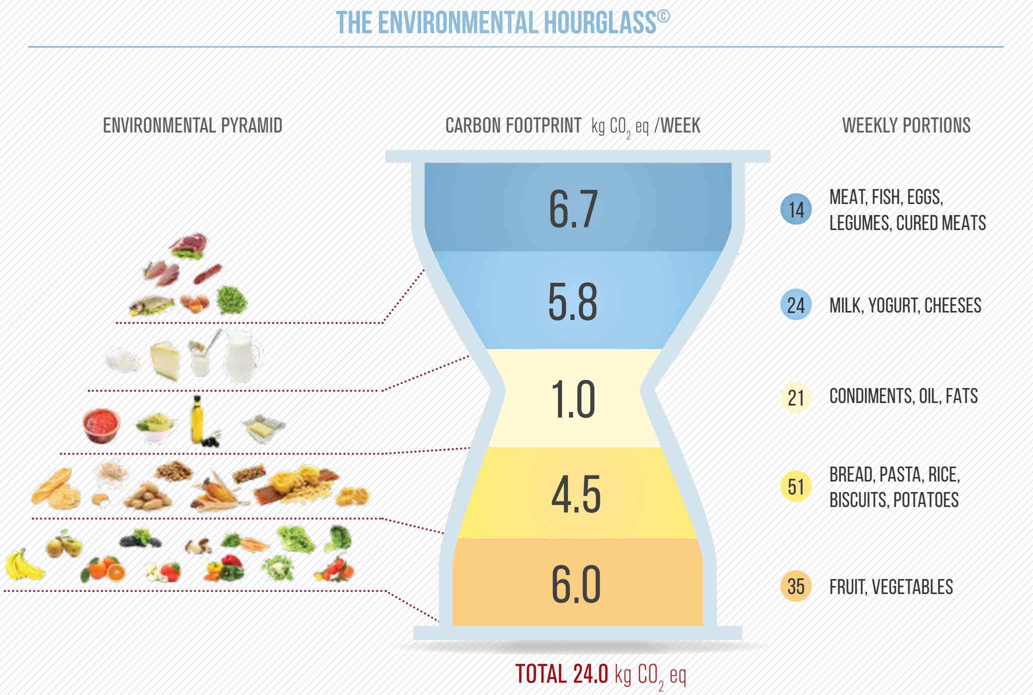
6.1.3 The different environmental hourglasses

The analysis of the variability of food choices leads us to observe, despite the different levels of consumption, that the profile of the hourglass does not vary substantially: on the contrary, in the case of the Mediterranean Diet (scenario A) it emerges almost paradoxically how low-impact foods such as fruit and vegetables have a greater impact than those of meat, an aspect also confirmed by an interesting study on the impact of various diets in the world[73], as anticipated in the introduction.

However, it should be remembered that the Mediterranean Diet is the bearer of values that go beyond considerations of a purely environmental or nutritional nature. As better described elsewhere[74], the Mediterranean Diet **emphasises** the **values of hospitality, sociability, neighbourliness, intercultural dialogue and creativity** and represents a way of life guided by respect for diversity. These are social and cultural aspects so important that they deserve to be included among the intangible heritage of humanity by UNESCO.

THE ENVIRONMENTAL HOURGLASS
CARBON FOOTPRINT

The Environmental Hourglass represents the carbon footprint of the foods consumed in a week following **scenario B**.



The Environmental Hourglass is built considering the consumption frequency suggested by INRAN (now CREA – Food and Nutrition) in the 2003 guidelines for an adult who needs 2,100 kcal per day, and the portions suggested by SINU in the guidelines published in 2012.

BIBLIOGRAPHY

[1] FAO (2018), The Future of Food and Agriculture – Alternative Pathways to 2050, Rome, 224 pp. ISBN 978-92-5-130158-6.

[2] Internationally known foundation funded by yachtswoman Ellen MacArthur and supported by industry giants such as Google, H&M, Banca Intesa and the World Economic Forum.

[3] LaCanne C.E., Lundgren J.G. (2018), Regenerative Agriculture: Merging Farming and Natural Resource Conservation Profitably, PeerJ 6:e4428; doi: 10.7717/peerj.4428.

[4] McLarenet S. et al. (2021), Integration of Environment and Nutrition in Life Cycle Assessment of Food Items: Opportunities and Challenges, Rome, FAO, doi: 10.4060/cb8054en.

[5] Fulgoni V.L. et al. (2009), Development and Validation of the Nutrient-Rich Foods Index: A Tool to Measure Nutritional Quality of Foods, The Journal of Nutrition, 139: 1549–1554, doi: 10.3945/jn.108.101360.

[6] Tessari P. et al. (2016), Essential Amino Acids: Master Regulators of Nutrition and Environmental Footprint? Scientific Reports, 6:26074, doi: 10.1038/ srep26074.

[7] Doran-Browne N.A. et al. (2015), Nutrient Density as a Metric for Comparing Greenhouse Gas Emissions from Food Production, Climatic Change, 129:73-87, doi: 10.1007/s10584-014-1316-8.

[8] Source of the elaborations: Our World in Data (https://ourworldindata.org/emissions-by-sector).

[9] FAOSTAT Analytical Brief 31, The Share of Agri-food Systems in Total Greenhouse Gas Emissions: Global, Regional and Country Trends 1990– 2019. ISSN 2709-0078 [Online].

[10] Data extrapolated from the FAOSTAT website (www.fao. org/faostat/en/#data), going to 'Climate Change > Emissions > Emissions intensities'. The filter applied for the extraction is as follows:

- Regions (Total) > World
- Elements > Emission intensity
- Items > Cereals excluding rice; Hen eggs in shell, fresh; Meat of cattle with the bone; Meat of chickens; Meat of pig with the bone; Cattle milk; Rice
- Years > 1961÷2020

[11] FAO (2017), Global Livestock Environmental Assessment Model (GLEAM) [online version], Roma, Available in the 'Results' section of the website: www.fao.org/gleam/en/.

[12] OECD/FAO (2021), OECD-FAO Agricultural Outlook 2021-2030, OECD Publishing, Paris, doi: 10.1787/19428846-en.

[13] Luo X. et al. (2020), Understanding Divergent Domestication Traits from the Whole-Genome Sequencing of Swamp- and River-Buffalo Populations, Natl Sci Rev. 7(3): 686–701, doi: 10.1093/nsr/nwaa024.

[14] Marino M., Pratesi C.A. (2022), Il cibo perfetto: aziende, consumatori e impatto ambientale del cibo. Edizioni Ambiente srl. ISBN 978-88-6627-344-8.

[15] All information sourced ISPRA is taken from the ISPRA Report 360-2022. Italian Greenhouse Gas Inventory 1990-2020. National Inventory Report 2022.

[16] The greenhouse gas emission data, the National Inventory Reports and the results of the review processes are published on the website: https://unfccc.int/ghg-inventories-annex-i-parties/2021. The historical national series of emissions is also available on the website: http://www.sinanet.isprambiente.it/it/sia-ispra/historical-emissions-series.

[17] Developed by the World Resources Institute (WRI), the 'Aqueduct Water Risk Atlas' map shows overall water risk (www.wri.org/aqueduct). This is an aggregate value obtained by considering, for each point on the map, 8 indicators linked to the quantity of available water, 2 indicators linked to quality and 3 to governance (e.g., absence of sanitation services). For further details on the calculation, the following publication is available: Hofste et al., 2019. Aqueduct 3.0: updated decision-relevant global water risk indicators. World Resources Institute. 53 pp, doi: 10.46830/writn.18.00146.

[18] The Water Footprint Network is a global platform that brings together companies, organisations and individuals around the same table to address the problem of the water crisis, both through the conduct of scientific studies and through the promotion of initiatives for a fair and intelligent use of water. The ultimate goal is to arrive at an equitable sharing of the resource between all the communities of the world and nature. The platform was born on the initiative of Arjen Hoekstra, initially at the UNESCO-IHE Institute for Water Education and then during his teaching period at the Dutch University of Twente (chair in water management). Official website: https://water-footprint.org/en/resources/publications/.

[19] Method developed by the WULCA (Water Use in LCA) working group under the aegis of the UNEP-SETAC Life Cycle Initiative. Official website: https://wul-ca-waterlca.org/.

[20] Boulay A.M. et al. (2018), The WULCA Consensus Characterization Model for Water Scarcity Footprints: Assessing Impacts of Water Consumption Based on Available Water Remaining (AWARE), The International Journal of Life Cycle Assessment 23, 368–378. doi: 10.1007/s11367-017-1333-8.

[21] UNEP-SETAC Life Cycle Initiative (2016), Global Guidance for Life Cycle Impact Assessment Indicators. Vol. 1.

[22] Atzori A.S. et al. (2016), A Preliminary Study on a New Approach to Estimate Water Resources Allocation: The Net Water Footprint Applied to Animal Products, Agriculture and Agricultural Science Procedia, 8:50-57, doi: 10.1016/j.aaspro.2016.02.007.

[23] Mottet et al., 2017. Livestock: On our Plates or Eating at Our Table? A New Analysis of the Feed/Food Debate. Global Food Security, 14:1-8. doi. 10.1016/j. gfs.2017.01.001.
Data also available in the "Results" section of the GLEAM website: https://www.fao.org/gleam/en/.

[24] Article 2 Directive 2001/18/EC of 12th March 2001.

[25] GMO techniques use genetic engineering to modify genes through a process of transgenesis, i.e., the insertion of a foreign gene (the transgene) into the genome of a living organism.

[26] World Health Organization, Food Safety: 20 Questions on Genetically Modified Foods (www. who.int/foodsafety/areas_work/food-technology/faq-genetically-modified-food/en/).

[27] FAO, Weighing the OGM arguments: against, 2003 (www.fao.org/english/newsroom/focus/2003/gmo8.htm).

[28] Global Feed LCA Institute (www.globalfeedlca.org/).

[29] FAO and UNEP (2020), The State of the World's Forests 2020. Forests, biodiversity and people. Rome, doi: 10.4060/ca8642en.

[30] FAO (2020), Global Forest Resources Assessment 2020: Main report, Rome, doi: 10.4060/ca9825en.

[31] Weatherley-Singh and Gupta (2018), Embodied Deforestation" as a New EU Policy Debate to Tackle Tropical Forest Loss: Assessing Implications for REDD+ Performance}, Forests, 9(12):751, doi:10.3390/f9120751.

[32] https://www.worldwildlife.org/threats/deforestation-and-forest-degradation.

[33] ISPRA (2020), Forests and Biodiversity, Too Valuable to Lose Them. Answers to Frequently Asked Questions. ISPRA Nature and Biodiversity Notebooks No. 13/2020, ISBN 978-88-448-1001-6, 32 p.

[34] TRENDS: Ismea periodical of analyses and forecasts for the agri-food sector. Corn, barley and soy for the feed industry. Report n.1/2021 - November 2021.

[35] Data available on the ISMEA website in the section: Homepage > Data > BD foreign trade > The trade map (available at the website: https://www.ismeamercati.it/dati-agroalimentare/commercio-estero).

[36] Communication from the Commission. A plan for TSE. Brussels, 15.07.2005. COM(2005)322 final (available at the website: https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=CELEX:-52005DC0322).

[37] Communication from the Commission. TSE plan (2nd edition). Transmissible spongiform encephalopathies strategy paper for 2010-2015. Brussels, 16.7.2010. COM(2010)384 final (available at: https://eur-lex.europa.eu/legal-content/it/TXT/?uri=CELEX:52010DC0384) Commission staff working document accompanying the Communication on the TSE Roadmap COM (2010)384 Brussels, 16.7.2010. SEC(2010)899 final (available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52010SC0899).

[38] Nursing feedstuffs containing fishmeal reserved for not weaned ruminants are authorised.

[39] Potential BSE Risk Posed by the Use of Ruminant Collagen and Gelatine in Feed for Non-Ruminant Farmed Animals, EFSA Journal 2020; 18(10):6267, doi: 10.2903/j.efsa.2020.6267.

[40] EFSA (European Food Safety Authority) (2018), Updated Quantitative Risk Assessment (QRA) of the BSE Risk Posed by Processed Animal Protein (PAPs), EFSA Journal 2018; 16(7):5314. doi: 10.2903/j. efsa.2018.5314.

[41] Processed by CEVA (Centre for the Study and Valorisation of Algae), Pleubian, France. Data updated to December 2021. Sheets available on the website: https://www.ceva-algues.com/en/document/nutritional-data-sheets-on-algae.

[42] FAO (2021), Fishery and Aquaculture Statistics. Global Production Statistics 1950–2019. In: FAO Fisheries Division [online]. FishStaJ – Software for Fishery and Aquaculture Statistical Time Series. www.fao.org/fishery/statistics/software/fishstatj/en.

[43] Nasseri A. T. et al. (2011), Single Cell Protein: Production and Process. American Journal of Food Technology. 6(2):103-116, doi:10.3923/ajft.2011.103.116.

[44] Assessment of Environmental Footprint of FeedKind protein – REPORT.

[45] Wilkinson J. M. (2011), Re-defining Efficiency of Feed Use by Livestoc,. Animal 5(7), pp. 1014–1022.

[46] Elferink E. V. et al. (2008), Feeding Livestock Food Residue and the Consequences for the Environmental Impact of Meat, Journal of Clean Prod., 16(12), pp. 1227-1233.

[47] IDH, (2020), European Soy Monitor; Insights on the Uptake of Responsible and Deforestation-free Soy in 2018.

[48] All graphs in this section are taken from the following study focusing on the European beef supply chain: Pishgar-Komleh and Beldman, 2022. Literature review of beef production systems in Europe. Wageningen Livestock Research. 39 pp, doi: 10.18174/567148.

[49] Zampori L. and Pant R. (2019), Suggestions for Updating the Product Environmental Footprint (PEF) Method, EUR 29682 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76- 00654-1, doi:10.2760/424613, JRC115959.

[50] Opio C. et al. (2013), Greenhouse Gas Emissions from Ruminant Supply Chains – A Global Life Cycle Assessment. Food and Agriculture Organization of the United Nations (FAO), Rome.

[51] Gavrilova O. et al. (2019), Emissions from Livestock and Manure Management. Vol.4, chapter 10 of the book" 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories" (available at: https://www.ipcc-nggip.iges.or.jp/pu- blic/2019rf/index.html).

[52] Council Directive 91/676/EEC of 12th December 1991, on the protection of waters from pollution caused by nitrates from agricultural sources (available at: https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=celex:31991L0676).

[53] Manuale di Agricoltura, (1997), cap. 6.7 "Gestione delle deiezioni animali", HOEPLI ed.

[54] The chosen operations are the following: Natural gas: Electricity, natural gas, at power plant/ITU; Hydroelectric: Electricity, hydropower, at power plant/IT U; CHP plant powered by biogas: Electricity, biogas, at Mini CHP plant, allocation energy/H U; Average IT energy mix: Electricity, low voltage, at grid/IT (energy mix according to IEA OECD 2014 data).

[55] Global Agenda for Sustainable Livestock: http://www.livestockdialogue.org/.

[56] LEAP - Livestock Environmental Assessment and Performance Partnership (available at: http://www.fao.org/partnerships/leap/resources/ en/).

[57] Available on the website: https://saiplatform.org/.

[58] HP-CIAs (Highest Priority Critically Important Antibiotics) should only be used as a last resort, if other treatments have proved ineffective.

[59] Two examples of activities useful to guide farmers in their choices are:

- share with them the details of the provincial Commodity Exchanges, so that a fair remuneration is guaranteed to farmers.

- identify some financial and/or productivity indicators and give farmers the opportunity to see their positioning with respect to the benchmark (locally or nationally), so that each farmer can monitor their performance and compare them with the mean values.

[60] Available at: https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-a-gricultural-policy_it.

[61] Available at: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-gre-en-deal_it.

[62] In December 2019, the European Commission officially presented the European Green Deal, committing to achieve climate neutrality by 2050. The goal became binding in the summer of 2021, with the entry into force of the European climate law (EEC/EU Regulation No. 1119 of 30th June 2021).

[63] Communication from the Commission COM/2020/381 final. «A farm to fork strategy for a fair, healthy and environmentally friendly food system» (available at: https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=CELEX:52020DC0381).

[64] Barreiro H. et al. (2021), Modelling Environmental and Climate Ambition in the Agricultural Sector with the CAPRI Model, EUR 30317 EN, Publica-

tions Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-20889-1, doi: 10.2760/98160, JRC121368.

[65] Beckman J. et al. (2020), Economic and Food Security Impacts of Agricultural Input Reduction Under the European Union Green Deal's Farm to Fork and Biodiversity Strategies, Economic Brief n.30, U.S. Department of Agriculture, Economic Research Service.

[66] Beckman J. et al. (2021), Market Impacts of Farm to Fork: Reducing Agricultural Input Usage. Applied Economic Perspectives and Policy. 1-19. doi: 10.1002/aepp.13176.

[67] COOP, The Sustainability of COOP Branded Beef - The Economic, Social and Environmental Impacts of the Meat Supply Chain, published in November 2013 and available on www.e-coop.it

[68] Ulaszewska et al., 2017. Assessment of Diet-related GHG Emissions using the Environmental Hourglass Approach for the Mediterranean and New Nordic Diets. Sci Total Environ. 574:829-836, doi: 10.1016/j.scitotenv.2016.09.039.

[69] Portion quantity standards taken from: SINU (2012), Italian Society of Human Nutrition. LARN, Reference Intake Levels of Nutrients and energy for the Italian population.

[70] SINU, (2014), Italian Society of Human Nutrition. LARN Levels of Reference Assumption of Nutrients and Energy for the Italian population. IV Revision. SICS, Milan.

[71] Nutritional guidelines developed in 2003, by the working group made up of INRAN (became "CREA – Food and Nutrition" in June 2015, acronym for Council for Agricultural Research and Analysis of the Agricultural Economy - Research Centre for foods and nutrition), by the Ministry of Health and by the Institute of Food Science of the "La Sapienza" University of Rome, with the aim of developing a type of diet towards which to direct the citizen, recommending the appropriate variations. Specifically, the recommendation relating to 2,100 kcal per day was considered.

[72] Bach-Faig A. et al. (2011), Mediterranean Diet Foundation Expert Group. Mediterranean Diet Pyramid Today, Science and cultural updates, Public Health Nutr. 14(12A), pp. 2274-2284.

[73] Cambeses-Franco C. et al. (2022), Driving Commitment to Sustainable Food Policies within the Framework of American and European Dietary Guidelines, Science of the Total Environment 807 (2022) 150894.

[74] Ascione E. et al. (2020), Il Mediterraneo: il tempio della Dieta. FrancoAngeli, ISBN 9788835114154.

THE NUTRITIONAL VALUE OF MEAT

- DIET AS A FOOD MODEL: THE FOOD PYRAMID
- THE NUTRIENTS OF MEAT
- NUTRITION AT DIFFERENT STAGES OF LIFE
- MEAT AND HEALTH
- IS MEAT CONSUMPTION SUSTAINABLE?

Introduction

MEAT IS AN IMPORTANT SOURCE OF PROTEIN, ESSENTIAL AMINO ACIDS AND OTHER NUTRIENTS THAT ARE FUNDAMENTAL TO THE HUMAN ORGANISM

THE MEDITERRANEAN DIETARY MODEL SUGGESTS MODERATE CONSUMPTION OF MEAT

THE PER CAPITA CONSUMPTION OF MEAT IN ITALY IS SIGNIFICANTLY LOWER THAN IN OTHER DEVELOPED COUNTRIES

*When it comes to nutrition is important to understand the concept of nutrition according to the model of Greek medicine, namely a **way of life** towards health, that takes into account all aspect of daily life, from food to exercise, to rest. In general the diet was based on the principles of balance, moderation and simplicity, and natural and whole foods, seasonal and locally sourced. Nutrition education should therefore encourage people to to follow a balanced "food model" that includes the consumption of all foods without excess. In this sense, the Mediterranean diet is helpful, as it recommends a balanced consumption of all foods, including meat and cured meats, in order to obtain the nutrients we need on a daily basis to maintain our health.*

*To be more specific, each food provides **nutrients to the organism** that are useful for the physiology of the body. **Meat and cured meats**, for example, are **sources of essential proteins**, but also many **micronutrients** and **bioactive compounds** that support a number of specific functions. Sometimes these components are more bioavailable (i.e. better assimilated) compared to plant-based sources, in some cases (for example **vitamin B12**) **they are present only in foods of animal origin such as meat and cured meats.** Furthermore such nutrients and protective substances sometimes work synergistically to meet the needs of the human body at different stages of life. Moving from the nutritional to the medical field one enters the area of **clinical diseases**, which in many cases can be linked more or less directly to food consumption. In the case of meat, the most attention regards the alleged correlation between the consumption of meat and cured meats with some cancer pathologies. A recent review of the literature signed by Nature Medicine underlines how weak and insufficient the evidence is to formulate conclusive recommendations on the consumption of red meat. According to Nature Medicine, red meat does not pose a health risk, as already highlighted by other publications such as the PURE study, conducted on 164,000 participants, which showed that the consumption of moderate amounts of unprocessed meat does not increase the risk of cardiovascular disease, nor does it affect mortality.*

*Despite numerous hypotheses in this field, **the relationship between disease and moderate consumption is currently not demonstrable** and scientific studies do not provide definitive conclusions, other than to keep consumption within the levels suggested by each country's guidelines. **Consumption** is therefore a fundamental link to relate a food and its impact on health and sustainability in general. To the question "how much meat do you eat?" it is not easy to answer, data are scarce and often refer to food availability (**apparent consumption**) and not to **actual consumption**. With a thorough analysis of the information available one can however draw some general considerations: the first is that **the actual consumption of meat and cured meats in Italy is lower than that indicated** by normally used data that refers to apparent consumption; the second is that **the consumption of meat (per capita) in the world shows important differences between North American, Asia, African and European countries.***

1 DIET AS A FOOD MODEL: THE FOOD PYRAMID

The Mediterranean Diet is the result of thousands of years of food and cultural exchange between people from all the countries bordering the Mediterranean basin. This model, known to be one of the healthiest and most balanced, in the twentieth century has characterised the eating habits of the inhabitants of the Mediterranean region, originally based on agricultural and rural models.

The **Mediterranean diet** encourages the **consumption of all foods**, without exclusion, and suggests a high intake of vegetables, legumes, fresh and dried fruits, nuts, olive oil and cereals (especially whole grains); a moderate intake of fish, dairy products (especially cheese and yoghurt), meat and occasionally sweets. For this reason, it must be seen as **a model** in which no single nutrient or food should predominate, but the overall effect of diet. Not surprisingly, the benefits of the Mediterranean Diet are due to the synergistic combinations of the nutrients and protective substances contained in the foods, to an adequate daily intake of **energy** and **water** and the **practice of physical activity** in order to maintain a healthy physical and mental state.

THE FOOD PYRAMID DEFINED BY THE MEDITERRANEAN DIET FOUNDATION

Source: IFMeD.

Other strengths of the Mediterranean model include the consumption of traditional and local food products, the preference for whole grains and unsaturated fats, seasonality and food biodiversity.

1.1 The food pyramid

Starting from the first definition of the Mediterranean Diet, made after the Second World War by the scientist Ancel Benjamin Keys who first highlighted how cardiovascular diseases in Italy, Spain and Crete were almost unknown compared to the disturbing levels already reached at that time in the United States, and that such a low rate was due to the different eating habits of those countries[1], many examples of graphical representation of the Mediterranean nutritional model followed. Always with a single objective in mind: to simplify communication and to educate people. Following **UNESCO**'s recognition of the Mediterranean Diet as an **Intangible Cultural Heritage of Humanity in 2010**[2] and taking into account the worldwide interest, the Mediterranean Diet Foundation and its International Scientific Committee have developed in 2011[3] a position of consensus, by presenting a new pyramid with which scientists hoped to contribute to a better adherence to this healthy nutritional model and the Mediterranean basin lifestyle.

The food pyramid shows the lifestyles to be adopted and the food consumption frequency to adhere faithfully to the Mediterranean nutritional model and maintain in this way a nutritional balance. As shown in the diagram, the base of the pyramid provides a set of skills, knowledge, rituals, symbols and traditions in the **field of agriculture, fisheries and animal husbandry**, and in particular valorises the sharing of food consumption. **Eating together** is indeed one of the fundamental elements to be privileged as well as an active lifestyle, adequate rest and food consumption, preferably according to seasonality. The pyramid is structured to show the frequency of consumption, with foods that should be consumed daily at the base and those that should be consumed weekly at the top.

Every day we should drink at least 8-10 glasses of water, which equals 1.5-2 litres, but if the nutrition is rich in fruit and vegetables the recommended amount drops to 1.2 litres per day, i.e. 6-8 glasses, to be consumed at meals and during the day.

Climbing up the pyramid one meets the vegetables, fruit and nuts, group foods that provide fibre, vitamins, minerals and **chemical compounds such as flavonoids, phytosterols, terpenes and phenols**, which offer protection against oxidative processes, thus reducing the incidence of cardiovascular diseases[4]. Here can also be found cereals, which provide low glycaemic index carbohydrates, as long as you choose wholemeal often.

The consumption of fibre-rich products has been associated with a lower risk of diabetes, especially type 2, coronary heart disease and cancer, while refined grains are linked to an increased risk of diabetes, obesity, coronary heart disease and other chronic diseases[5]. **Extra-virgin olive oil** should be the main condiment, as it is rich in **oleic acid and polyphenols**, which have atherogenic, antioxidant and anti-inflammatory effects[6].

Halfway up the pyramid are milk and its derivatives such as yogurt and cheese, which provide high quality protein and easily assimilated calcium. In addition, the lactic bacteria contained in yogurt can help improve gastrointestinal health and immune response, and induces changes in the gut microbiome that are associated with a reduction in the risk of colon cancer[7]. The upper part of the pyramid includes the group of "**protein**" foods. Foods like **meat, fish and eggs** are valuable sources of high quality, easily digestible protein and they are rich in many essential micronutrients such **as iron, zinc, vitamin A and vitamin B12**, which can help to ensure a balanced diet and prevent nutritional deficiencies[8]. In addition, especially in children, these foods contribute to growth, cognitive function and physical activity.

This model, in addition to the advantages associated with high consumption of a **high consumption of antioxidants and polyphenols**, is characterised by an excellent **ratio between omega-6 and omega-3 essential fatty acids**. Polyunsaturated omega-3 fats (PUFA), contained in fish (for example, eicosapentaenoic and docosahexaenoic acid), regulate the haemostatic factors and provide protection against cardiac arrhythmias, cancer and hypertension[9], and play an important role in the preservation of **cognitive functions**[10].
Another important aspect of the Mediterranean dietary model is the **reduced consumption of sodium** which, when taken in high quantities, may cause disorders related to high blood pressure; the high consumption of preserved salty foods has been linked by several studies with a higher risk of stomach cancer and coronary heart disease[11].

1.2 Mediterranean Diet and health

The Mediterranean Diet has been scientifically proven to improve health by increasing protection against the most common chronic diseases, such as hypertension, diabetes, obesity and cancer, reducing the onset of cardiovascular disease and preventing neurodegenerative diseases, such as Alzheimer's and Parkinson's[12]. By now all the most important and influential scientific societies consider it the ideal style of diet to preserve the status of health and to reduce the occurrence of the most important chronic diseases. According to the World Health Organization, the Mediterranean Diet is one of the most promising strategies to prevent major diseases and improve the quality of life[13].
Like traditional Asian diets, the Mediterranean Diet has also had a prominent place in the study that characterises the so-called "**Blue Zones**" regions, where lifestyle models, including traditional dietary approaches, have been associated with **longevity and vitality**[14].
For example, a study published in the British Medical Journal[15] found a link between the Mediterranean diet and a slowing of the ageing process in a sample of over 4,000 middle-aged women. Beyond these specific quotes, one can observe how the scientific world is extremely cohesive in observing the close correlation between the beneficial effects on health and the Mediterranean nutritional model.
Inflammation is now recognised as an important factor in the development of many chronic diseases, including cardiovascular diseases, cancer, type 2 diabetes, metabolic syndrome, Alzheimer's disease, and is also associated with obesity. The Mediterranean Diet has a preventive effect also in this case, as demonstrated by recent studies which concluded that a low adherence to the Mediterranean Diet is associated with higher levels of inflammatory markers[16], while adopting the Mediterranean style provides greater protection against oxidative stress and inflammation and platelet aggregation[17].
In general, following the Mediterranean Diet means having a significant reduction in mortality from cancer, as well as a

lower incidence of different types of cancer[18]: colorectal cancer, in particular, but also cancer of the aero digestive pathways (pharynx or oesophageal cancer) and prostate cancer[19].

In addition, specific food nutrients or micronutrients characteristic to the Mediterranean Diet can play a role in the prevention of breast cancer: the intake of foods containing phytosterols, vitamins C and E, beta-carotene and calcium can exert a protective action, including the reduction of cell proliferation[20]. Consumption of substances such as ascorbic acid, carotenoids and other antioxidant vitamins is inversely related to gastric cancer and neoplasms of the upper digestive tract and respiratory tract.

The PREDIMED[4] study, an international survey that assessed the effects of the Mediterranean Diet on primary prevention of cardiovascular disease, demonstrated for the first time in a randomised clinical trial that the Mediterranean dietary model protects against cardiovascular disease and confirmed that it reduced classic and emerging cardiovascular risk factors.

Previous research confirmed by recent studies has provided strong evidence of the benefits of the Mediterranean Diet on cardiovascular health[12], including the reduction of cardiovascular outcomes and risk factors including obesity, hypertension, metabolic syndrome, and dyslipidemia. There is also evidence that it is associated with a lower incidence of diabetes and better glycemic control in diabetic patients compared to control diets. In prospective studies, adherence to the Mediterranean Diet reduced mortality, especially cardiovascular mortality, and therefore increased longevity. It has also been associated with less age-related cognitive dysfunction and a lower incidence of neurodegenerative disorders, particularly Alzheimer's disease.

In recent years, some authors have indicated that adherence to the Mediterranean dietary model reduces the incidence of the onset of diabetes and the main protective compounds are vegetable fibres and fats such as olive oil; in particular, this protection is guaranteed by the consumption of extra virgin olive oil for cooking, seasoning, baking and frying food. It would seem that diets rich in monounsaturated fats, such as the Mediterranean Diet, improve insulin sensitivity[21].

1.3 Portions and frequencies of consumption

Globalisation, urbanisation, changes in lifestyle and in the food chain have led to a change in eating habits and the loss of traditional food cultures. These changes, together with greater availability and marketing of products of low nutritional value, highlight the need for a coherent, simple and practical food guide to allow the population to choose a healthy diet, to prevent diseases and to guide countries in the development of policies regarding food, health and agriculture.

The guidelines for healthy eating show how you can follow a healthy, balanced diet that meets your nutritional needs. The indications are often **summarised in graphical form as a pyramid (Spain), a plate (USA) or a wheel, and vary from country to country** depending on their cultural heritage. France has a scale with nine rules (9 Repères), Sweden has a Circle of Foods (Matcirkeln) accompanied by an ideal diet for men and women, while the United States has the dish (MyPlate); but in general the representations try to make the concept of a balanced diet easily understandable: we eat to satisfy the **need for essential nutrients such as carbohydrates, proteins, fats, vitamins, minerals, fibre, water.**

To facilitate the task of meeting the needs of essential nutrients every day, the food has been divided into groups, based on the substances they contain and give to the organism. A diet complete from a nutritional point of view, is the result of a choice of foods that, with quantities adapted to the personal needs of nutrients and energy, comes from all the food groups. Although they are coherent with the needs of the local population, many nutritional guidelines have common rules. The majority of them promotes variety and a high consumption of plant foods as well as a reduced intake of saturated fats, salt and sugar.
The guidelines in fact give indications also on the dimensions of the portions and on their consumption frequency, but how many adhere to such indications? It is now clear that the size of the portions of food in general and those packaged in particular have increased over the last 30 years[22], so much so that it is thought to be one of the factors contributing to the rise in obesity.
In 2014, the SINU (Italian Society of Human Nutrition) published the new LARN[23] (Levels of Reference Assumption for the Italian population) which contains, among other things, suggestions relating to the portions of each food.
These portions and frequencies of consumption were also included in the **CREA Guidelines for Healthy Eating in 2018**.

PORTIONS OF REFERENCE FOR PROTEIN FOODS

GROUPS OF FOOD	FOODS	STANDARD PORTIONS (g)	PRACTICAL UNITS OF MEASUREMENT
MEAT FISH EGGS	"red" meat fresh/frozen (bovine, ovine, pork, equine)	100	1 slice, 1 hamburger, 4-5 pieces of stew, 1 sausage
	"white" meat fresh/frozen (chicken, turkey, other poultry, rabbit)	100	1 slice of chicken or turkey breast, 1 small chicken leg
	cured meats	50	3-4 medium slices of ham, 5-6 medium slices of salami or bresaola, 2 medium slices of mortadella
	fish, shellfish, fresh/frozen shellfish	150	small fish, 1 medium fillet, 3 prawns, 20 shrimps, 25 mussels, fish, molluscs, crustaceans
	fish, molluscs, preserved crustaceans	50	1 small tin of tuna in oil or brine, 4-5 thin slices of smoked salmon, ½ fillet of cod
	eggs	50	1 egg
LEGUMES	fresh or canned legumes	150	half a plate, a small box
	dry legumes	50	3-4 tablespoons
DAIRY PRODUCTS	milk	125	1 small glass, 1/2 medium cup
	yogurt	125	1 jar
	fresh cheese	100	1 small mozzarella cheese
	aged cheese	50	-

Source: SINU (Società Italiana di Nutrizione Umana - Italian Society of Human Nutrition), 2014; CREA - Guidelines for healthy eating. 2018 Revision. ISBN 9788833850375.

MEAT IN THE MEDITERRANEAN DIET

The Mediterranean Diet has always included the consumption of animal proteins. In fact, in the Mediterranean Dietary pattern, **meat, fish, eggs and legumes** are considered part of the group of foods that provide proteins, as well as naturally the milk and derivative group. This model invites you to choose a variety of protein foods to improve your intake of valuable nutrients for health. The suggestion is to limit their consumption according to **portions and frequencies that depend on age, sex and levels of physical activity.** Especially for meat, the fundamental suggestions are to prefer lean cuts and to prepare seasoning using only extra virgin olive oil, limiting sodium intake.

2 THE NUTRIENTS **OF MEAT**

Meat and meat products have been among the most important food products for human nutrition for centuries. The type and quantity of meat consumed have been conditioned in the past by various factors (religion, social status and supply), but there is no doubt that meat consumption has played a key role in the development of human civilisation. For example, **the development of the brain and its functionalities was only possible thanks to an omnivorous diet**, which guaranteed a lot of energy and specific nutrients[24] typical of meat and fish.

The human digestive system is typically omnivorous, as it has developed functionalities and enzymes useful for assimilation of animal and vegetable food. Precisely the development of the brain and the sociality connected to hunting-related practices have contributed to the evolution of intelligence, to the development of language and to the skills of planning, cooperation and socialisation.

Homo sapiens is therefore the perfect example of an **omnivorous species**. It was only later that environmental constraints, such as the need to support a high population density, accompanied by cultural adaptations (food restrictions and taboos, usually present in religious commandments), have transformed meat into a relatively rare food for most people in traditional agricultural societies.

A return to higher meat consumption worldwide began in Europe and North America with the acceleration of industrialisation and urbanisation during the second half of the nineteenth century; during the last 100-150 years, in fact, the fastest form of evolution has been recorded compared to the rest of history: **in a short time, people have reached a greater height and greater longevity.**

Not only did health care and medical knowledge improve, but nutrition also played a key role. In the second half of the nineteenth century there was still a widespread diet problem in Italy. In fact, one could observe a substantial differentiation in weight and height, depending on the economic and therefore nutritional availability (in particular the availability of meat and other noble foods): a poor man at 17 had the height of a rich man at 14; at 19 the poor man had the stature of a rich man aged 15 and the difference in height between a poor and rich 19-year-old was on average 12 cm[25].

In general, a balanced diet that includes both animal and plant foods promotes harmonious growth, **but removing any of the essential nutrients will cause the body to stop growth: iron deficiency alone** during the first years of life and development can lead to reduced growth and a **reduction in the IQ of a boy in relation to his potential.**

THE ROLE OF MEAT IN THE MEDITERRANEAN DIET

A SOCIAL HISTORY OF MEAT IN ITALY

By Silvana Chiesa

The presence of meat in human nutrition has been demonstrated from the fossil evidence found in all the archaeological sites, from the Upper Palaeolithic to the Neolithic, showing that even hominids were omnivorous, that is, they alternated their diet of foods of vegetable origin with the consumption of meat. The concomitant presence of findings of broken animal bones and sharp instruments to cut the carcasses, however, does not say much about the methods of procuring meat. It seems indeed that Homo habilis as well as Homo erectus consumed both those deriving from carcasses of already dead animals (killed by other predators) as well as those obtained by hunting in groups. We know nothing about the quality and quantity of plant foods in relation to those periods, because unfortunately there are no "remains" to be subjected to chemical/physical analysis.

*The arrival of Homo sapiens and his settling permanently in temperate areas, seems to have initially resulted in an increase in meat consumption to compensate for the periodic shortage of plant foods in adverse seasons: autumn and winter[26]. Later, with the constant use of fire to cook food and the gradual phasing out of hunting and gathering in favour of agricultural practices, the foundations of what has been called the "**birth of agriculture and civilisation were created**" and, from the point of view of nutrition, the fundamentals of what we call today **"Mediterranean Diet".***

*By choosing to practice agriculture to produce their own food, not only humans gradually changed their **lifestyle, which from nomadic became stable,** but also profoundly changed the natural environment in which they decided to settle. To create areas to cultivate they practiced systematic deforestation, control and deviation of water courses, levelling and fencing of soil, artificial seeding, harvesting and conservation of seeds gathered and finally the transformation of seeds into food. All this work found its maximum expression in the production and consumption of a new food, that is BREAD, which does not exist in nature and which symbolised the abandonment of mankind's "wild" state. If bread as a result became a symbol of civilised men, who no longer consumed what nature gave them, but what they had invented themselves, even meat could no longer be derived from hunting alone. Meat became symbolically the product of "choice", from the domestication and selection of some animal species. The breeding of sheep, cattle and pigs was itself a symbol of civilisation and detachment from a "wild" life, so much so that **humans decided to build fences and shelters for the animals, to defend them from wild predators, and ensure that they always had food and water available, in a word they became breeders.***

*The "proximity" between men and animals (**synanthropy**) posed, perhaps for the first time, the problem of "guilt" inevitably resulting from the killing/slaughtering of animals, in particular towards the cattle considered "Ox plough" therefore a precious collaborator for mankind. Ritual sacrifices dedicated to the gods have been interpreted as a way of justifying the violent act against a* *synanthropic animal, and the subsequent division and consumption of meat as a moment of sharing and social recognition[27]. In fact, men were differentiated in "participants" and "excluded" from the sacrificial banquet, and subsequently the distribution of the meat distinguished those who were entitled to the first and more abundant portions (princeps) from those who divided the rest (populus)[28]. Naturally from such a significant context a movement of rejection of sacrifice and the consequential consumption of meat is born and identified. Among the first that we can identify are the Orphic and Pythagorean movements which, in turn, applied strategies of cohesion and identity, refusing to participate in sacrificial rites.*

In the Roman world, from the Republican to the late Imperial age, there is a progressive increase in the consumption of meat, especially in the cities and among the upper classes. This can be partly justified by urban procurement policies and in part by the progressive disengagement from slaughter of religious rituality, to be incorporated into a series of rules that today we would define "hygiene and protection of public health". Even the progressive affirmation of the Christian religion freed the consumption of meat from sacrificial rites, but preserved (and sometimes strengthened) the use of celebrating the "major" religious festivals with meat banquets. The so-called "Mediterranean Diet" became questioned in its principles of identity (bread as the main food, then porridges of cereals, vegetables, dairy products and little meat) by the establishment in Italy of the Roman-Barbaric Kingdoms (from the fifth century AD) that brought forward the cultural, economic and food values of the populations from northern Europe. These, while practicing agriculture (cultivating barley to produce beer), are represented as meat eaters, and in particular pork and/or hunted game.

The barbaric culture, which will be assimilated and elaborated in the ***Italian medieval culture, considered meat as the most important source of strength and energy for mankind and in this logic it became the prerogative of great warriors, leaders and powerful people.*** *Even the conversion of the Barbarians to the Christian religion, in a certain sense strengthened the symbolic value of meat because penitence obliged the respect of the days of abstinence, in which the consumption of meat was forbidden (Lent, Wednesday and Friday of each week), which became fasting and assumed great importance and significance only if inserted in a strongly carnivorous culture.*

The same consideration can be made regarding the food choices of the origins of monasticism (5^{th}-6^{th} century) which considered abstention from consumption of meat an obligation for religious men and women who, in this way, marked the difference in lifestyle between themselves and those who lived "in the world".

Even ***medieval medical thought*** *believed that the consumption of meat was necessary to restore the "****health of the body****" and was shared and widespread knowledge found in dietetic rules such as the Regimen sanitatis, but also in other monastic rules:*

«I dare neither forbid nor allow you to eat meat because of your weakness... Those who have sufficient strength are abstained from the meat... Those who need physical force make use of meat; for example, those who work in mines, who fight in war, who build tall buildings or those who struggle in different jobs. / The use of meat helps recreate the forces» (Regola di Leandro, 580 A.D.).

«You never eat meat. Do not distribute chickens or any other kind of birds to the community / they are to be obtained only for the sick and those of delicate health» (Regola di Aureliano per le vergini, 6^{th} Century).

The centuries therefore from the ninth to the twelfth are those of the greatest pres-

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tige for meat consumption, and represent also a period in which almost the entire population (without class distinction) is able to access this resource thanks to a defined ***agro-forestry-pastoral*** *economy that supported, as well as agriculture (almost entirely absorbed by the production of cereals and legumes) breeding and the exploitation of uncultivated spaces where hunting was practiced both of large prey (noble hunts) and of small mammals (peasants and villagers). The fact that almost everyone could eat meat, however, does not mean that this was the same for everyone: different "quality and quantities" for the various social classes indicate, referring to the studies of* ***J.L. Flandrin***[29]*, how the* ***statute of meat****, has been defined, meaning by this term the set of* ***social, economic, political and cultural values that the consumption of meat represents.*** *If in fact from the ninth to the twelfth century the warriors, nobles and rich people consumed meat of large mammals (cattle, bears, deer, fallow deer, wild boar) and in large quantities, or at least in banquets a great abundance of meat was shown, the lower classes ate chickens, geese, rabbits, hares and especially pork, which provided meat reserves with* ***cured meats and sausages also for the winter.***

Even the religious, and in particular the upper hierarchies of the monasteries and the major dioceses, while scrupulously respecting fasting in the days of abstinence, show intolerance towards the prohibition of consuming meat and a fine example is what Pietro Abelardo wrote in the twelfth century:

«If the popes themselves, the guides of the Holy Church, the clergymen communities can eat meat without committing sin, because they are not bound by any vote, who could blame us for being condescending with women, especially if they endure a greater restraint than the rest?... We, therefore, considering both the possibilities of men and their nature, do not forbid any food but only excess. We wanted to adopt a measure for the use of meat: do not eat more than once per day, do not offer different portions to the same person, nor are other dishes added to it, it is not allowed to eat it more than three times a week, that is on Sundays, Tuesdays and Thursdays, even if they interpose with feast days» (Regola di Abelardo, 1140 A.D.).

From the 13th century onwards, a series of political and economic changes began, where the nobles, owners of the lands and forests, forbade access to the woods to villagers and peasants, who then could no longer obtain meat freely. This fact led to the radicalisation of two opposing food models, namely that of the countryside, which consumed very little meat, and that of the city in which every food (including meat) was always available and the only limit consisted of economic wealth. Even gastronomy was organised on the same basis developing an urban and "bourgeois" model that focused on the cooking of meat (especially beef) as an emblem of wealth, refinement and sophisticated elegance, while rural gastronomy provided very few meat dishes, mainly pork, chicken and rabbit, and above all was characterised by an attention to the use of all the parts of the animals (muscles and viscera) and an abundance of recipes of "second processing" (from ***meatballs and meatloaf*** *to "redone" meat) just to* ***avoid wasting food so rare and highly desired.***

The chronic lack of meat in rural areas in the diet of Italian populations became a constant that lasted until around the beginning of the twentieth century, and the information received unfortunately disregards any type of qualitative/quantitative surveys, relying mostly on narratives, or dramatic reports of doctors and nurses.

With the birth of the Italian nation (1861) and then with the establishment of the Institute of Statistics (ISTAT) we finally have also available numerical data which, if on the one hand in an irrefuta-

ble way confirms the paucity of meat consumption (about 11 kg/year per person),on the other does not differentiate the consumption of citizens in towns from those in rural areas[30].

That meat was anyway one of the most desired foods can be seen above all from the testimonies of Italians who, because of hunger and misery, found themselves facing a migratory adventure since the Eighties of the nineteenth century, which involving Piedmontese, Venetian, Calabrian, Sicilian, etc. The destinations were mostly Argentina, United States, Brazil and the common news was almost always the amazement about the food consumption in the countries of destination and above all for the abundance of meat and the possibility of consuming it even every day (!).

Lastly, even the Calabrian labourers that arrived in the United States were amazed by the "equality" of eating habits, and this equality consisted precisely in the fact that everyone could indiscriminately have access to the consumption of meat daily. In 1890, the results of the Inquiry into the hygienic and sanitary conditions of the workers of the earth were published in Italy by Mario Panizza (a summary of the more famous Jacini-Bertani Inquiry) which stigmatised once again the constant lack of food for rural populations with a strong emphasis on the lack of an adequate consumption of meat that was limited to religious festivals, weddings, baptisms and little else. This situation lasted until the first third of the twentieth century; in fact, what Ancel Keys saw at the end of the Second World War in central and southern Italy was a chronic habit of not consuming meat, but what he did not see was the fact that this was not a "life choice", but rather the result of centuries of "chronic impossibility of accessing meat consumption".

The period of the ***Sixties*** *of the twentieth century* ***in Italy*** *were years of great economic development and finally hunger was defeated as well as areas of undernourishment. The consumer food model spread and* ***meat, so desired for centuries, finally became available to everyone.***

Eating meat was a kind of declaration of freedom from misery and poverty. Doctors and paediatricians continued to suggest the consumption of meat as a factor to improve the growth of children and young people. The daily meat ration of military conscripts was 200 g (even today this is the daily ration as by OG), canteen meals always provided a meat dish, and throughout the next decade what was the "second course" of Italian gastronomic tradition, became almost exclusively meat (steak, slice, roast, boiled, cutlet, escalope) making them forget, for a certain period, the gastronomic variety that the traditional and poor alimentation had developed over the centuries.

From the Mid-Eighties of the twentieth century the attitude against the consumption of meat began to change: forgotten the initial enthusiasm, the first signs of damage due to excessive consumption of meat and animal fats were also discovered in Italy and inevitably triggered the same and opposite reaction for which the consumption of meat was considered cause of the main health problems.

Partly supported by the large producers of pasta, a new model of Mediterranean Diet was re-elaborated which, taking as an example the gastronomic culture of the Mediterranean countries, proposed as a food base, bread, pasta and the use of the rich heritage of vegetables, fruit and cheeses that characterises the Mediterranean basin, bringing the consumption of meat to be a necessary complement of a balanced diet.

Since the beginning of the 21st century, meat consumption is therefore recommended in limited quantities *during the week, but it is fully present in the Mediterranean Diet as it has always been for millennia.*

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THE CONSUMPTION OF ANIMAL PROTEINS AND THE CO-EVOLUTION OF MAN AND HIS DIET

Paleoanthropologists all agree that hominins, a term that recently substituted that of hominids in order to encompass all the extinct species related to Homo, (for example the parantropus) evolved from species that were nurtured almost exclusively with unripe leaves and berries. Our ancestors, however, did not have only one food pattern, but were non-specialised frugivorous: the dental coating, in fact, although changing in the various evolutionary stages, suggests that our ancestors never turned into strict carnivores, but kept always a certain degree of vegetarianism, therefore remaining always omnivorous[31].

This versatility in the diet resulted in the ability of hominins to inhabit a wide variety of different food niches, even though they have a poorly developed digestive system, small teeth and weak jaws.

The comparison between the teeth of H. sapiens and P. boisei shows that the latter had to spend 6 to 8 hours a day chewing fibre-rich vegetable foods[32] (fig. 1). Likewise, the cranial ridge of P. boiesi was particularly developed because the powerful maxillary muscles were attached to it, a feature that has completely disappeared in modern man (fig 2).

Fig.1 Comparison between the teeth of Homo sapiens and Parantropus boisei.

Fig.2 The cranial ridge of P. boisei, disappeared in modern man, indicate the presence in this hominin species of powerful masticatory muscles for the crushing of vegetables.

Modern man preserves the memory of this prevalence of vegetables in the diet with a tract of the intestine (the colon) that is responsible for the fermentation of fibre, which cannot be digested by gastric juices, of which vegetables are rich. But if today we try to nourish ourselves with the foods selected in nature by our distant cousin, the chimpanzee, we would discover that the time dedicated to chewing is enormous (6-8 hours), that our teeth and muscles are inadequate and that fruits are too immature to please us[33]. Among other things, as anthropologists know well, the chimpanzees themselves, are passionate hunters, spending about 10% of their time hunting small *mammals, mostly baboons, other species of monkeys and porcupines*[34]*.*

The introduction of food cooking, around 800,000 years ago, was certainly a fundamental turning point to make a large number of foods safe and more digestible including the meat of large animals, which men began to hunt by organising themselves into communities and therefore starting a fundamental phase of social evolution[31]*.*

*Why has mankind during his evolution moved his own preferences from a substantially vegetarian diet to a more diversified one that foresees a substantial contribution from foods of animal origin? One of the most reliable hypotheses is the so-called "**hungry brain**" put forward by Robert Martin in 1996*[35]*. Man has a brain mass, if compared to body weight, about twice that of other mammals. This means a large constantly hungry brain that **consumes about 20% of the energy spent daily by an adult** (up to 50% in a new-born) and therefore needs to feed on foods that are highly digestible and of higher biological value than those of leaves and unripe fruits. Because the development of the intestinal mass is inversely proportional to the quality of the foods consumed, **the reduction of the size of the intestines in favour of the development of the brain mass was only possible thanks to an overall improvement in the quality of the diet due to the introduction of foods with a high concentration of nutrients such as meat***[31]*. Thus, despite not having the dentition of a carnivore, mankind, thanks to the discovery of fire, was in the condition to consume large animals and, therefore, to organize themselves to hunt, giving life to an evolutionary advantage of the groups better organised and capable also of transmitting this prerogative orally.*

*According to paleoanthropologists, the Neolithic man assumed **more than 35% of total daily calories from meat and this**, translated in quantity, means more than **800 g per day, which is about 4 times the amount consumed on average by the North American population in our own time***[36]*. At the same time, cholesterol intake was twice that of the current one, but the total amount of fat was about half. The meat of the animals hunted by the Neolithic man, in fact, was characterised by a low fat content compared to body mass (less than 5%) and a very rich fat composition in polyunsaturated acid fats*[37]*.*

*These selective pressures, environmental as well as later cultural, have made sure that the genotype of man, selected over a period of at least 2-3 million years, is that of the "saver", that is to say **an organism accustomed to eating a protein based diet, unsaturated fats, vegetable fibres, fructose and a large quantity of secondary metabolites of plants.** Until the Neolithic, only occasionally it happened that men had large quantities of carbohydrates, which are able to trigger the mechanism of insulin response to promote the deposition of lipid reserves. This mechanism has allowed the activation of another great selective advantage that derives from the ability to accumulate fat in periods of excess energy and then mobilise it during periods of shortages. It is in fact known that the mobilisation of lipids in the phases of negative energy balance permits the maintenance of cognitive work even in conditions of food shortages, thanks to the capacity of the brain to efficiently use the ketone bodies formed as a result of the oxidation of mobilised lipids for energetic purposes. **Our evolutionary adaptation to meat consumption** has had as confirmation, in the **cerebral and physical development** and the analysis of the archaeological finds has shown that the adult physique in the Neolithic era was comparable to that of current professional athletes*[38]*, Furthermore, the adaptation of the human genotype to a diet rich in meat has affected* *the longevity of the human species, which has increased in an extraordinary way compared to that of the chimpanzees: the genes involved, in fact, are those of resistance to inflammation and parasites, but also coding for longevity[39].*

The result was that the current Neolithic populations (with cultures at pre-agricultural stages) are hunters and include in their diet a quota >50% of proteins of animal origin. In vast areas of the planet the only agricultural practice is livestock farming. Populations such as the Inuit, the Masai, the Lapps, the Andes Indio's and the Himalayan natives survive a totally hostile environment thanks to the interface with animals, usually ruminant herbivores, who explore feeding niches absolutely useless to humans. These peoples derive more than 90% of their daily energy requirements from animal products, without showing the slightest sign of the diseases that afflict us Westerners. It was the forced "modernisation" of their diet, vice versa, which led to severe metabolic disorders and in extreme cases to the total disruption and the loss of traditional cultures.

Agriculture has only recently intervened in human history: in the face of an evolution that began about 4 million years ago, ***the processes of domestication of plants and animals began only 10,000 years ago. Over 70% of daily ingested calories by modern humans derive from food*** *(especially simple sugars, starches, milk and alcohol)* ***that simply did not exist for the Neolithic man****[37]. To this is added that about 50% of the total calories of our diet are made by only three types of cereals (rice, wheat and maize)[31].*

Furthermore, modern man gets 90% of animal origin food from only 14 of the over 40 species of bred animals and of this 90% the majority is taken from only 5 species (cattle, sheep, goats, pigs and poultry)[40]. In fact, agriculture over time has greatly reduced the nutritional multiplicity to which man had access in his pre-agricultural evolutionary path. Of the approximately 300,000 generations who have made us what we are, only 400 have known agriculture, too few for an overall adaptation of our genome to this artificial food niche[41].

2.1 The fundamental nutrients of meat and cured meats

The positive nutritional value of meat and cured meats can be summarised in two fundamental aspects: on the one hand, the presence of **proteins (complete as a composition in essential amino acids)**, on the other hand the high concentration of micro-nutrients always considered essential for human growth and development. Many of the **micronutrients** supplied by meat are involved in processes of **regulation of energy metabolism**. A further very important feature is the simultaneous presence of many of these micronutrients that can be of great importance: **vitamin A** (present in large quantity in offal) and **riboflavin** are, for example, both necessary for **iron mobilisation and haemoglobin synthesis** to the point that the sole administration of iron cannot successfully treat anaemia, if these others nutrients are lacking. Protein-energy malnutrition, **sideropenic anaemia** and **vitamin A deficiency** can be avoided if sufficient quantities of meat are consumed.

Many of the nutrients of meat are obviously also found in foods of **plant origin**, although in some cases plant nutrients have **lower bioavailability**, or are less readily absorbed by the body and used by cells. When comparing the strengths and weaknesses of **vegetarian diets and meat consumption**[24], it is evident that only the **presence of both in the nutrition** of an individual can effectively contribute to a **healthy and well balanced diet**. To obtain, for example,

DIET COMPARISON BASED ON MEAT AND VEGETABLES

VEGAN AND VEGETARIAN DIETS

ADVANTAGES

- *High fibre content*
- *Generally lower energy content*
- *Ingestion of superior antioxidants*

DISADVANTAGES

- *Less bioavailability of iron*
- *Risk of vitamin B12 and zinc deficiency*
- *Risk of lack of EPA + DHA sources*
- *Proteins of lower biological value*

MEAT CONSUMPTION

ADVANTAGES

- *High nutritional density*
- *Proteins of high biological value*
- *Best source of iron, zinc and complex vitamin B groups, in particular B12*

ADVANTAGES

- *High fat/saturated fat content in some cuts*
- *Sodium content (cured meats)*

Source: *Pereira & Vicente, 2013*[24].

the adequate amount of essential amino acids from an exclusively plant diet, you risk introducing at the same time an excessive amount of other nutrients compared to the needs of your body.
The combination of cereals and legumes is often referred to as an appropriate substitute for meat because of its protein intake, as the deficiencies of essential amino acids in cereals are covered by those of legumes and vice versa.

But to get the same protein quality of amino acids contained in 70 grams of meat, a small slice of less than 80 kcal, you would have to eat 2 portions of pasta and beans, with a contribution of over 700 kcal.

70 g of lean meat
80 kcal

2 portions of pasta and beans
700 kcal

THE NUTRITIONAL COMPOSITION OF MEAT

	KCAL	PROTEIN (g)	FAT (g)	CHOLESTEROL (mg)	SAFA (g)	MUFA (g)	PUFA (g)	VITAMIN B12 (µg)	IRON (mg)	ZINC (mg)
Beef front cuts	145	20.5	7	66	2.20	2.27	1.55	2.00	1.30	4.47
Beef rear cuts	117	21.5	3.4	60	1.14	1.12	0.68	2.00	1.60	3.30
Veal lean meat	92	20.7	1	70	0.42	0.48	0.04	2.00	1.20	2.80
Pork, fat meat, without fat	268	17.2	22.1	88	7.81	8.64	3.44	1.00	1.40	1.80
Pork, semi-fat meat, without fat	141	19.9	6.8	61	2.17	2.31	1.77	1.00	1.70	1.80
National raw ham*	235	27.8	13.7	75	4.84	6.35	1.89	0.38	0.80	2.10
Baked ham*	138	15.7	7.6	49	3.20	3.52	0.50	0.09	0.50	1.10
Whole chicken with skin	171	19	10.6	93	3.27	4.12	2.29	TR	0.60	1.10
Whole chicken without skin	110	19.4	3.6	75	1.23	1.08	0.81	1.00	0.70	1.30
Whole turkey with skin	135	18.2	6.9	195	2.22	1.66	2.96	2.00	0.90	2.80
Whole turkey without skin	109	21.9	2.4	63	0.90	0.62	0.60	2.00	1.00	2.70

*The nutritional composition of the meat and its micronutrients varies according to the animal species and the different types of cut. Data from the Bank of Food Composition Data for Epidemiological Studies (BDA) or *INRAN food composition tables containing 100 g of food.*

Obviously not all types and cuts of meat have the same characteristics. Muscle portions are richer in essential amino acids (with greater biological value and more digestible) than connective tissues; the amount of fat (especially saturated) varies from species to species and so on.

Proteins: the bricks of our organism

Proteins are essential nutrients, as they provide the amino acids used by our body to synthesize the proteins necessary for the different vital roles:

- **structural** (skeleton, skin, tissues and supporting tissues, cells);
- **protective** (barriers, immune system, anti-inflammatory);
- **transport and communication** (plasma proteins, hormones, membrane receptors);
- **enzymatic** (digestion, metabolism, homeostasis, synthesis);
- **energy** (energy source).

The **amino acids necessary** for the synthesis of proteins useful to humans are 20, but they are not all the same: **9** of these **are considered essential**, because the body is **not able to produce them and must necessarily be ingested with food**. Furthermore, it is essential to remember that every protein synthesized by the body has its own specific amino acid composition and when it needs to be synthesized it needs the presence of all the amino acids that compose it: if even just one of these is deficient, protein synthesis is limited. In reality there is no specific food requirements for proteins, but these must be taken in such a way as to provide in sufficient quantity all the amino acids necessary for synthesis by the body. **In children semi-essential amino acids** are also considered **cysteine, taurine, tyrosine and arginine**, since synthesis mechanisms are not yet fully developed.

On the basis of the amino acid characterisation of proteins it is therefore possible to identify which foods have **proteins of high biological value**, and are therefore capable of supplying all the essential amino acids. It is said that a food has proteins of high biological value when it provides **all the amino acids mentioned that we need**, even those that **we are unable to produce**, and in the right quantities. And not all achieve this! **Only meat, fish, eggs and milk have proteins of high biological value.**
Among the essential amino acids, **methionine** plays a fundamental role in the growth of the individual.
The proteins of the vegetables are generally poor in sulphur amino acids such as methionine, on average 0.6g/100g of protein, while red meat, poultry meat and fish contain between 1 and 1.26g of sulphur amino acids/100g of protein. More generally, **vegetable proteins** are consid-

ESSENTIAL AMINO ACIDS
NON-ESSENTIAL AMINO ACIDS

ESSENTIAL AMINO ACIDS	NON-ESSENTIAL AMINO ACIDS
Phenylalanine	Aspartic acid
Isoleucine	Glutamic acid
Histidine	Alanine
Leucine	Arginine
Lysine	Asparagine
Methionine	Cysteine
Threonine	Glycine
Tryptophan	Proline
Valine	Serine
	Tyrosine

Essential amino acids must necessarily be assumed through food, because the human organism is not able to produce them.

ered of **lower quality** because they are **unbalanced in the ratio between cysteine and methionine** necessary for growth, which should be in favour of methionine. Considering the total of amino acids containing sulphur, red meat, poultry meat and fish have 30-40% of cysteine and 60-70% of methionine, while soybeans, beans, peas and lentils have 60% **cysteine** and 40% **methionine**[42].
Another method of protein evaluation recently developed by the scientific world is the DIAAS (Digestible Indispensable Amino Acid Score), which defines with a numerical index the protein quality of some foods: the higher the value, the better is the protein quality.
If it is therefore clear that the nutritional value of animal proteins is high, it is also interesting to evaluate the protein content respect to the portions suggested by the new LARN[23] and compared to caloric intake. **Fish and meat have the highest ca-**

PROTEIN VALUE INDEX OF FOODS

FOOD OR PROTEIN ISOLATES	VALUE OF DIAAS
Whole milk	139
Beef	131
Whey protein isolate	125
Soy isolate	102
Chickpeas	66
Peas	64
Rice	64
Corn	52
Barley	51
Wheat	43

Source: Caballero B., Finglas P.M., Toldrà F. (2015), Encyclopedia of Food and Health, Academic Press.

COMPOSITION OF AMINO ACIDS OF SOME FOODS

grams per 100g of Protein

AMINO ACIDS (g PER 100g OF PROTEINS)	RAW HAM	BEEF TENDERLOIN	SEA BREAM BRED (FILLET)	WHOLE COW'S MILK	WHOLE EGG	FRESH BORLOTTI BEANS	PASTA
Phenylalanine	4.02	3.84	7.66	5.03	5.34	5.89	4.97
Isoleucine	5.18	4.13	4.33	5.49	5.30	5.45	4.17
Histidine	3.61	3.69	2.37	2.66	2.40	2.97	2.07
Leucine	8.31	8.02	7.58	10.14	8.40	8.68	7.65
Lysine	8.62	8.62	9.89	7.77	7.10	7.00	2.01
Methionine	2.51	2.77	3.88	2.31	3.53	1.18	1.68
Threonine	4.53	3.93	4.37	4.69	5.03	4.20	2.88
Tryptophan	1.05	1.04	1.29	1.43	1.59	1.11	0.96
Valine	5.27	4.49	4.82	6.66	6.63	6.04	4.99

Source: Food Composition Tables - INRAN, Rev. 2000.

loric protein efficiency (Proteins/Kcal*100), meaning that per portion they have a higher quota of excellent quality proteins, but with a reduced caloric intake: a **notable advantage in terms of overweight and obesity prevention**.
Proteins of plant origin are often associated with a reduced content of saturated fats and are therefore recommended as an alternative to proteins of animal origin. But **if we wanted to cover our protein needs only with foods of plant origin**, we would have to take **3 to 5 times more calories than the calories obtained with foods of animal origin**, in particular from lean cuts of meat or fish. The protein requirements for an individual have however been defined by the experts (LARN) in the daily amount of 0.9 g per body weight (e.g. a 70 kg adult man needs a protein intake of 63 g per day). But it is also important to remember that 100 g of meat are sufficient, which provide an average of 22-25 g of high biological value proteins, to cover more than 1/3 of the daily requirement.

PROTEIN, ENERGY AND PROTEIN-ENERGY EFFICIENCY PER PORTION OF SOME FOODS

FOOD	PORTIONS (g)	PROTEINS (g)	KCAL	ENERGY PROTEIN EFFICIENCY
Fish, molluscs, crustaceans (bream)	150	29.70	141	21
Meat (bovine fillet)	100	20.70	107	19
Preserved meat (raw ham)	50	13.90	117	12
Eggs	50	6.20	64	10
Seasoned cheese (parmesan)	50	16.75	193	9
Fresh or canned vegetables (borlotti beans)	150	15.30	199	8
Fresh cheese (mozzarella)	100	18.70	253	7
Dried legumes (borlotti beans)	50	10.10	145	7
Yogurt	125	4.75	82	6
Milk	125*	4.12	80	5
Pasta	80	8.72	282	3
Corn	80	7.36	282	3
Bread	50	4.30	144	3
Rice	80	5.36	265	2

** The milk portion is expressed in ml.*
*Source: data processing Food Composition Tables - Update 2000 - INRAN *Rev. 2013.*

Fats: an important source of energy, but without exaggerating

According to the main nutritional indications, fats should cover **between 25 and 35%** of the total energy consumed by an individual because, if ingested in appropriate quantities, they play a number of important roles: they supply **essential fatty acids (such as linoleic and alpha-linoleic acid) and fat-soluble vitamins** (A, D, E and K); they represent one of the main sources of energy; **promote a sense of satiety** due to the effects on the slowing of gastric emptying and reduce, for the same reason, the bioavailability of carbohydrates (and, therefore, the glycaemic response); finally, they improve the taste, smell, and consistency of foods. But all fats are high in calories. If you take more calories than necessary, you gain weight. The World Health Organization estimates that excess weight is responsible for 21% of cases of ischemic heart disease, 23% of ischemic stroke, 58% of type 2 diabetes and 39% of cases of hypertension. Obesity also increases the risk of some types of cancer, as well the risk of non-fatal diseases, such as joint problems and infertility[41].

Saturated and unsaturated fats, stearic acid, no effect on total cholesterol and LDL

Saturated and unsaturated fats are differentiated by the composition of their molecule: a saturated fat has single chemical bonds between the atoms that compose it, while unsaturated fat has at least one double bond. It is this double bond that makes it unsaturated, not complete, because there is a possibility to add hydrogen to the double bond and make it saturated, i.e. devoid of space for new additions. **Liquid fats** are composed mostly of **unsaturated fats, such as olive oil** which is monounsaturated (i.e., has only one double bond) and **solid** ones (**margarine**, **butter** or **palm oil**, for example) **are mostly saturated**. Fats are found both in plant-based foods and in foods of animal origin. Apart from some exceptions, such as tropical oils (palm and coconut), vegetable fats are mostly unsaturated, while those of animal origin are composed of about half of saturated fatty acids.

For several decades, dietary guidelines have recommended reducing the consumption of saturated fats, believed to be among those responsible for certain cardiovascular diseases, thus leading to significant reduction in the consumption of animal products, especially meat. It should be remembered that **saturated fats are not all the same**, because some contribute more than others to **cardiovascular risks**, in addition to **considering the increasing evidence of the role of carbohydrates for this pathology.** Recently, the PURE[43] study, a study involving more than 135,000 people on 5 continents, concludes that a high carbohydrate intake is associated with increased mortality.

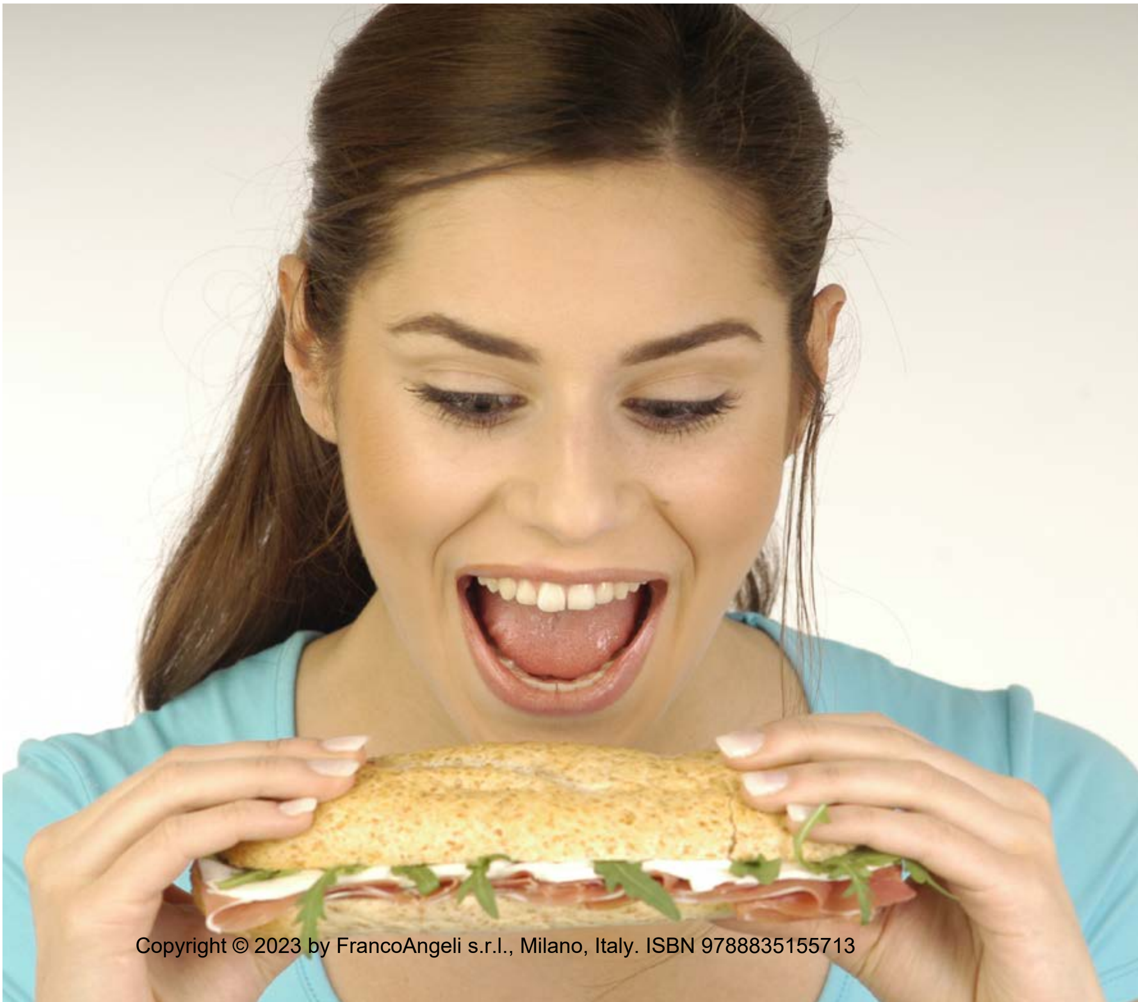
In contrast, a **higher intake of saturated and unsaturated fats has been reported as associated with a lower total mortality**. The authors observe that saturated fats do not necessarily need to be limited. The healthiest diet should include no **more than 50-55%** of the calories derived from carbohydrates and **no more than 35% from fat**, including both **saturated and unsaturated.**

In practice, according to the study, there is no evidence that taking less than 10% of energy from saturated fats is beneficial, but going below 7% can be dangerous. The right amount of **saturated fats should be around 10 to 13%.**

In addition, the largest constituent of saturated meat fats, **stearic acid, has been**

shown to have a neutral effect on cholesterol and LDL totals (low-density lipoprotein).

Growing attention to the quantity and quality of fats contained in meat has led producers and **farmers to study productive practices** (cutting techniques) and **farming** (animal diets), in order to **produce generally leaner meats** and also to favour an ever more balanced fat composition. Cooking can have a great influence on the meat fat content, as well as in the composition of fatty acids. Some authors have shown significant reductions in the amount of fat in different cuts of meat that are grilled or pan-fried without added fats. In particular, as regards to the **fatty acid** composition, there has been an increase in the **polyunsaturated/saturated ratio**, probably because polyunsaturated fatty acids are part of the cell membrane and therefore tend to remain in the meat fibres.



FAT CONTENT OF SOME OF THE MAIN FOODS

FOOD	FATS (g)	OF WHICH SATURATED (g)	OF WHICH SATURATED (%)
Parmesan cheese (50 g)*	14.05	9. 27	66%
Salami (50 g)*	19.15	7.24	38%
Milk chocolate (30 g)*	11.28	6.75	60%
Croissant, brioches (50g)*	9.15	5.10	56%
Butter (10 g)	8.34	4.87	58%
Palm oil (10 g)	10.00	4.71	47%
Sponge cake type snacks (50 g)*	11.15	4.70	42%
Margarine (10 g)*	8.28	4.25	51%
Shortbread biscuits (40 g)*	8.40	4.18	50%
Pork steak (100 g)	8.00	3.66	46%
Whole chicken with skin (100 g)	10.60	3.27	31%
Cheese crackers (30 g)*	7.65	2.83	37%
Raw ham (50 g)	6.85	2.42	35%
Beef front cuts (100 g)	**7.00**	**2.2**	**31%**
Peanut oil (10 g)*	10.00	1.93	19%
Egg (one egg 61 g) *	5.30	1.93	36%
Baked ham (50 g)	**3.80**	**1.60**	**42%**
Extra virgin olive oil (10 g)	10.00	1.44	14%
Whole chicken without skin (100 g)	**3.60**	**1.23**	**34%**
Beef rear cuts (100 g)	3.40	1.14	34%
Veal fillet (100 g)	2.70	1.14	42%
Cocoa and hazelnut cream (10 g)*	3.24	0.99	31%

Source: Food Composition Tables - Research Centre for Food and Nutrition.
** Source Food Composition Database for Epidemiological Studies in Italy – BDA-IEO.*

MEAT
IS INCREASINGLY LEAN

It is estimated that in the United States alone the total quantity of fats in products derived from cattle has decreased by 44% since 1970[44]. Even in Italy meat is noticeably "slenderised". If you compare data from food composition tables (INRAN, now CREA – Food and Nutrition) related to 1996 and 2005, it turns out that fats in ***beef tenderloin*** *has gone* ***from 5% to 2.2% (-56%)****, those of loin from 5.2% to 2.9% (-44%). A reduction that affected all beef cuts, also those of pork and cured meats. The new nutritional values of Italian cured meats emerging from the analyses carried out by INRAN and ASSICA (Experimental Station for the Food Preservation Industry) in 2011, confirm that cured meats are even more nutritious than in the past and have a better nutritional profile, because of less fat, with less cholesterol, salt and preservatives and more proteins, vitamins, minerals and essential fatty acids.*

Pork meat from the Eighties has reduced its fat content by about 30%, also in order to meet the wishes of consumers. The loin is the leanest part of both beef and pork, while the breast is generally the leanest part of poultry meat. The skin is the main source of fat in poultry meat. The fat content in the major retail cuts of the poultry ranges from 1 to 17%, and the cuts containing the skin have the highest values. In particular, the energy value of poultry meat varies between chicken breast and chicken thighs with skin: the presence of the skin (due to its fat content) increases the caloric value by about 25-30%. Fats, mainly found in the skin, can therefore be easily removed. The lipid content of chicken and turkey is about 1% in leaner cuts, such as chicken and turkey breast, and about 17% in chicken wings cooked with skin. However, compared to other types of meat, poultry appears to be relatively low in fat.

COMPARISON OF THE REDUCTION OF LIPIDS CONTAINED IN MEAT

BEEF	FAT (%)		REDUCTION
	1996	2007	
Round steak	2.8	1.1	-61%
Fillet steak	5.0	2.2	-56%
Sirloin steak	5.2	2.9	-44%

PORK	FAT (%)		REDUCTION
	1993	2011	
Baked ham	14.7	7.6	-49%
Raw ham - San Daniele PGI	23.0	18.6	-19%
Mortadella	28.1	25.0	-11%

Cholesterol: new research completely rehabilitates meat

To determine the nutritional value of meat it is best to consider also the cholesterol content, which in red meat is between 49 and 88 mg/100 g, while in poultry it is between 63 and 95 mg/100 g.

Lean meat has a low energy value which, in an appropriate diet, also reduces the concentration of plasma lipids, as indicated by several authors. For example, one study assessed how **lean beef and skinless chicken** have similar effects on plasma lipoproteins and how **they are interchangeable in cholesterol-lowering diets**.

In a similar research, other authors have compared the effect of lean red meat and lean white meat. **In the long experiment, which lasted 36 weeks, diets with one of the two types of meat reduced the level of LDL cholesterol and increased the level of good HDL cholesterol in the plasma**[45].

The use of meat in diets to lower the level of cholesterol in the blood is only valid for lean meat.

Vitamins and Minerals: essential micronutrients for metabolic functions

Meat is an excellent source of different vitamins and minerals, fundamental micronutrients present in biochemical forms that make them easily digestible. About 25% of the recommended daily allowance is covered with 100 grams of red meat (RDA) for **riboflavin, niacin, vitamin B6 and pantothenic acid and two thirds for vitamin B12**.

Chicken breast is a particularly good source of niacin (100 g provides 56% of the RDA) and vitamin B6 (27%), while 100 g of turkey breast provide 31% of niacin and 29% of vitamin B6. Meat is also one of the best sources of **zinc, selenium, phospho-**

THE MICRONUTRIENT OF RED MEAT

NUTRIENTS	RECOMMENDED DAILY ALLOWANCE (RDA)[45]	BEEF	VEAL	PORK
Thiamine (mg)	1.1	source of	-	rich in
Niacin (mg)	16	rich in	rich in	rich in
Vitamin B12 (μg)	2.5	rich in	rich in	rich in
Vitamin D (μg)	5	-	source of	-
Iron (mg)	14	-	source of	-
Selenium (mg)	55	-	-	source of
Zinc (mg)	10	rich in	rich in	rich in
Potassium (mg)	2000	source of	source of	source of

Micronutrient content of red meat, classified as a source of or rich in (EC REGULATION No. 1924/2006 on nutrition and health claims given on foodstuffs).

rus and iron: the lean cuts of beef provide about 37% of the reference intake of selenium, 26% of zinc and 20% of potassium in a 100g portion.
Lean red meat contains a number of vitamins and minerals that are important for all stages of life. For some of these nutrients, the meat could be defined as[47] **"source of"** or **"rich in"**, using the evaluation of the European Union, which is based on the recommended daily allowance (RDA). Food can be defined as **"source of"** if it contains ≥15% of the RDA per 100g for a particular vitamin or mineral, or as **"rich in"** if it contains ≥30% of the RDA.

An iron mine

Iron plays a crucial role in maintaining health, since one of its **deficiencies is connected to the malfunction of different biological mechanisms of the organism**, as well as **disturbances in the growth of a child and during development.** Taking into account physiological losses through the skin, intestines, urinary tract, airways and menstruation in women, diet plays a key role in maintaining the balance of iron.

Heme iron and non-heme

Iron can be found in a wide variety of foods, but it is essential to note that it can take two different forms: **heme iron** e **non-heme iron**. The substantial difference concerns the greater ease of assimilation of the heme form: **the bioavailability of heme iron is greater than 15%** and is absorbed at enterocyte level as an intact molecule, while the absorption of **non-heme iron** is linked to other components of the diet, which can increase or reduce absorption, and is estimated at around 5%.
In fact, the assimilation of iron by the human organism can be facilitated or inhibited depending on which other components are present in foods. An example is given by the role of **meat proteins, which contribute to an increase in the absorption of iron and zinc from other food sources.**
The sources of **vegetable iron**, on the other hand, are particularly **rich in potential in-**

VITAMINA B12

Meat and cured meats bring to our body a significant amount of **vitamin B12**, important for various functions of the body especially with **regards to red blood cells**. It is in fact involved in the synthesis of haemoglobin, where it acts in combination with folic acid in the formation of blood cells. **Vitamin B12 deficiency** is the main cause of **megaloblastic anaemia** and is strongly associated with high levels of **homocysteine in the blood**, which is a **risk factor for cardiovascular disease**. It can also **cause depressive symptoms and neurological disorders**. In children, vitamin B12 deficiency may be a risk factor for **neural tube defects**.

Vitamin B12 is found exclusively in foods of animal origin, mainly in liver, kidneys, meat, fish, eggs, milk, clams; however, it can also be found in some types of algae. For **people** who follow **diets without food of animal origin**, with a complete abolition of meat, fish, eggs and milk, it is essential to **use vitamin B12 supplements** to avoid the development of hypovitaminosis. The situation is to be monitored also for **vegetarians who, while eating some products of animal origin (eggs and dairy products), do not get enough**.

hibitors of iron absorption, such as phytates, and of some phenolic compounds such as polymerised flavans, which are found in legumes such as beans and broad beans. Legumes are also an important source of non-digestible carbohydrates, which can compromise iron absorption. Although **ascorbic acid (vitamin C) can improve the absorption of non-heme iron.**

Heme iron is present in haemoglobin and in myoglobin, so it is present only in some foods of animal origin. In particular **meat is the best source of heme iron**, because more than half of the iron in meat is of the heme type. The adult bovine has the highest content of heme iron, the loin contains about 77%. Both heme and non-heme iron is present in much lower quan-

TOTAL IRON AND HEME IRON CONTENT IN RAW AND COOKED MEAT

mg/100 g

		RAW MEAT		COOKED MEAT	
		IRON TOTAL	HEME IRON	IRON TOTAL	HEME IRON
CHICKEN	Breast	0.40	0.12	0.58	0.16
	Thigh	0.70	0.20	1.34	0.30
TURKEY	Breast	0.50	0.14	0.70	0.21
	Thigh	0.99	0.49	1.46	0.57
ADULT BOVINE	Sirloin	2.07	1.72	3.59	2.64
	Fillet steak	2.35	2.11	3.36	2.86
	Roastbeef	2.04	1.77	3.74	3.14
	Topside	1.93	1.68	2.88	1.89
VEAL	Filet	0.85	0.71	1.58	1.33
LAMB	Cutlet	2.23	1.68	3.20	2.25
HORSE	Filet	2.21	1.75	3.03	2.16
OSTRICH	Filet	2.43	1.76	3.78	2.85
RABBIT	-	0.45	0.25	0.60	0.31
PORK	Loin	0.36	0.20	0.46	0.21
	Steak	0.49	0.32	0.79	0.56

Source: Lombardi-Boccia et al., 2004 [48].

tities in poultry meat. The dark parts, like the thigh, contain them in slightly larger amounts. Pork meat, defined as red meat, may contain the same amount or even less iron than the chicken or turkey thigh, which fall into the so-called white meat. From the examination of the data it is deduced, moreover, how the iron content in the meat of different animal species depends on the use of the muscle by the animal itself. It is evident, therefore, that the classification of meat as generally defined has a limited importance from the nutritional point of view and that it would be much more informative to use the adjective referring to the species of belonging (beef, pork, poultry, sheep, etc.).

Meat and meat products can contribute **up to 18% of the daily iron requirement**, an important contribution to a healthy and balanced diet that is fundamental in preventing one of the most common nutritional deficiencies.

Despite its vital role in the human body, an excessive dose of iron can be dangerous. High doses of iron can cause damage to the intestinal mucosa and lead to systemic toxicity. This excess can also induce damage from the free radicals to different tissues, and recently several studies[49] have associated very high doses of iron to an increased risk of colorectal cancer, cardiovascular disease, infections, neurodegenerative diseases and inflammation.

The maximum level of **iron** intake in order to avoid negative health effects in **adults equals 50 mg/day**[50]**: the amount contained in two kilos and a half of beef!**

Bioactive compounds of meat

In addition to a variety of biologically active phytochemicals present in plants (e.g. fruit and vegetables), it is good to know that there are several interesting bioactive compounds in meat and cured meat [51], such as **carnosine, choline, L-carnitine, acid conjugated linoleic acid, coenzyme Q10, glutathione, lipoid acid, bioactive peptides, taurine and creatine**, which have been studied for their physiological properties.

Conjugated linoleic acid (CLA): anti-carcinogenic properties

In meat there are also trans-fatty acids, which are formed as a result of bio-hydrogenation by bacteria in the rumen. The most common is conjugated linoleic acid (CLA), a trans-fatty acid that has been linked to several health benefits in the prevention of cardiovascular disease, diabetes and obesity. Almost 40 years ago, a substance that was capable of inhibiting the activity of mutagenic substances was discovered in roasted meat extracts. Subsequently, it was demonstrated that this substance was indeed **conjugated linoleic acid**, which in experimental studies has repeatedly demonstrated **strong anti-carcinogenic properties**[52].

Conjugated linoleic acid shows its anti-cancer activity already at relatively small concentrations. It is interesting to note that among the other effects of CLA there is also the influencing of fat metabolism and that in experimental animals it reduces the amount of body fat.

The content of conjugated linoleic acid in milk and ruminant meat is influenced by diet, especially in the content of polyunsaturated fatty acids and by rumen conditions. **The intake of CLA food in our diet is completely dependent on the consumption of meat and milk of ruminants**, in particular the consumption of milk and meat fats, with higher values in pasture animals, which generally also have higher levels of polyunsaturated fats.

Coenzyme Q_{10}: an antioxidant to fat levels

Coenzyme Q_{10} is a component of the mitochondrial electron transport chain and to it is attributed antioxidant properties in fat, protein and DNA. Meat is an important source of coenzyme Q_{10} and its content is closely related to the number of mitochondria present in muscle cells. The best sources are meat and fish, but cooking can cause a loss of about 15-32%.

Carnosine: anti-aging and antioxidant properties of cells

Carnosine is a dipeptide formed from the amino acids B-alanine and histidine. It possesses strong antioxidant and anti-genotoxic activities, as well as anti-aging properties of cells. In studies on mice fed with carnosine-supplemented diets, a lower oxidative and inflammatory progression induced by neurodegenerative diseases has been observed. Carnosine and its derivatives are potential therapeutic agents in many diseases including cancer, neurodegenerative diseases, diabetes and schizophrenia[53]. It is located in meat and fish, but not in vegetables. Cooking meat reduces its content by 25-40%.

Taurine: a stimulant of the endocrine and immune system

It is a sulphured amino acid synthesised by methionine, found in the liver that can be both as a free acid and as a constituent of proteins, and is present in high quantities in most animal tissues. Taurine plays an essential role in the synthesis of bile acids that derive from cholesterol and facilitate its elimination. Bile is also essential for the absorption of fat-soluble vitamins. Along with zinc, taurine is also important for vision. A critical role was revealed in 1975, when it was discovered that retinal degeneration occurred in subjects with a deficiency of taurine and it was found that consumption of formula-free milk without taurine could cause cardiac and retinal dysfunction in preterm infants. Both of these problems can be prevented by adding synthetic taurine to artificial milk.

It is now recognised that taurine plays an important role in human physiology and nutrition, and that its positive effects are found in the digestive, endocrine, immune, muscular, neurological, reproductive, visual and cardiovascular systems. Studies in rats subjected to intense physical activity have shown that it reduces oxidative stress at muscle level and, therefore, the damage of muscle cells. Taurine seems to counteract the aging process thanks to its anti-free radical action. This amino acid is important for the synthesis of nitric oxide, a powerful vasodilator; as a result, it seems to stimulate efficiency and cardiac contractility, increasing myocardial blood supply. Taurine is only present in food of animal origin.

Creatine: for the improvement of muscle performance

Creatine and its derivative, creatine-phosphate, play an important role in muscle energy metabolism. So much so that, under certain circumstances, the addition of creatine to the diet promotes muscle performance. Muscle creatine is slowly converted into creatinine by the removal of water, with the formation of a ring structure, a phenomenon accelerated during the cooking of meat. Not being present in vegetables, those who follow a strictly vegetarian diet have lower levels of creatine than non-vegetarians, and this can lower the level of muscle performance.

Glutathione: the most powerful antioxidant

It is a tripeptide formed by cysteine, glycine and glutamic acid. According to many authors it is the most powerful endogenous antioxidant: inside the cell, glutathione has the ability to inactivate free radicals such as hydrogen peroxide, thus protecting the cell from lipids or oxidised proteins and preventing DNA damage. Glutathione also exerts a detoxifying activity, blocking heavy metals such as lead, cadmium, mercury, aluminium and other toxic substances (drugs, alcohol, tobacco, etc.), so as to make it easier and faster to eliminate and preventing de facto that these poisons bind to the SH groups of tissue proteins and enzymes deteriorating them. Furthermore, it favours the bioavailability of iron. Finally, glutathione carries out a pro-immune activity and protects the central nervous system. Some fresh vegetables, eggs and meat, especially pork and beef, have high glutathione contents.

Lipoic acid: antioxidant molecule

Lipoic acid is an antioxidant molecule capable of protecting both the membranes and the organelles of the cell; it is present in the mitochondria of animal cells, then in larger quantities in the muscles of the animals that move the most. **Lipoic acid is also a powerful chelator**, capable of removing excess metals, such as iron and copper, and toxic metals such as cadmium, lead and mercury.

L-carnitine

L-carnitine is a small molecule derived from lysine that plays an important role in the metabolism of fatty acids, facilitating their entry into the mitochondria and their consequent oxidation. L-carnitine is produced from methionine and lysine and its synthesis is strongly influenced by the bioavailability of these elements. After its biosynthesis, the L-carnitine passes into the blood and is distributed to organs and tissues, depending on their energy capacity, especially to the muscles and the heart. In addition to its endogenous origin, L-carnitine is supplied by foods. With an omnivorous diet, at least 80% of the L-carnitine present in the body derives from the diet.
The percentage decreases dramatically in vegan diets because most of the L-carnitine is supplied by meat, fish and dairy products. It is considered to be a vitamin-like nutrient and the lack or insufficient supply of L-carnitine in muscles or in cardiac cells can cause myopathies and cardiac disorders.

Choline: the memory of a lifetime

Choline is an essential nutrient that is found in many food sources and plays a critical role in the development of the central nervous system. Pregnancy and breastfeeding are periods in which the choline maternal reserves tend to run out. Animal studies have shown that the pre- and post-natal choline status can have long-lasting effects on the attention and memory of the unborn child. Choline during pregnancy and during the early stages of life can change brain functioning, resulting in improved memory throughout life. This change in memory function seems to be the cause of changes in the development of the memory centre (hippocampus) in the brain, with long-term effects so much so that memory in the elderly may, in part, be determined by what the mother ate during pregnancy. The richest choline foods are beef liver, chicken liver and eggs, but also pork meat.

Choline as a precursor of acetylcholine is involved in the regulation of sleep, in the control of muscle activity, in the regulation of anxiety states, in learning and may be linked to a slowing of the loss of cognitive abilities in the elderly.

Bioactive peptides of meat: immune system strengthening with a protective activity

In addition to bioactive compounds, in meat there are peptide derivatives of proteins that are another group of compounds functional with protective activity. When evaluating the quality of a protein, in addition to the composition of essential amino acids, it is also important to consider their ability to generate specific bioactive peptides during digestion. Bioactive peptides are sequences of 2-3 amino acids with protective effect on consumer health and play an important role especially in the prevention of diseases associated with the development of the metabolic syndrome and mental illnesses. Meat contains different proteins and peptides with important physiological activities. Although the activity of these peptides is latent, when they are part of the protein sequence, during digestion in the gastrointestinal tract they are released and activated. The same happens during fermentation, seasoning or food processing. Peptides modulate physiological functions through the binding interactions to specific receptors on cells that lead to physiological responses.

For example, it has been demonstrated that collagen-derived peptides have a positive effect on bone function, but in general the beneficial health effects of meat peptides include **antihypertensive, antioxidant, antithrombotic, modulating immune response and antimicrobial effects.**

2.2 Are there any alternatives to meat consumption?

In all parts of the world, the Guidelines for Healthy Eating recommend a high consumption of fruit, vegetables, cereals, legumes, foods rich in essential nutrients and protective substances, essential for the health of the organism[54].

An exclusively vegetable nutrition must be integrated with a careful selection of foods and supplements[55]. Some nutrients like mineral salts, vitamins like A, D or B12, essential fatty acids (especially omega-3) or essential amino acids (for example, methionine and threonine in addition to tryptophan and lysine) may not be consumed in optimal quantities, especially in more restrictive vegetarian diets[56].

An example can also be that of iron which is present in many plant foods. By consulting the composition tables of foods, it turns out that spinach is the vegetable that contains more (2.9 mg/100g), and in legumes, lentils and beans are the richest (8-9 mg/100 grams of dried legumes). **Unfortunately, for metabolic reasons, our body is able to absorb at best 8% of these quantities**: this means that **to cover the daily need for iron** using **only raw spinach you would have to eat between 4 and 17 kg** per day because boiling causes it to lose a lot in the cooking water.

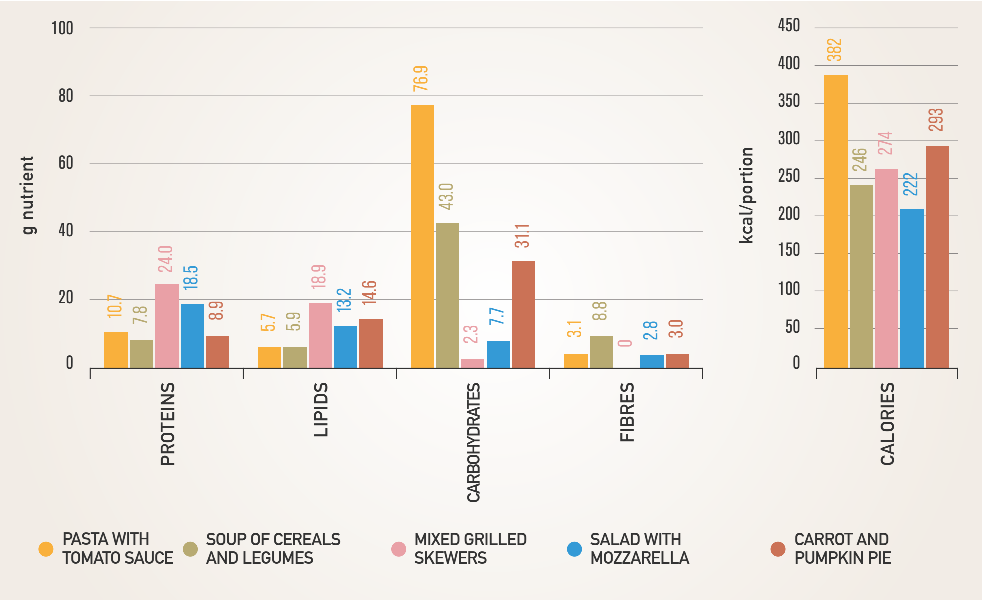
This example shows how it is essential to take into account **bioavailability, that is the aptitude of a nutrient to be absorbed by the intestine** and then the assimilation by the cells that must use it. Many factors can influence the bioavailability of iron. **Vitamin C increases it**, so it is good practice to season vegetables cooked with lemon or eat fruits and vegetables that contain vitamin C; **the fibre makes it decrease, as well as tannins.**

Many scientific studies have focused on the role of quantity, quality, type and timing of protein consumption and consequences of effects on health[57].

Today it is believed that a daily protein intake moderately superior to the recommendations (recommended intake for the population - 0.9 g/kg × day) for adults[58] may be useful for some people, such as the **elderly**[59] and physically active individuals[60]. Furthermore, a moderately high **protein intake in the diet** can help reduce **the risk of chronic diseases such as obesity, cardiovascular disease, type 2 diabetes, osteoporosis and sarcopenia**[61]. But it is essential that it derives from different types of foods, both of animal and vegetable origin.

In the group of foods rich in proteins, those of animal origin, in addition to providing complete proteins from the amino acid composition point of view, contribute to the daily intake of nutrients such as iron, zinc, vitamin B12, phosphorus and calcium, while proteins of plant origin contribute more to the intake of dietary fibre, vitamin E, magnesium. It is precisely these characteristics that support the advice for eating a variety of protein food sources, both for health reasons and to help meet nutritional recommendations[62].

CONTRIBUTION OF NUTRIENTS FROM DIFFERENT FOODS



The value of a varied and balanced diet is evident in the analysis of the contribution of nutrients from different foods.

NUTRITIVE ELEMENTS OF SOME RECIPES

RECIPE	INGREDIENTS (PER PORTION)
PASTA WITH TOMATO SAUCE	Pasta 90g, Peeled tomatoes 80g, Oil 5g
CEREALS AND LEGUMES SOUP	Cereals 50g, Legumes 40g, Oil 5g
MIXED GRILLED SKEWERS	Chicken breast 40g, Pork sausage 40g, Veal rump 40g, Peppers 30g, Oil 7g, Wine 10g
SALAD WITH MOZZARELLA	Cabbage 50g, Tomatoes 50g, Mozzarella 80g, Green salad 50g
CARROT AND PUMPKIN PIE	Eggs 20g, Almond flour 25g, Sugar 25g, Carrots 15g, Pumpkin 10g, Powdered sugar 2g

By comparing the nutritive elements of some recipes, we can see how, in a balanced diet, meat provides more proteins than other foods.
(Source of the recipes: Elaborations within the working group).

ARE MEAT SUBSTITUTES ALTERNATIVES TO MEAT?

*To be defined as an 'alternative', a food product must have **nutritional characteristics and sensory qualities** comparable to those of the food it is intended to replace. A rather difficult challenge, when the food being imitated is meat.*
*The first challenge – that of obtaining a compound suitable for being shaped and cooked in a similar way to minced meat – was already won in ancient times. For example, tofu has been incorporated in the diet of Asian cultures for many centuries, while legume-based compounds (such as chickpea flour) made their appearance on European tables in the Middle Ages. However, no further progress has been made since then, and with the improvement of lifestyles, plant protein sources – perceived as 'poor food' – have lost popularity in the diet of Western societies and in recent decades have been consumed above all by two specific groups of consumers: **vegetarians and vegans**. Legumes are precious foods that are fully included in the Mediterranean diet and contribute, together with products of animal origin, to ensuring the correct protein intake for all age groups, as well as being a cornerstone of traditional Italian cuisine which often combines them with meats, cured meats and fish in the widespread culinary preparations throughout the country.*
Today, the situation is changing rapidly and products that mimic the properties of meat are attracting increasing market interest. The renewed interest of consumers derives from multiple factors:

- *aesthetic improvement (in terms of appearance, texture and taste);*
- *increased consumer awareness about the environmental impacts associated with the consumption of meat and about the degree of animal welfare (during breeding and slaughtering);*
- *increased consumer concern about their health, especially with reference to the consumption of large quantities of red meat (bovine, pigs, sheep) or which has undergone processing (such as sausages, cured meats and smoked meats).*

*The increase in demand has obviously pushed many private companies and the world of scientific research to develop ever more attractive products, which has led to a further increase in their market share. In fact, thanks to advances in food biotechnology, **many plant-based foods** (typically gluten or soy-based) **are now perceived as valid substitutes for meat**. However, there is a but. These alternatives are becoming increasingly similar to meat in appearance, but not in nutritional value.[a] In fact, they are protein sources of lower quality than animal ones, as they **lack some essential amino acids and various micronutrients, such as vitamins A, B 12, D, K and***

***minerals such as iron and zinc and long chain polyunsaturated fatty acids**. These nutrients play essential roles in the development and regeneration of tissues[b], which will therefore be assumed through the consumption of food supplements, if foods of animal origin are completely excluded from the diet. Then there is a second aspect, even more relevant: although all plant-based foods are considered healthy, this is only true when consumed in their 'whole food' form, i.e. in the form of grains, fruits and vegetables, legumes, nuts and seeds. In contrast, plant substitutes are classified as ultra-processed foods in the Nova Classification, highly Processed Foods and Beverages (the result of industrial formulations and typically obtained with five or more ingredients) and are generally unhealthy (**high-calorie and low in nutrients and sometimes rich in salt**). Therefore, plant substitutes for meat fall into this category, as well as plant based substitutes for milk, refined cereals, carbonated drinks, snacks and plant-based confectionery products. In addition to **stabilisers, preservatives and trans hydrogenated fats** (which are harmful to the arteries together with excess salt), ultra-processed foods often contain **additives** such as **flavourings** and **colourings**, the purpose of which is to imitate the sensory qualities of foods or to mask undesirable aromas and flavours of the final product. Restricting attention to **plant-based substitutes for meat, to date there is still little information about their nutritional value and the health impacts in the medium-long term are unknown**, as they are new foods with complex formulations. Furthermore, among the meat substitutes there may be included two products deriving from two different sources - **cultured meat and insect proteins** - which should not have many of the many of the of the disadvantages mentioned above, typical of plant-based substitutes. But since these are products that are almost absent on the market, developed by a few pioneering companies, knowledge about them is even more scarce.*

	LEGUMES	GLUTEN AND SOY	UNICELLULAR ORGANISMS (MUSHROOMS OR ALGAE)	CULTURED MEAT[d]	INSECTS
NUTRITIONAL VALUE	Rich in protein and in fibres, but also in starches.	Quite rich in protein. Soy protein is rich in fibre and isoflavonoids (which lower the cholesterol level in the blood), gluten-based ones have a higher calorie content.	Rich in protein, fibre and micronutrients. Low calorie content. Microalgae also rich in vegetable oils. Content of secondary metabolites unknown.	Potential quantity and quality of protein content identical to that of conventional meat. Secondary metabolite content, unknown.	Quantity and quality of protein content similar to that of conventional meat. Medium-high fat content. Very high keratin content.
PERCEPTION BY THE WESTERN CONSUMER	Well-known products, present on the market unprocessed or processed in various ways (e.g., chickpea flour, canned legumes). Low interest (perceived as 'poor food').	Present on the market under various names (seitan, tofu, various types of veg-burgers). To date, they represent the main alternative to meat.	Products of fungal origin present on the market under various names (Quorn and other types of veg-burgers). Microalgae currently perceived as a resource in cosmetics and nutraceuticals or for the production of biogas, but not as a protein food.	Perceived by some, as real meat, but produced without inflicting suffering to animals. Considered by others, synthetic meat to avoid as an artificial product.	If in the form of flour, they are accepted much more easily than if presented as whole animals. Italian consumers are not in favour of direct consumption.
INTEREST FROM THE INDUSTRY	Little interest.	Very high interest.	High interest in products of fungal origin, already on the market at fairly competitive prices. Few pioneer companies in the field of microalgae.	Venture capital provided by private investors, with growing interest by the meat industry.	High interest only for use as feed in livestock, above all to aquaculture. Medium-low interest in products intended for humans.
INNOVATION	Some companies are trying to invent new, more attractive ones (veg-burgers).	It is necessary to develop products that are increasingly attractive to the consumer and better from a nutritional point of view.	For algae, it is necessary to lower the production costs: from collection, protein extraction (indigestible cell walls), up to colour change (de-greening). In general, the development of more attractive products for the consumer is necessary.	Necessary to lower its production costs through the identification of more performing growth substrates and scale-up (passage from pilot scale to industrial scale). Necessary to develop attractive products for the consumer.	Necessary to lower its production costs through the identification of more performing growth substrates and scale-up (passage from pilot scale to industrial scale). Necessary to develop attractive products for the consumer.

[a] *Plant-Based Diets and their Impact on Health, Sustainability and the Environment: a Review of the Evidence: WHO European Office for the Prevention and Control of Noncommunicable Diseases. Copenhagen: WHO Regional Office for Europe; 2021. Licence: CC BY-NC-SA 3.0 IGO.*

[b] *van Vliet S., Kronberg S.L., Provenza F.D. (2020), Plant-Based Meats, Human Health, and Climate Change. Frontiers in Sustainable Food Systems, 4. https://doi.org/10.3389/fsufs.2020.00128.*

[c] *Monteiro et al. (2016), NOVA, The Star Shines Bright. World Nutrition 7 (1-3): 28-38. https://worldnutritionjournal.org/index.php/wn/issue/view/1.*

[d] *Artificial meat, also known as in meat in vitro, cultured meat, laboratory meat, clean meat or even synthetic meat, is a new food produced in the laboratory from animal muscle stem cells taken from living animals and reproduced in culture.*

ULTRA-PROCESSED FOODS:
WHICH ARE THEY AND WHY THEY ARE BAD FOR YOUR HEALTH

Nutrition is a crucial factor in the development of some chronic diseases. For example, dietary habits influence many risk factors for cardiometabolic health, leading to type 2 diabetes, stroke and heart disease, which are among the leading causes of death globally. Over the last two decades, the availability ***and consumption of ultra-processed foods, food products with low nutritional quality and high energy density, have in fact increased significantly in many countries. Excessive consumption of these foods has been linked to high rates of overweight/obesity and an increased risk of various non-transmissible diseases***[1]*. In particular, high consumption of ultra-processed foods (>4 servings per day) was associated with a 62% higher risk of all-cause mortality. For each additional serving of ultra-processed foods, all-cause mortality increases by a further 18%*[2].

But how are ultra-processed foods classified? The following table classifies foods according to the NOVA[3] *system, still widely used, but which has some limitations. According to some authors*[4] *the use of the NOVA classification in the formulation of public health policies must in fact be reviewed, considering in addition to the processing phases, also the overall nutritional value of foods, in the context of the global diet.*

NOVA FOOD CLASSIFICATION

GROUPS	CHARACTERISTICS	FOOD EXAMPLES
GROUP 1 **Unprocessed or minimally processed foods**	**Not processed** Edible parts of plants (fruits, seeds, leaves, stems, roots, tubers) or animals (muscles, fat, offal, eggs, milk), as well as mushrooms, algae. Spring and tap water. **Minimally processed** Unprocessed foods but altered by industrial processes such as the removal of inedible or unwanted parts, drying, pulverizing, squeezing, crushing, grinding, fractioning, cooking and pasteurisation, refrigeration, freezing, packaging including vacuum, non-alcoholic fermentation and other methods that do not add salt, sugar, oils or fats or other food substances to the original food.	Fresh, juiced, chilled, frozen or dried fruits and vegetables, leafy and root vegetables; grains such as rice or corn, grains, wheat; legumes; starchy roots and starchy tubers; mushrooms; meat, poultry, fish and seafood; fresh, powdered, chilled or frozen eggs; fresh, powdered or pasteurised milk; fresh or pasteurised fruit or vegetable juices (without added sugar, sweeteners or flavourings); fresh or pasteurised yogurt; tea, coffee and drinking water. Also includes foods made from two or more of this group, such as mixed dried fruit, grain-based granola, nuts, and dried fruit with no added sugar, honey, or oil; pasta, couscous and polenta and foods with added vitamins and minerals usually to replace nutrients lost during processing, such as wheat or corn flour enriched with iron and folic acid.

GROUPS	CHARACTERISTICS	FOOD EXAMPLES
GROUP 2 **Processed culinary ingredients**	Substances obtained directly from group 1 foods or from nature by industrial processes such as squeezing, centrifugation, refining, extraction. Used to prepare, season and cook group 1 foods. They may contain additives which extend the shelf life of the product, protect the original properties or prevent the growth of microorganisms.	Vegetable oils obtained from seeds, nuts or fruits (especially olives); butter and lard; sugar and molasses; honey and maple syrup; starches and cereals; vegetable oils with added antioxidants; salt extracted or obtained from sea water, and table salt with the addition of drying agents. Also included are products consisting of group 2 items, such as salted butter, and group 2 products with added vitamins or minerals, such as iodized salt.
GROUP 3 **Processed foods**	Products obtained by adding salt, oil, sugar or other group 2 ingredients to group 1 foods, using preservation methods such as canning and bottling, and, in the case of bread and cheese, using non- alcoholic fermentation. The processes and ingredients are designed to increase the shelf life of group 1 foods and make them more palatable by modifying or improving their sensory qualities. They may contain additives that extend the life of the product, protect the original properties or prevent the growth of microorganisms.	Canned or bottled pickled vegetables and legumes; salted or sugared nuts and seeds; salted, dried, cured or smoked meat and fish; canned fish (with or without added preservatives); canned fruit (with or without added antioxidants); unpackaged fresh bread and cheeses.

GROUPS	CHARACTERISTICS	FOOD EXAMPLES
GROUP 4 **Ultra-processed foods**	Ingredient formulations made using a variety of industrial processes: fractionation, chemical modifications, food assembly using industrial techniques such as extrusion, moulding and pre-frying; the use of additives in various stages of production whose function is to make the final product palatable or hyper-palatable; sophisticated packaging (plastic and other synthetic materials). Ingredients include sugar, oils or fats, or salt, usually in combination, and substances such as high fructose corn syrup, hydrogenated oils and protein isolates; classes of additives whose function is to make the final product palatable or more pleasant, such as flavourings, flavour enhancers, colourings, emulsifiers and sweeteners, thickeners, etc., preservatives. The processes and ingredients used are generally designed to create low-cost, long-life, ready-to-eat, hyper-palatable ingredient products.	Many ready-to-drink products, such as carbonated soft drinks; sweet or savoury snacks packaged snacks, chocolate, candy (confectionery); ice creams; packaged bread and rolls; margarines; cookies, pastries, cakes and pie dough; breakfast cereals. cake mixes; breakfast cereals, energy bars; energy drinks; milk drinks, fruit drinks and yogurts; cocoa drinks; instant sauces. Many products ready to be reheated, including cakes and dishes of pasta and pizza; poultry and fish such as nuggets and sticks, sausages, hamburgers, hot dogs and other reconstituted products, hot dogs and other products with a reconstituted meat base; instant powdered and packaged soups, noodles and desserts. Infant formulas, follow-on formulas and other products for infants; "health" and "slimming" products, "baby products"; "health" and "slimming" products such as shakes and meal replacement powders.

[1] *Monteiro C.A., Levy R.B., Claro R.M. et al. (2010), A New Classification of Foods Based on the Extent and Purpose of their Processing, Cad Saude Publica 26, 2039–2049., Lane M.M., Davis J.A., Beattie S., Gómez-Donoso C., Loughman A., O'Neil A., Jacka F., Berk M., Page R., Marx W., Rocks T., Ultraprocessed Food and Chronic Noncommunicable Diseases: A Systematic Review and Meta-analysis of 43 Observational Studies, Obes Rev. 2021 Mar; 22(3):e13146, doi: 10.1111/obr.13146. Epub 2020 Nov 9. PMID: 33167080.*

[2] *Rico-Campà A., Martínez-González M.A., Alvarez-Alvarez I., Mendonça R.D., de la Fuente-Arrillaga C., Gómez-Donoso C., Bes-Rastrollo M., Association between Consumption of Ultraprocessed Foods and all Cause Mortality: SUN Prospective Cohort Study, BMJ, 2019 May 29;365:l1949, doi: 10.1136/bmj.l1949. PMID: 31142450; PMCID: PMC6538973.*

[3] *Monteiro C.A., Cannon G., Lawrence M., Costa Louzada M.L. and Pereira Machado P. 2019. Ultra-Processed Foods, Diet Quality, and Health Using the NOVA Classification System, Rome, FAO.*

[4] *Visioli F., Marangoni F., Fogliano V., Del Rio D., Martinez J.A., Kuhnle G., Buttriss J., Da Costa Ribeiro H., Bier D., Poli A., The Ultra-processed Foods Hypothesis: A Product Processed Well Beyond the Basic Ingredients in the Package, Nutr Res Rev. 2022 Jun 22:1-11, doi: 10.1017/S0954422422000117, Epub ahead of print, PMID: 35730561.*

ANIMAL MEAT
OR VEGETABLE SUBROGATE?

Despite the apparent similarities of nutritional values, the metabolomic analysis has shown that the metabolites present in natural meat differ by 90% from those contained in vegetable substitutes.

Producing plant-based alternatives to meat is not easy. The most widely used technology is extrusion, but other techniques are being developed, including mycelial cultivation, 3D printing and recombinant proteins[1]. Extruders are systems capable of combining humidity, high heat and mechanical energy. Typically, protein powders, such as soy protein isolate, wheat gluten flour, water, steam, and oils are mixed in a two-screw extruder, where the ingredients are chopped, blended, and homogenized. The mixture obtained is compressed and heated and finally extruded through a suitable die are a long way from muscle tissue made up of muscle fibres, connective tissue and adipose tissue organised in complex structures, which determine the physical-chemical and sensory qualities of meat. Not to mention the fat component: the distribution of adipose tissue within the muscle mass of the animal infiltrates the muscle fibres creating veins that are difficult to replicate with vegetable ingredients.

*Several food safety and nutritional quality issues may be related to plant-based meat analogues. For example, many plant proteins are known allergens, including **soy, wheat, pea and lupin proteins**, which can cause health problems in some consumers[2] and **gluten which is not suitable for coeliacs**. Plant proteins are blended with various other functional ingredients necessary to achieve the desired look, feel and taste of the final product, including **flavours, dyes, emulsifiers, texture modifiers, gelling agents and binding agents.** The long list of ingredients creates concern for consumers and the **high level of saturated fat and salt**, for nutritionists[3]. Some plant-based meat alternatives are indeed higher in saturated fat than conventional meat products, as well as unprocessed processed plant-based protein sources, such as beans and lentils[4]. Some plant-based meats contain relatively high amounts of salt, and high levels of salt in the diet can increase the risk of high blood pressure, cardiovascular disease, osteoporosis, kidney disease, and stomach cancer[5].*

*A study[6] that aimed to use metabolomics to provide an in-depth comparison of the metabolite profiles of a popular plant-based meat alternative and pasture-derived meat found that **despite the apparent similarities in nutritional values, the metabolite analysis differs by 90%**. Several metabolites were found exclusively (**22 metabolites**) or in higher quantities (**51 metabolites**) in beef and nutrients such as docosahexaenoic acid (ω-3), niacinamide (vitamin B3), glucosamine, hydroxyproline and the antioxidants allantoin, anserine, cysteamine, spermine and squalene were among those found only in beef. **Plant-based meat alternatives lack certain amino acids and their derivatives – such as creatine, taurine and anserine** – which are thought to be important for human health, as they*

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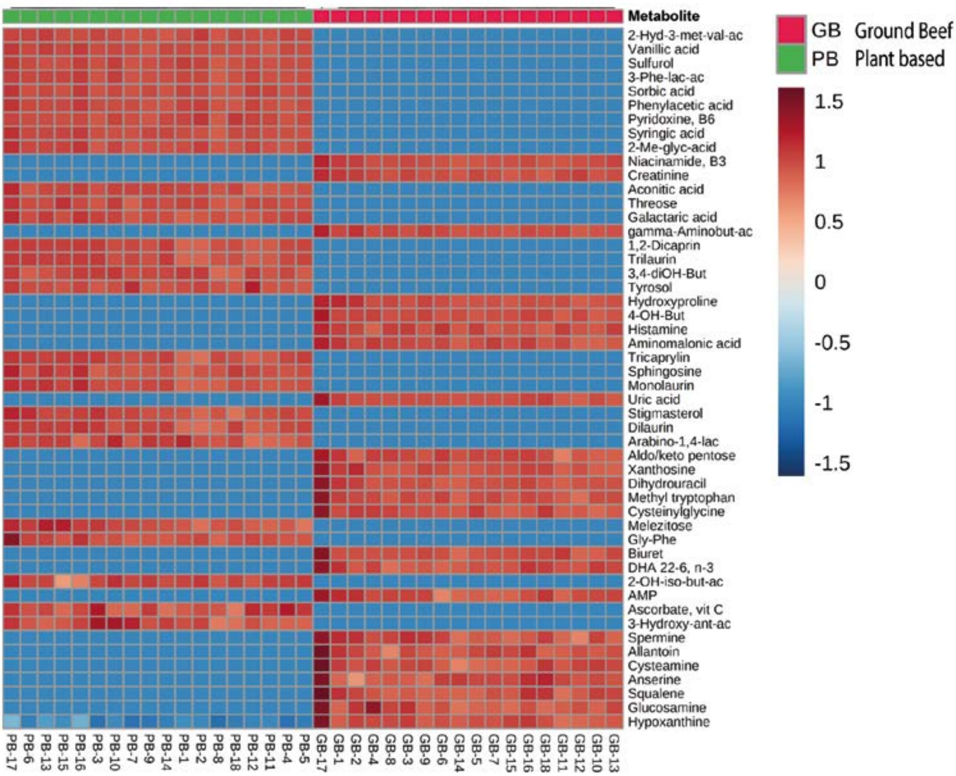
can ***affect brain and muscle function****. Several other metabolites were found exclusively (31 metabolites) or in higher amounts (67 metabolites) in the plant-based meat alternative. Ascorbate (vitamin C), phytosterols, and several phenolic antioxidants such as loganin, sulphur, syringic acid, tyrosol, and vanillic acid were among those found only in the plant-based alternative to meat. The study authors indicate that because of large differences in metabolites within* ***various classes of nutrients (e.g., amino acids, dipeptides, vitamins, phenols, tocopherols, and fatty acids)*** *with physiological, anti-inflammatory, and/or immunomodulatory roles,* ***the two foods should not be seen as truly nutritionally interchangeable, but could be seen as complementary in terms of the nutrients provided****. Some researchers have also expressed concern about the inclusion, in some plant-based foods, of* ***leghaemoglobin****, an iron-containing haemoprotein that can be obtained from soy root nodules. This protein is used to provide the desirable red colour and meaty flavour normally associated with the haemoglobin*

COMPARISON OF THE METABOLOMIC PROFILE OF BEEF WITH PLANT-BASED ALTERNATIVES



Heat map of the top 50 metabolites, ranked by p-values (lowest to highest), which are significantly different (p↓0.05) between Grass Fed beef and the plant-based alternative. Red colour (strength ranges from 0 to 1.5) indicates higher abundance of the corresponding metabolite, while blue indicates lower abundance (strength ranges from -0 to -1.5).

of real meat[7]. Because of the difficulty of obtaining large enough amounts from soybeans, leghaemoglobin is also produced from genetically modified yeast cultures. For example, one way of producing it is by using bioengineered yeast fermentation. Scientists modified the yeast Pichia pastoris with a gene encoding soy leghaemoglobin, along with other ***genetic modifications related to the metabolic pathways of the yeast****. When fermented with sugars, amino acids, and vitamins, yeast synthesizes heme-linked soybean leghaemoglobin. A separation process opens the yeast cells, extracting the protein, filtering out the solids and concentrating the liquid, which is blood red in colour. The final recombinant product is indistinguishable from leghaemoglobin isolated from soy and is* ***not labelled as genetically modified in the USA****. Its status as a non-GMO product probably derives from the precedent created decades ago by the production by fermentation of* ***chymosin****, an enzyme used in the production of cheese. To produce chymosin, microbes transformed with a* ***bovine gene*** *encoding the enzyme are fermented, releasing the enzyme, which is then separated and added to milk as a coagulant. The final cheese is not considered bioengineered. The American Food and Drug Administration recently authorised the use of this globin (also called "vegetable blood") in foods as an analogue of haemoglobin and myoglobin in meat.*

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[1] Rubio N.R., Xiang N., Kaplan D.L., Plant-based and Cell-based Approaches to Meat Production, Nat Commun, 2020 Dec. 8, 11(1):6276, doi: 10.1038/s41467-020-20061-y. PMID: 33293564 PMCID: PMC7722853.

[2] Lemken D., Spiller A., Schulze-Ehlers B. (2019), More Room for Legume - Consumer Acceptance of Meat Substitution with Classic, Processed and Meat-resembling Legume Products, Appetite, Dec 1;143:104412, doi: 10.1016/j.appet.2019.104412. Epub 2019 Aug 22. PMID: 31445994.

[3] Bohrer B.M. (2019), An Investigation of the Formulation and Nutritional Composition of Modern Meat Analogue Products. Food Science and Human Wellness, 8 (4) (2019), pp. 320-329.

[4] Alessandrini R., Brown M.K., Pombo-Rodrigues S., Bhageerutty S., He F.J., MacGregor G.A., Nutritional Quality of Plant-Based Meat Products Available in the UK: A Cross-Sectional Survey, Nutrients, 2021 Nov 25;13(12):4225, doi: 10.3390/nu13124225. PMID: 34959777; PMCID: PMC8709452. Tso R., Forde C.G., Unintended Consequences: Nutritional Impact and Potential Pitfalls of Switching from Animal- to Plant-Based Foods, Nutrients, 2021 Jul 23;13(8):2527, doi: 10.3390/nu13082527. PMID: 34444686; PMCID: PMC8398225.

[5] He F.J., Tan M., Ma Y., MacGregor G.A, Salt Reduction to Prevent Hypertension and Cardiovascular Disease: JACC State-of-the-Art Review. J Am Coll Cardiol. 2020 Feb 18;75(6):632-647, doi: 10.1016/j.jacc.2019.11.055. PMID: 32057379.

[6] van Vliet S., Bain J.R., Muehlbauer M.J., Provenza F.D., Kronberg S.L., Pieper C.F., Huffman K.M., A Metabolomics Comparison of Plant-based Meat and Grass-fed Meat indicates Large Nutritional Differences despite Comparable Nutrition Facts Panels, Sci Rep. 2021 Jul 5;11(1):13828, doi: 10.1038/s41598-021-93100-3. PMID:34226581; PMCID: PMC8257669.

[7] Hu F.B., Otis B.O., McCarthy G. Can Plant-Based Meat Alternatives Be Part of a Healthy and Sustainable Diet? JAMA. 2019 Oct 22;322(16):1547-1548, doi: 10.1001/jama.2019.13187. PMID: 31449288.

CULTURED MEAT

WHAT IT IS AND HOW IT IS PRODUCED

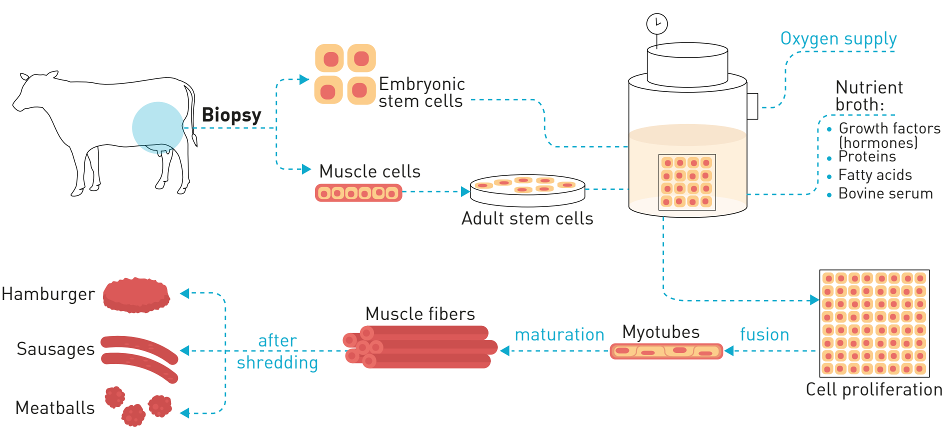
Cell culture technology consists in making cells grow and proliferate in artificially controlled environments, with appropriate nutrients. The result is to produce a large amount of biomass from an initially small number of cells.
The cultured cells can be obtained through two alternative ways:

*- **Biopsy:** the removal of a piece of tissue from a living organism. These cells generally have limited replicative capacity and tend to become "senescent", an aspect which implies the repetition of biopsies over time (to take new material with which to start new cultures).*

*- **Development of "cell lines":** each culture derives from a previous culture and the continuous sampling of tissues from live animals is no longer necessary. To obtain cells with unlimited replicative capacity, the use of genetic engineering techniques is necessary, capable of acting selectively on the genes involved in cell proliferation ("immortalisation" process). The cultured cells are pluripotent stem cells, i.e., capable of specialising in all cell types of adult individuals.*

*The cells are grown in a special substrate, the culture medium. Depending on the protocol followed and the characteristics of the **culture medium**, stem cells can differentiate into different types of mature tissue: muscle fibres, adipose tissue, connective tissue, vascular tissue. Subsequently, the cells naturally fuse into smaller fragments of tissue, which are finally attached to an*

CELL-BASED MEAT PRODUCTION PROCESS



Source: Prof. Paul Wood, Monash University, Australia.

organic sponge-like scaffold. This structure floods the fibres with nutrients, leading to an increase in both their size and protein content. But what does the culture medium contain? Essentially, all the elements – nutrients (sugars, amino acids, minerals, vitamins, etc.) and growth factors[1] – necessary to satisfy the specific metabolic needs of the cells in culture.

MAIN CRITICALITIES

Among the various supplements available, the one with the best performance is foetal bovine serum (FBS). FBS is very rich in nutrients – it contains 200-400 different proteins and thousands of metabolites – and is therefore a universal supplement, excellent for the culture of any type of cell[2]. However, the use of this component of animal origin presents many critical issues. In fact, in ***addition to a very high market price, FBS involves risks of contamination of the substrate but above all it violates the ethical principle at the basis of the product: producing meat without killing animals****. As the name implies, FBS is serum[3] obtained from the blood taken from the calf during the slaughter of a pregnant cow. The numerous criticalities of this substance are leading research institutions and companies involved in the production of laboratory meat towards the development of substrates free from animal components, at lower prices than FBS and with sufficiently high performance[4]. It is therefore not a single universal supplement, but a series of compounds with much simpler formulations than that of FBS, each suitable for the development of a limited number of cell lines. Some of these products are already commercially available and are mainly composed of amino acids and proteins obtained through microbial fermentation or derived from vegetable hydrolysates.*

In addition to the limits on the use of FBS as a supplement, the heavy restrictions on genetically modified foods already in place in Europe, added to the aversion from the average consumer, make production starting from immortalised cell lines impractical. A similar argument applies to the use of synthetic hormones which, although identical to natural hormones, are prohibited in Europe on the basis of the precautionary principle.

In summary, ***the only viable way in Europe will be to cultivate meat starting from cells obtained by biopsy, using non-hormonal growth factors and alternative substrates to FBS.***

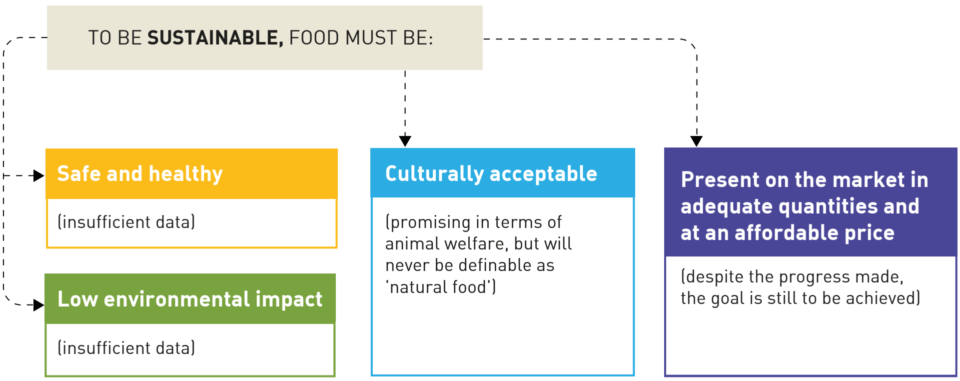
BUT IS IT REALLY A SAFE PRODUCT?

In Europe, *approval from the European Commission on the advice of the European Food Safety Authority (EFSA) under the Novel Food Regulation is required before cultured meat can be marketed. The main purpose of this regulation is to ensure* ***food safety*** *and to avoid the placing on the market of foods unfit for consumption (an aspect that has* ***not been fully demonstrated for cultured meat)****[5]. Once authorised, cultured meat products will have to be labelled correctly, in order not to mislead consumers as to the origin of the food or its nutritional characteristics (different from those of the foods they seek to replace).*

The European consumer is therefore adequately protected. But when will they be able to find on the market the first products based on cultured meat? Not soon. As well explained in a recent publication, ***cultured meat is currently not a sustainable healthy food product*** *according to the definition provided by FAO and WHO[6]. Furthermore, a recent comparative evaluation concludes that cultured meat is no greener than that derived from livestock; its relative impact depends instead on the availability of decarbonised energy generation and the* *specific production systems that are implemented. In practice it will certainly become more ecological when the energy used for production comes mostly from renewable sources*[7].

In other words, a rapid switch from conventional to laboratory meat seems highly unlikely in the foreseeable future. In particular, the lack of in-depth research related to risk characterisation appears to be the biggest obstacle to bringing a safe product to market.

CULTURED MEAT DOES NOT MEET THE DEFINITION OF A SUSTAINABLE FOOD PRODUCT[5]



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[1] *Growth factors, are substances naturally present in living organisms and capable of stimulating cell proliferation and differentiation. Some growth factors are hormones.*

[2] *Post et al., (2020), Scientific, Sustainability and Regulatory Challenges of Cultured Meat, Na Food, 1: 403–415, doi: 10.1038/s43016-020-0112-z.*

[3] *It is the liquid component of blood that is obtained after removing red blood cells, white blood cells, platelets and other clotting factors. It is very watery and full of nutrients.*

[4] *Chen L. (2022), Large-scale Cultured Meat Production: Trends, Challenges and Promising Biomanufacturing Technologies, Biomaterials 280:121274, doi: 10.1016/j.biomaterials.2021.121274.*

[5] *Chriki S. et al. (2022), Is "Cultured Ceat" a Viable Alternative to Slaughtering Animals and a Good Comprise between Animal Welfare and Human Expectations? Animal Frontiers, 12(1): 35–42, doi: 10.1093/af/vfac002.*

[6] *Sustainable healthy diets are food models that promote individual health and well-being, have a low environmental impact, an affordable market price and are culturally acceptable. For further information: FAO and WHO. 2019. Sustainable healthy diets – Guiding principles. Rome.*

[7] *Lynch J., Pierrehumbert R. (2019), Climate Impacts of Cultured Meat and Beef Cattle, Front Sustain Food Syst. 3:5, doi:10.3389/fsufs.2019.00005.*

3 NUTRITION AT DIFFERENT STAGES OF LIFE

The nutrient requirement starts at the beginning of life and continues in all its phases, with variations due to age and specific needs. All nutrients are essential, but each period of life is characterised by a lesser or greater requirement of some nutrients or energy. **Meat provides useful nutrients at all stages in life**, but there are some special situations such as pregnancy and lactation, as well as during growth and exercise, where it is advisable not to deprive yourself of this food. For example, during pregnancy, breastfeeding, growth and aging the needs of certain nutrients or compounds increases such as proteins, essential fatty acids, choline, and micronutrients such as iron, zinc, calcium and vitamin B12, and you should not forfeit the best sources of these nutrients: foods of animal origin. Adults can satisfy their needs even with limited quantities of meat.
Recently a position paper[63] of the Sipps (Italian Society of Preventive and Social Paediatrics), together with the FIMP (Federation of Italian Medical Paediatricians) and the Italian Society of Perinatal Medicine concludes that vegetarian and vegan diets that are not supplemented with vitamin B12, DHA, iron, vitamin D, calcium and zinc, must be considered inadequate to guarantee a correct psychomotor development. Vegetarian pregnant or nursing women, children and adolescent must be periodically evaluated to verify that the supplementation is sufficient.

3.1 Pregnancy and lactation

The baby in the womb is totally dependent on the nutrients that are provided by the mother. Maternal eating habits and the nutritional status before conception, during pregnancy and lactation affect the unborn child, its growth and its health. Therefore it is important that the foods that a pregnant or nursing woman takes provide all the necessary nutrients to support the growth and development of the child, and this can only be achieved through a varied and balanced diet.
Proteins are a primary nutrient, because they guarantee the bricks necessary for the construction of the tissues of the unborn child: it goes from two cells at the time of fertilisation to about ten thousand billion in the new-born! But we must provide also the proteins necessary for the development of the placenta, for the mother's mammary and uterine tissues and for the growth in volume of the circulating blood (more haemoglobin, more proteins of the plasma), besides that of the amniotic fluid. Foods that contain proteins of high biological value are milk and derivatives, eggs, meat and fish. The same foods help to supply the body with other important nutrients during pregnancy and lactation like calcium, iron, zinc, iodine, B vitamins, vitamin D, and some fats from the omega-6 family, such as arachidonic acid (AA).
In pregnancy and during lactation a frequent consumption of **fish is highly recommended to obtain the precious long-chain**

omega-3 fatty acids, present albeit in smaller quantities even in meat, such as **docosahexaenoic acid (DHA)**. In fact, DHA is one of the main structural components of cell membranes and is essential for the formation of new tissues, **in particular for foetal development of the brain, nervous system and retina, which continue to mature during the first months of life**.

A good supply of calcium, together with phosphorus and vitamin D, is essential for foetal development and the first months of life. It is not only bones and teeth that benefit from it, but also the nervous functions, muscular contractions and blood coagulation. In pregnancy it is also necessary to pay close attention to the intake of sufficient quantities of iron and iodine. The greater iron requirement is due to the greater volume of blood: the baby's cells breathe with oxygen transported by the iron (haemoglobin) of the mother. Adequate iodine intake is essential for an optimal production of thyroxine, a thyroid hormone needed in larger quantities to control the major underlying metabolism induced by pregnancy. In addition to consuming fish regularly, it is good to replace salt with iodized salt.

During pregnancy, iron deficiency can impair brain functioning, learning and memory: children with low levels of iron have a delay of neuro-cognitive and motor development, a fact confirmed also by a recent research conducted at the paediatric hospital in Los Angeles and published in Paediatric Research[64]**.**

All vitamins are important in pregnancy, but some even more so: **vitamin A and vitamin C, necessary for tissue growth, and B vitamins**, essential for energy transformation and protein metabolism, found in cereals, legumes and foods of animal origin. Special attention is needed for folic acid, an essential vitamin for the proper development of the foetus's spinal cord

in the first 3 months after conception, to the point that during pregnancy a higher consumption is recommended. It also intervenes in the formation of red blood cells and is capable of reducing the risk of heart disease. During this phase of life, the **requirement of vitamin B12** also increases, **which goes from 2.4 μg per day to 2.6 μg in pregnancy and 2.8 μg during lactation.**

3.2 Growth and development

The nutrition of children and adolescents is based on the same principles of adult nutrition, but with different quantitative needs. The first 2 to 3 years of a child's life are fundamental for his physical and mental development, and in this context, proteins play a key role in the correct functioning of bones, muscles, blood, skin and hormones. Animal proteins, especially meat, are therefore very important foods: an 80 to 100 gram portion of most types of meat contains about 20 grams of protein, an easy way to help the child achieve its goals of protein intake. In addition to this, a correct intake of vitamin B12 is essential for neurodevelopment and cell growth. Iron and zinc are significant for the growth and development of infants and children. The child grows more during this period than at any other stage of life and if it does not feed properly, it can get sick easier, or in general not develop in the right way.

For example, having a healthy weight before the onset of puberty is critical for several reasons: obese children and adolescents often remain obese into adulthood; obesity during adolescence is significantly associated with an increased risk of cardiovascular and metabolic diseases such as type 2 diabetes in adulthood; recent data have shown a strong association between an elevated body mass index during adolescence and an increased risk of several malignancies in adulthood[65]. Some nutritional deficiencies, **such as iron deficiency, can cause low levels of attention and concentration in the child, with consequent poor academic results**[66].

Most of the studies investigating the association between nutrition and cognitive development have focused on single micronutrients that are considered essential for the proper development of the brain: they are omega-3 fatty acids, vitamin B12, folic acid, zinc, iron and iodine[67], all nutrients supplied preferentially from food of animal origin. In children, the association between **vitamin B12 and cognitive development** was observed above all in children born to vegetarian or vegan mothers or who followed a macrobiotic diet. These diets can cause vitamin B12 deficiency because vitamin B12 is found exclusively in foods of animal origin. Studies on children with vitamin B12 deficiencies have highlighted abnormal clinical and radiological signs, including: hypotonic muscles, involuntary muscle movements, apathy, and reduced growth and demyelination of nerve cells. After treatment with vitamin B12, a rapid improvement occurs of the neurological symptoms in children with deficiencies, but in many the damage is permanent with lifelong delays in cognitive development and language[68]. The long-lasting effect of vitamin B12 deficiency is supported by the results of some studies[69] in which researchers examined the cognitive functioning of adolescents who consumed a macrobiotic diet up to the age of 6, compared to boys who followed an omnivorous diet. Those adolescents who followed a macrobiotic diet up to 6 years of age had lower levels of fluid intelligence, spatial capacity and short-term memory compared to control subjects.

Zinc deficiency appears to be a major problem worldwide, affecting 40% of the population. Some research suggests that children, adolescents, elderly and people with diabetes are at high risk of zinc deficiency[70]. Zinc is thought to be an essential nutrient for the brain, with important structural and functional roles. More specifically, zinc is a cofactor for more than 200 enzymes that regulate different metabolic activities of the body including proteins, DNA and RNA synthesis. Furthermore, zinc plays a role in neurogenesis, maturation and migration of neurons and synapse formation.

Zinc is also found in high concentrations in the synaptic vesicles of the hippocampal neurons (which are involved in the learning and memory centre). Zinc supplementation has a positive effect on the immune status of new-borns and can prevent congenital malformations[67].

One of the most common nutritional deficiencies in both developing and developed countries is **iron deficiency**. It is believed that iron is involved in different enzyme systems in the brain, including those involved in energy production, in the synthesis of dopamine receptors, in the myelination of nerve cells and in the regulation of brain growth. Furthermore, iron appears to modify developmental processes in hippocampal neurons by altering dendritic growth. Some authors have found significantly lower performances in language skills, motor skills and attention in 5-year-olds, whose levels of ferritin were lower[67]. There is a broad scientific consensus[71] that iron deficiency has a negative impact on cognitive, behavioural and motor skills and these cognitive deficits can appear at any age.

The lack of iron is in fact clearly linked to cerebral alterations at the hippocampus level, mitochondria of the brain, metabolism of dopamine, a neurotransmitter, and the myelination of nerve fibres.

One of the most worrying consequences of **iron deficiency in children is behavioural alteration and cognitive performance**, for which there is a wealth of clinical, biochemical and neuropathological research that shows how iron deficiency can have a deleterious direct effect on brain learning and development, which can also occur with normal haemoglobin levels[72].

Iron supplementation improves cognitive functions and meat, especially beef, provides heme iron, a different form of iron that the body absorbs to a greater extent and is not found in plant or fortified foods. If iron deficiency occurs very early in life, the damage can be irreversible, and it may not be possible to reverse the brain damage with iron treatment[73].

Infants who are breast-fed only, at 9 months of age, get only 10 percent of the iron and zinc they need, and if during post weaning there are only cereals, fruit and vegetables they only get 30% of their needs of these important nutrients. Introducing meat instead as early as the sixth month is an effective way to provide iron and zinc in appropriate quantities[74].

Meat and other products of animal origin, such as milk, contain nutrients such as iron, zinc and calcium which is difficult to find elsewhere, or which are in a highly absorbable form and usable by the body, such as iron.

The World Health Organization recommends the intake of food of animal origin from 6 months of age, highlighting how diets based only on vegetables are not able to meet the nutritional needs of the child, unless the use of supplements or fortified products is used[75].

3.3 The nutrition of adults

During this phase of life, it is important not to increase weight too much, because overweight and obesity are connected to greater health risks. Meat, given its high nutritional density, can therefore be of help to limit calories, while ensuring an adequate supply of nutrients. The prevalence of obesity in Italy has more than doubled in the last 25 years and numerous studies indicate that diets with higher proportions of proteins, obtainable for example with lean cuts of meat and cured meats, are effective for weight loss and maintenance. Meat, thanks to its protein contribution, can also contribute to satiety and consequently reduce the intake of food and energy. As with children and adolescents, adults are also at risk of iron, zinc and iodine deficiencies. Only an adequate diet, which includes also foods of animal origin and in particular meat, can avoid this risk.

A study[76] conducted on 127 young non-anaemic women between 18 and 35 years which wanted to evaluate the relationship between iron status and cognitive performance, highlighted the association between some haematological indicators of the iron status (haemoglobin, amplitude of blood cell distribution, saturation of the transferrin, ferritin, transferrin receptor, and total body iron) with brain function (attention, logic, memory, etc.). In practice better the iron status, better is the performance in sustained attention tasks and planning ability.

3.4 Meat for athletes

It is important for those who practice physical activity to follow a healthy and balanced diet, which provides calories and nutrients sufficient to meet the energy and nutritional needs and can ensure optimal performances during exercise[77]. A good nutrition in fact helps the athlete to train hard, to recover quickly and to adapt effectively to environmental conditions, with less risk of illness and injury. It is no coincidence that physical activity creates a higher energy demand, as well as macronutrients such as carbohydrates, fats and proteins.

Carbohydrates and fats are the primary fuels for exercise, while proteins are necessary for the growth and repair of body tissues: the muscles contain about 40% of the total proteins of the body. When the requirement of amino acids is not satisfied by the diet, **the muscle proteins supply the body with the necessary amino acids, but this happens even after exercise, during the phase of recovery, during which it is essential that there is an adequate supply of protein.**

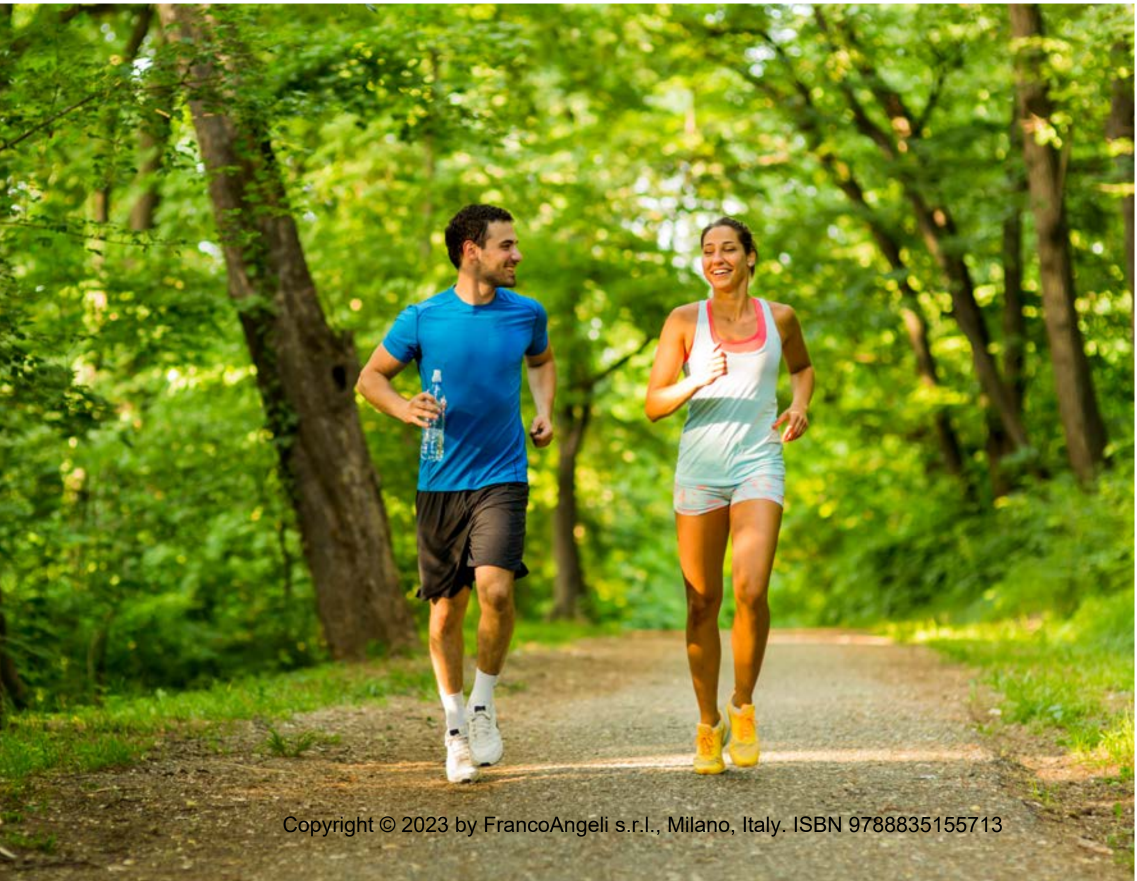
Numerous studies have shown that the **consumption of proteins, and in particular of the essential amino acids that constitute them, before, during, but especially immediately after the workout is capable of stimulating muscle protein synthesis.** It is clear that proteins alone are not enough. But studies on the effects of protein on muscle power have identified some forms, that more than others, are able to optimise muscle protein synthesis, inhibit protein catabolism and therefore stimulate muscle growth. In fact, it is necessary to favour proteins rich in essential amino acids, such as those supplied by milk and its derivatives, eggs, fish and meat. Foods or snacks that contain high quality protein, such as meat and cured meats, fish, eggs or milk should be consumed regularly during the day. In particular, immediately after exercise, to **maximise protein synthe-**

sis, to help maintain muscles and help repair damaged tissues.

Exercise increases the need for some vitamins and minerals. A varied diet capable of balancing energy expenditure satisfies the greater needs of athletes for some micronutrients, but for others, present in a highly digestible form in the products of animal origin like calcium, iron, zinc and magnesium and vitamin B12, there may be a deficiency problem especially in athletes and vegetarians. Iron is a vital component of haemoglobin and myoglobin, proteins found respectively in red blood cells and muscles. **Haemoglobin and myoglobin provide oxygen to the tissues during exercise and the athletic performance of athletes**, especially aerobic sports athletes, depends strongly on the oxygen supply to the muscles so that they can work efficiently. When the state of iron becomes low, less oxygen is delivered to the muscles and sports performances are reduced. Iron deficiencies, often evident in athletes, can therefore compromise sports performances and can be avoided by the intake of highly absorbable and usable iron, such as that contained in beef.

Zinc intervenes in many very important functions such as growth, construction and repair of muscle tissue, the transformation of energy. Athletes, especially women, are at risk of deficiency of this mineral, whose best food source is represented by meat, but also by eggs and fish products.

Some B vitamins (thiamine, riboflavin, vitamin B6, niacin, pantothenic acid, biotin) are involved in the energy transformation process during exercise, while folate and



vitamin B12 are necessary for the production of red blood cells, protein synthesis, tissue repair and maintenance. Although the need for these vitamins is slightly higher in athletes, it is generally covered by the increased energy intake necessary for athletes to maintain body weight.

3.5 The importance of foods of animal origin for the elderly

After 70 years of age you need less calories, because you no longer move like before and metabolism slows down. But to maintain health **the organism still requires the same amount of nutrients and even higher levels for some of them, like proteins**. Even the stomach and the intestine become less efficient. There is a decrease in gastric acid secretion, which can limit the absorption of iron and vitamin B12. With passing of years, the body reduces progressively the perception of feeling hunger and thirst; the regulation mechanisms of glucose and protein synthesis also become less efficient. Even taste fades and very tasty foods tends to be preferred, or excessive quantities of salt and seasonings are added to the food. The losing of teeth or the decrease in taste and smell always make favourite foods less attractive[78].

Meat and cured meats are part of a balanced diet for the elderly[79] and their consumption is recommended as it provides high biological value proteins and microelements including iron, vitamin B12, zinc and selenium. Once you reach adulthood muscle mass begins to decrease and the rate at which it is reduced accelerates after 50 years of age: **muscles represent about the 45% of body weight between 20 and 30 years, falling to only 27% of body weight at the age of 70.**

This tendency to lose muscle mass, called **sarcopenia**, is accentuated if one does not assume sufficient quantities of protein. It is therefore very important for adults to consume adequate amounts of high quality protein at every meal, in combination with exercise[80]. It is clear that essential amino acids are fundamental for **the optimal stimulation of the synthesis of muscle proteins** and the amino acid leucine is a powerful signal of this process. Animal proteins have the highest proportion of the amino acid leucine[81].

Sarcopenia has numerous consequences in the elderly: **loss of strength** and ability to perform the activities of daily life, **loss of independence, an increased risk of falls[82], frailty, disability, poor health and lower longevity**[83]. In the PURE study, for example, which followed 140,000 adults aged between 35 and 70 in 17 countries, it was shown that greater muscle strength is associated with longevity and reduced cardiovascular risk[84].

A slightly larger amount of protein than in adulthood can be useful for the elderly, who can increase their reserve capacity and counteract the progressive loss of muscle mass, but also **to prevent the fragility of the skin and the reduction of immune functions, resulting in better recovery from disease**[85].

A vitamin B12 deficiency in the elderly is associated with decreased memory and hearing. Another nutrient at risk of deficiency in the elderly is **zinc, involved in the process of healing wounds, vision, taste and smell.** Most of the nutrients for which the needs in the elderly are increasing are found in large quantities and in easily assimilated form in foods of animal origin.

LONGEVITY: WHY MEAT CONTRIBUTES TO INCREASING LIFE EXPECTANCY

Life expectancy at birth is a measure that expresses the average life span in a population. It is estimated that 20-30% of life expectancy in humans is determined by genetic factors and ***70-80% by environmental factors****, such as* ***diet****.*

A recent study[1] conducted by the University of Adelaide in Australia and published in the International Journal of General Medicine examined the overall effects of meat consumption on health in over 170 countries around the world. The study showed that ***populations that consume more meat have a longer life expectancy****. Total meat consumption is in fact* ***related to greater longevity****, independent of confounding effects such as total calorie intake, economic well-being, urban advantages or obesity. The authors of the research argue that the reason for the result lies in the ability of meat not only to provide energy, but also a high amount of essential nutrients for the human body.* ***Evolutionarily, meat has probably been an indispensable component of the human diet*** *for millions of years, as genetically demonstrated by meat-digesting enzymes and the anatomy of the digestive tract. The complete nutritional profile of meat and human adaptation to meat consumption have allowed man to obtain many physical benefits, including a longer life expectancy. The authors of the study argue that although the recent epidemiological literature shows that the increase in the consumption of meat, especially in its processed forms, can increase the risk of cancer, cardiovascular disease, obesity and diabetes, clinical evidence to consolidate these data is currently lacking. From a statistical point of view, the results of this study indicate unequivocally and independently that the consumption of meat is* ***beneficial for life expectancy****. Furthermore, the epidemiological literature is not reflected in the guidelines for healthy eating published by government authorities for the general public.*

These guidelines always include meat as the ***main component*** *of the human diet. Meat contains a high protein content with all essential amino acids and is a good source of minerals (iron, phosphorus, selenium and zinc) and vitamins (B12, B6, K, choline, niacin, riboflavin). Simply put, by eating meat humans get* ***virtually all of the constituent compounds*** *of his body. Well-planned vegetarian diets, including vegan ones, may be nutritionally adequate and suitable for different individuals at all stages of life, but only because their nutritional composition adequately mimics and substitutes those commonly supplied by meat.*

[1] You W., Henneberg R., Saniotis A., Ge Y., Henneberg M., Total Meat Intake is Associated with Life Expectancy: A Cross-Sectional Data Analysis of 175 Contemporary Populations, Int J Gen Med., 2022 Feb 22, 15:1833-1851, doi: 10.2147/IJGM.S333004. PMID: 35228814; PMCID: PMC8881926.

4 MEAT AND **HEALTH**

Dietary habits are intimately linked to different aspects of human life, such as growth, development, resistance to disease, and it is well established that they represent the most influential environmental factors in duration and quality of life.

To date, many nutritional strategies have been studied to prevent or delay the beginning of a disease, or even to optimise the therapy. But it is clear that not all individuals respond in the same way to dietary changes and part of this variability is due to individual genetic and epigenetic differences, which can in turn influence absorption, digestion, metabolism, excretion and the action of bioactive food compounds. Although dietary factors are important in many of the chronic degenerative diseases that are the main causes of illness and death in wealthy societies, **it is very difficult to determine with certainty a cause-effect relationship.** In fact, chronic diseases have many causes and take years to develop: eating habits can however be clearly a "risk factor".

The scientific methods for investigating chronic diseases, their causes, treatment and prevention are mostly epidemiological, a method that studies the prevalence of the frequency with which diseases occur and the conditions that favour or hinder their development, including dietary habits. These studies can focus on the subjects after the diagnosis of the disease (retrospective studies), or before the diagnosis (prospective studies). The influence of data and recommendations from developed countries on nutritional guidance **has often overshadowed the recognition of essential micronutrients and the contribution of proteins which, for example, meat contributes towards and whose legacy of key proteins and micronutrients is often underestimated**[86].

For example, in recent decades there has been an increase in the prevalence of some chronic diseases related to diet and lifestyles such as overweightness and obesity, hypertension and diabetes. While the incidence of these diseases continues to grow over the years, the general increase in food consumption that characterises the era in which we live, has partly reversed the trend, especially for some foods such as meat, whose daily intake has decreased over time.

The key to the question of **meat** is therefore the quantity to be consumed, since it is a f**ood with a high nutritional value**, and the modest quantities recommended by the Mediterranean diet allow us to benefit from its valuable effects without any risk to our health[87].

4.1 Cardiovascular diseases: saturated meat fats are acquitted after 40 years of accusations

Diseases that affect heart and blood vessels - cardiovascular diseases - include numerous health problems, many of which are linked to a process called arteriosclerosis, a condition that develops when a substance called plaque is deposited on the walls of the arteries. Its accumulation restricts the arteries, making the flow of blood more difficult. If a clot forms inside the arteries, blood flow can be stopped. This can cause a heart attack or stroke. **Cardio-cerebrovascular diseases are one of the most important public health problems in Italy (consider that approximately 35% of all deaths are due to cardiovascular diseases).**

Cardiovascular diseases are for the most part preventable through the adoption of healthy lifestyles, especially **healthy nutrition, regular physical activity and the abolition of cigarette smoking**. Meat is often considered with concern regarding **heart health, but not all scientific studies agree on this point**[88].

A reasonable amount of lean beef can be included in a healthy heart diet, and can have favourable effects on the metabolic syndrome and coronary heart disease. For example, in some studies it has been observed that adults with high cholesterol, taking 100-115 g of lean beef per day, but limiting the intake of saturated fat to less than 7% of total calories, have had a significant decrease in total cholesterol and LDL cholesterol compared to subjects with a diet low in meat but with 12% of total calories from saturated fats[89].

A recent cohort study conducted in the United States and published in the scientific journal JAMA suggests that, among US adults, higher intakes of processed meat, unprocessed red meat or poultry, but not fish, were significantly associated with a small increase in the risk of cardiovascular disease, while higher intakes of processed meat or unprocessed red meat, but not poultry or fish, were significantly associated with a small increase in the risk of all-cause mortality[90].

The EPIC study also showed a significant increase in the risk of death due to cardiovascular disease linked to the increase in consumption of processed meat (HR 1.72 [95% CI 1.29-2.30]) comparing higher and lower consumption (> 160 g per person per day compared to 10-19.9 g)[91]. There was no significant correlation with unprocessed white and red meat with regards to cardiovascular death.

In summary, the indications of the WHO to prevent cardiovascular diseases are to **reduce the consumption of saturated fats**, in order to control the level of "bad cholesterol" in the blood: hence the suggestion to prefer lean cuts in the choice of meats. But also to pay attention to other foods: **saturated fats are also present in dairy products, in many baked goods and fried foods.**

Some plant foods, such as **palm oil or coconut oil**, for example, contain **large quantities of saturated fats**. Taking into consideration the food composition tables of some products already shown in the nutrients section, it turns out that meat and cured meats are in effect among the least responsible foods for the intake of saturated fats.

In 2017, the results of the important PURE (Prospective Urban Rural Epidemiology) study do not support current recommendations to limit daily intake of fats to less than 30% of total energy and that of saturated fats to less than 10%, because **it is unlikely that decreasing the overall consumption of fat leads to an improvement in health, as would happen by reducing carbohydrate consumption**. Limiting total fat consumption to around 35% of energy taken daily and contemporaneously carbohydrate intake can reduce the risk of total mortality.

4.2 Tumour pathologies

Cancer is one of the main causes of morbidity and death all over the world: on average each year there are about 14 million new cases and 8.2 million cancer-related deaths. The five most common types of malignant cancer in men are those of the lung, prostate, colorectal, stomach, and liver tumours; on the other hand, the five most common types of neoplasms in women are breast cancer, colorectal, lung, cervical and stomach cancers.

Although dark areas remain, it is now established that the **interaction between genetics and the environment promotes carcinogenesis**. In particular, some physical carcinogens (such as **ultraviolet and ionising radiation**) and biological (**viral, bacterial or parasitic infections**) interact with behavioural and **food risk factors such as obesity**, insufficient consumption of fruit and vegetables, **lack of physical activity, the use of tobacco and alcohol**, to promote the transformation of a normal cell into a malignant cell. A phenomenon that can be amplified in individuals particularly predisposed genetically[92].

Amongst the various factors, **eating habits play an important role in increasing or reducing the risk of various cancers**. Although the causal relationship between diet and cancer is complex and can hardly be unveiled due to the fact that diets are characterised by many different foods and nutrients, there is substantial evidence that certain foods may be more harmful than others[93]. Despite progress in scientific knowledge, however, areas of disinformation persist, sustained by prejudices and health simplifications, not always spread correctly by some mass media. And so foods are often classified as "**good**" and "**bad**", which disorients the consumer even more.

In fact, **no product can be considered good or bad for health, but must be evaluated by the nutrients which it contributes towards the daily diet, keeping in mind that the daily limit for each category of food in a balanced diet is not exceeded**. It must in fact always be remembered that cancer diseases are diseases extremely complex because:

- there are over 100 types of cancer for which the causes are not always known;
- people's diets contain an almost imponderable number of different components, some of them may decrease and others increase the risk of developing tumours;
- the development of a tumour takes place over a very long time making it very difficult to establish a sure and reliable relationship of cause and effect;
- many questions on diet and tumours remain unanswered, and often studies are based on tests done on animals in the laboratory without direct evidence on humans;
- recommendations for a correct diet that reduces the risk of contracting a tumour must be based on relevant scientific evidence, and not refer to a single study.

IARC studies

As seen, the nutrition-cancer correlation is very difficult to study because there are many elements, real or presumed, that can favour the onset and development of tumour pathologies. In support of the recommendations of national authorities there are the studies of the International Agency for Research on Cancer (IARC) based on national studies that highlight and classify the **agents considered, undoubtedly or presumably, responsible for the onset of tumour pathologies.**

RED MEAT DOES NOT CONSTITUTE A HEALTH RISK:
NEW SCIENTIFIC EVIDENCE

*In 2021, the study[1] published in **Nature Medicine** and carried out by the IHME, the **Institute for Health Metrics and Evaluation** showed that "**red meat does not pose a health risk**". According to the study's authors, many of the previous meta-analyses that have linked red meat consumption to various health problems such as heart disease, stroke and cancer have **significant methodological limitations and do not assess the strength of the evidence**. In the study, the scientists of the IHME of the University of Washington instead examined decades of research on the consumption of red meat, developing a new, more scrupulous analysis procedure that **overcomes the serious limitations of past research** and were able to conclude that **only weak evidence exists** and therefore nonsignificant evidence that red meat consumption may be linked to colorectal cancer, breast cancer, type 2 diabetes, and ischemic heart disease, and no link was found between red meat consumption and the occurrence of ischemic strokes. For haemorrhagic strokes there would also be a reduction in the risk associated with the consumption of red meat.*

*In 2019, **NutriRECS**[2] - an independent and international research group that works with the aim of producing guidelines in the clinical, nutritional and public health fields - had already published recommendations[3] regarding the consumption of meat, stating that adults should not change their consumption due to the **uncertainty of increased risk** associated with higher consumption. These recommendations are based on parallel systematic reviews on the possible effect of unprocessed and processed red meat consumption on cardio-metabolic and cancer factors and on a systematic review on consumer preferences regarding meat consumption. Although based on very solid studies, even the Nutri-RECS guidelines continue to have gaps. Indeed, most of the evidence on meat intake and health outcomes comes from studies conducted in North America, Europe, and Japan, where the amount and type of meat consumed differs from other regions of the world (e.g., South Asia and Africa). An **even more recent multinational study**[4] helped fill this gap by exploring the possible health consequences of meat intake in low-, middle-, and high-income countries. To conduct their research, the authors drew on findings from the Prospective Urban Rural Epidemiological (PURE) study, a long-term study that began in 2003.*

*The PURE study tracked the dietary habits and health outcomes of more than 164,000 participants from 21 low-, middle-, and high-income countries across five continents. The results showed **that the consumption of moderate amounts of unprocessed meat does not increase the risk of cardiovascular disease or affect mortality**. Conversely, higher intake of processed meat is associated with higher risks of both total mortality and cardiovascular disease.*

[1] *Lescinsky H., Afshin A., Ashbaugh C., Bisignano C., Brauer M., Ferrara G., Hay S.I., He J., Iannucci V., Marczak L.B., McLaughlin S.A., Mullany E.C., Parent M.C., Serfes A.L., Sorensen R.J.D., Aravkin A.Y., Zheng P., Murray CJL., Health Effects associated with Consumption of Unprocessed Red Meat: a Burden of Proof Study. Nat Med. 2022 Oct;28(10):2075-2082, doi: 10.1038/s41591-022-01968-z. Epub 2022 Oct 10. PMID:36216940.*

[2] *Nutritional Recommendations (NutriRECS) Consortium https://www.nutrirecs.com/.*

[3] *Johnston B.C. et al. (2019), Unprocessed Red Meat and Processed Meat Consumption: Dietary Guideline Recommendations from the Nutritional Recommendations (NutriRECS) Consortium, Ann Intern Med. 171(10):756–64, doi:10.7326/M19-1621.*

[4] *Iqbal R. et al. (2021), Associations of Unprocessed and Processed Meat Intake with Mortality and Cardiovascular Disease in 21 countries [Prospective Urban Rural Epidemiology (PURE) Study]: A Prospective Cohort Study, Am J Clin Nutr.:1-10, doi: 10.1093/ajcn/nqaa448/6195530.*

The mere presence of an agent in the classification does not immediately make it dangerous because it is necessary to understand, in addition to the level of carcinogenicity, also what are the **quantities and durations of exposure** that transform the theoretical into real risk, as well as what the real factors of risk are. Cigarette smoke is certainly carcinogenic, but those who smoke a single cigarette a day do not run a real risk of tumour development. The chemical compounds that are generated in cooking over a high flame and involve the burning of food are risky: **the modification of cooking habits immediately reduces the risk**. In the case of **processed and red meats**, the most probable cancer pathology is related to colorectal which could be more likely attained by consumers of large quantities than moderate ones. The IARC studies have associated **excess consumption with an increase in the relative risk** of about 18% for transformed and 17% for red meat. It is essential, however, not to confuse **absolute risk** (for simplicity we could to say real) with relative, which **only represents the increase of the absolute risk**. IARC data tell us: people that consume larger quantities of red meat (more than 100 g per day) have a 17% increase in the risk of colon cancer compared to those who consume a small amount of meat. According to IARC, processed meat increases the risk by 18% with 50 g per day. These figures, however, **represent a relative risk**. In reality they mean that if 6% of people in a population are likely to develop colon cancer (60 out of 1000 people), among those who eat small amounts of meat this number is

IARC CLASSIFICATION

Amongst all classified agents, only 6 (red meats, processed meats, coffee, alcohol, matè, salted fish Chinese style) are foods/beverages. The others are made up of substances or molecules belonging to various groups, amongst which pollutants and by-products of industrial production stand out. All other agents are chemicals or work environments that are potentially at risk.

GROUP 1 - CARCINOGENIC TO HUMANS: an agent characterised by an evident level of carcinogenicity in humans. This class contains 120 substances (e.g. tobacco smoke, alcohol (from 2012), arsenic, asbestos, plutonium, atmospheric pollution, solar radiation, etc.).

GROUP 2A - PROBABLY CARCINOGENIC TO HUMAN: limited evidence of carcinogenicity in humans and sufficient evidence in experimental animals. The substances included in this category are 82, the only food/drink present is matè (infusion) incriminated also by the fact of being consumed very hot, a risk factor for cancer of the oesophagus and the oral cavity.

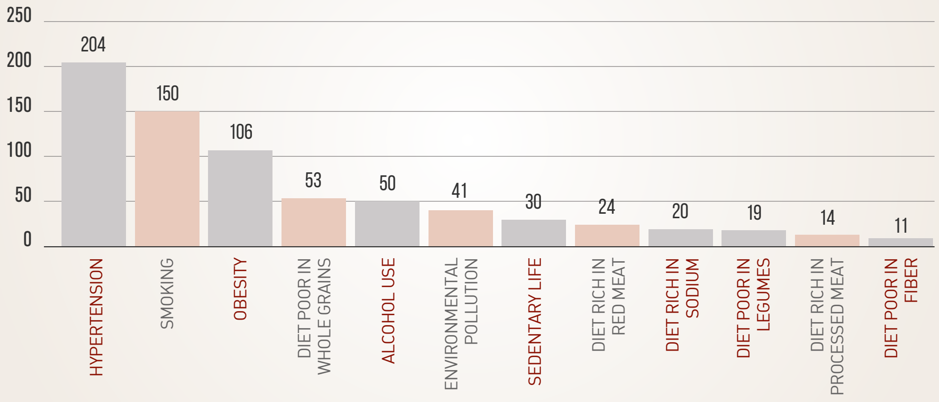
GROUP 2B - POSSIBLY CARCINOGENIC TO HUMANS: limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals. A category that includes 302 substances.

GROUP 3 - NOT CLASSIFIABLE AS TO ITS CARCINOGENITY TO HUMANS: a category usually used for agents for whom the evidence of carcinogenicity is inadequate in humans and inadequate or limited in experimental animals. This is the most numerous category with 501 substances.

GROUP 4 - PROBABLY NON CARCINOGENIC TO HUMANS: absence of carcinogenicity both in humans and in experimental animals. At the moment the only substance included in this category is caprolactam, the precursor in nylon production.

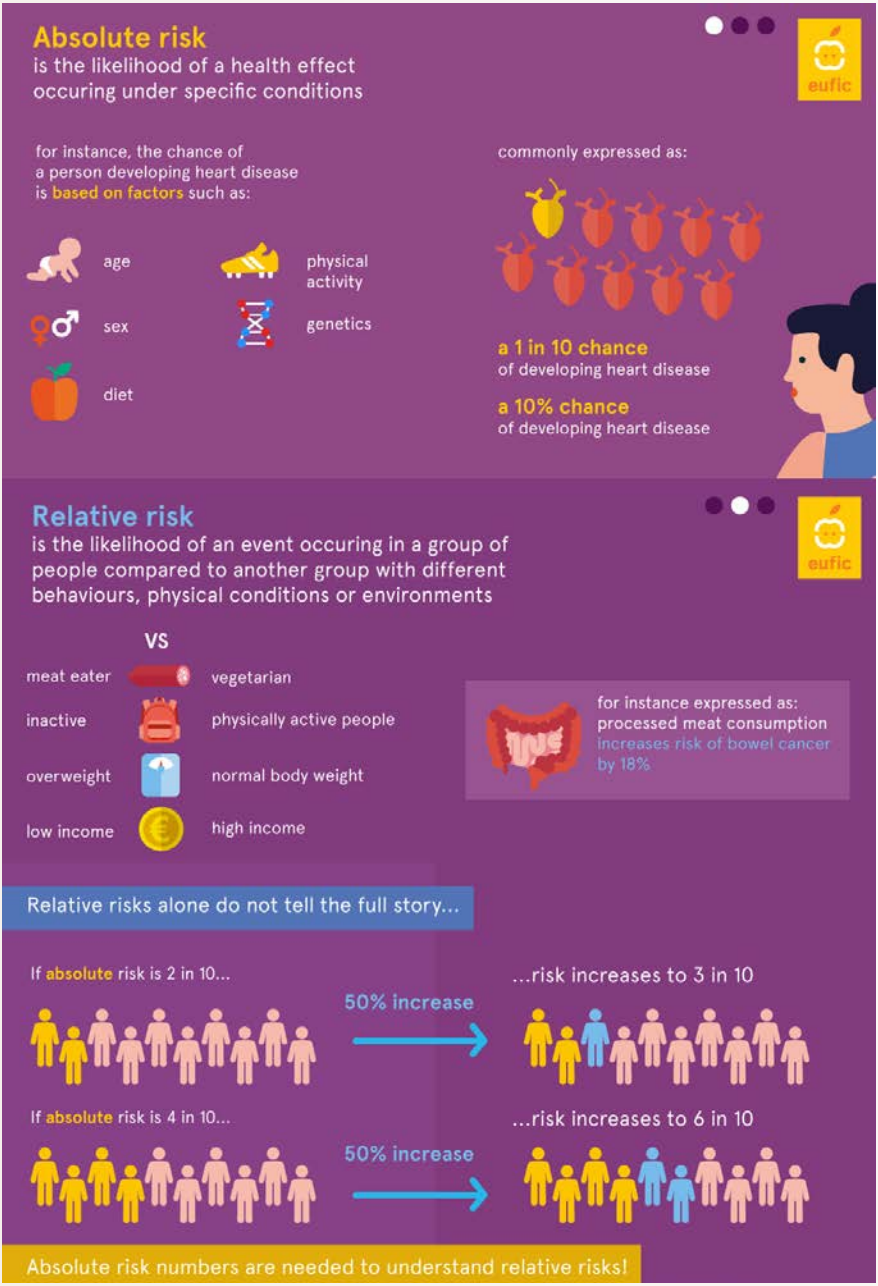
more likely to be 5.6% (56 people in 1000), and among high-volume consumers this number is expected to rise to 6.6% (66 people in 1,000). **So the absolute risk between those who eat too much or too little meat is only 1%.** Another very important element concerns the quantities covered by IARC research, which are **50 g of processed meat or 100 g of red meat per day.** These consumptions are **much higher than those of typical Italian consumers** and, in general, those of the world. Wanting to examine in depth even if in a preliminary way the issue of risks to people's health, the information can be used published on the project database of the **Global Burden of Disease** project (www.healthdata.org/gbd), which is proposed as a health measurement system aimed to estimate the weight of single factors (for example, tobacco consumption) or groups of factors (physical environment, accidents) on the development of diseases and therefore able to guide policies and programmes. From these data, it emerges that colorectal cancer is actually one of the main causes of death in developed countries, but with a rather low incidence (about 3% of deaths in 2019). If the analysis moves on to risk factors, regardless of the type of pathology generated, it is instead interesting to observe how the first risk factor worldwide is that of high blood pressure, followed by cigarette smoking. **A diet low in whole grains causes almost twice the number of deaths as a diet high in red meat: further confirmation of the importance of following the Mediterranean diet guidelines.**

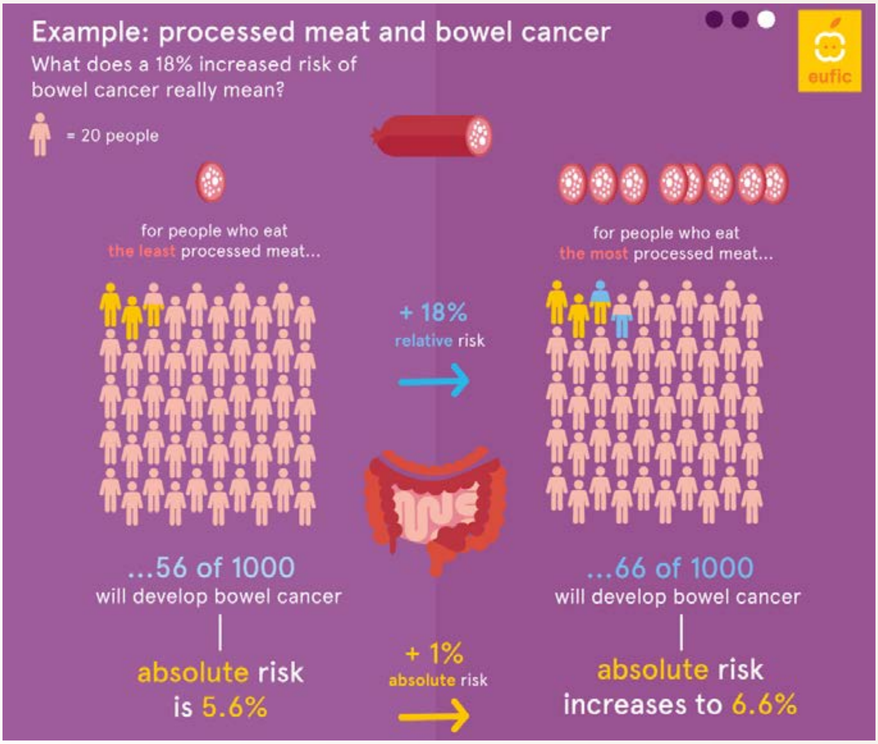
BEHAVIORAL RISK FACTORS FOR HEALTH: NUMBER OF DEATHS EVERY 100,000 PEOPLE



Source: Institute for Health Metrics and Evaluation GBD 2019; extraction made in August 2022 taking into account behavioural risk factors in Italy.
It should be noted that the data reported for red meat is decidedly higher than the historical series analysed by the GBD of previous years (equal to 1.14 in the 2016 GBD) and is still subject to discussion by the scientific community, therefore it could suffer changes in future editions.

THE DIFFERENCE BETWEEN ABSOLUTE RISK AND RELATIVE RISK





Source: EUFIC, 2015 - How To Talk about Food Risk? A Handbook for Professionals. pp. 40-41.

In the report "How to talk about food risk? A Handbook for Professionals", the EUFIC, the European information food board council (a non-profit organisation, established in 1995, which fights for scientific information on food and health), contains an interesting study on the importance of the ***distinction between absolute and relative risk.***

Absolute risk *is the difference between the disease rate of a risk category and that of a control group; the* ***relative risk****, instead, is the relationship between the illness rate of a risk category and that of a control group. Relative risks, if not reported in the context of absolute risk, may be misleading.*

Absolute risk data, on the other hand, is necessary to understand the implications of the relative risks and how specific factors or behaviours can influence, for example, the likelihood of developing a disease or a particular health status. In other words, the absolute risk measures the clinical impact associated with exposure to a certain risk factor, the one related to the strength of the association. The infographic shows an example of ***treated meat consumption*** *and the risk of bowel cancer. The* ***relative risk*** *of developing bowel cancer for those who eat less treated meat respect to those who eat more treated meat increased by 18%; when related to* ***absolute risk****, this involves a small increase, equal* ***to 1%****, from 5.6% to 6.6%.*

ELEMENTS OF CANCER RISK IN MEAT

According to the IARC, the risk factors of meat are due to substances that may be particular to meat (e.g. ***heme iron****), and/or* ***originated during processing or cooking at high temperature (e.g. NOC nitrous compounds or HAA aromatic amines).*** *These substances in the long run, when introduced into the organism, can be co-responsible for the development of forms of tumour due to different biochemical mechanisms.* ***An example can be that of aromatic amines (HAA), genotoxic substances potentially capable of damaging genetic information inside a cell causing mutations and inducing changes in DNA. The suggestion of limiting the consumption of red meat is therefore accompanied by that of avoiding cooking with an open flame, such as the barbecue.*** *For completeness it is useful to observe that this phenomenon is not typical of meat, but of the method of cooking: the same dangerous compounds, even if to a lesser extent, are formed in other foods, such as for example grilled vegetables or pizza cooked in a wood oven.*

NITRATES AND NITRITES + HEME IRON + COOKING

Nitrosamines*: are organic compounds containing a nitrous group, -N = O, bound to the amino nitrogen. They are obtained in very acidic conditions or at high temperatures due to the reaction of the nitrites with a secondary amine, which may be present within a protein structure. Many nitrosamines are carcinogenic, i.e. provoke genetic mutation, as demonstrated by animal studies in laboratory; their intake is linked to the development of stomach and oesophagus cancer. The problem of nitrosamines is linked to the presence of* ***nitrate*** *as a* ***natural component of food, convertible into nitrite in the mouth thanks to saliva,*** *and to the use of nitrite as a food preservative, essential to prevent the development of micro-organisms in foods such as the botulinum bacterium. Nitrite finds optimal conditions to produce nitrosamines inside the stomach or through cooking methods such as frying or roasting.*

Heme Iron*: is found in meat in the form of haemoglobin and myoglobin. The heme iron is released by these proteins due to the low pH in the stomach and the action of proteolytic enzymes in the stomach and small intestine, to be then absorbed by the mucosa and transported in the blood directly to the cells to make haemoproteins. The negative effects of very high amounts are cytotoxicity and increased formation of endogenous N-nitrous compounds (NOCs), which can increase the overall mutation rate in the DNA of the colon tissue.*

Heterocyclic amines*: form in meat and bread if they are burned, due to cooking at too high a temperature. In human populations an association between the ingestion of "burned" meat and the risk of cancer has not been identified. Probably it has a limited effect and is difficult to identify.*

COOKING AND SMOKING

Polycyclic aromatic compounds: *are formed after cooking at high temperatures and smoking. Although more than a hundred different PAHs exist, IARC (International Agency for Research on Cancer) has added to the lists those most dangerous or more responsible for serious damage to human health. Repeated exposure to certain types of PAHs has been shown to increase the onset of cancer significantly.*

Not all meats are the same

Once clarified which substances are characterised by the greatest risk factors, it is advisable to analyse in-depth relative to their presence in the various cuts of the meat.
A first analysis is about nomenclature: it must be clarified what is meant by red and processed meat. In traditional culinary terminology, meat is conventionally classified as "red" when characterised by a typical red colour, while "white" usually defines a sub-type with a lighter colour. Although the semantic debate is still open, the first type defines "**red**" as the meat of the majority of large mammals (**cattle**, **pigs**, **sheep**, **goats**, **horses**) while the "**white**" type identifies poultry (**chicken, turkey**) and rabbit.

One of these substances, **heme iron**, is characterised by a marked variability both between red and white meat and between groups of red meats.
Nitrites, another critical substance, is mainly contained in **processed meats** (where they play the **role of preservative**), but also in other **foods**. Fresh vegetables, for example, contain high amounts of **nitrates, which can be turned into nitrites**. It should be remembered that most PDO cured meats are free of these substances[42].

As for **aromatic amines (HAA)**, their presence is strictly **related to cooking methods**: the data published in the EPIC study observed in fact the change in the content of the main substances between fresh meat (with zero value) and cooked meat in various ways. In this context, **communication to consumers should recommend a change in meat cooking methods**, rather than a general reduction in consumption[97]. Finally, for **polycyclic aromatic hydrocarbons**, the EFSA opinion indicates that indicates that the two major contributions to **dietary exposure are cereals, products derived from cereals, and seafood** and their derivatives. For these substances it is also important to observe how **in smokers the contribution of the diet is almost zero compared to that of the smoke.**

PRESENCE OF IRON AND HEME IRON IN MEATS

in mg/100 grams

MEAT TYPE	CUT	FE TOT	FE HEME
BEEF	Fillet steak	2.3	2.1
	Roast beef	2.0	1.8
	Rump	1.9	1.7
SHEEP	Sheep thigh	2.2	1.7
	Lamb thigh	0.9	0.4
PORK	Loin	0.4	0.2
	Steak	0.5	0.3
POULTRY	Breast convent.	0.4	0.1
	Thigh convent.	0.7	0.2
	Bio breast	0.6	0.3
	Bio thigh	1.0	0.5

Source: Lombardi-Boccia G. et al., 2004[48] - Mele M. et al., 2015[42].

PRESENCE OF NITRATES AND NITRITES IN SOME FOODS

in mg/100 grams

NITRITES AND NITRATES: THE HIGHEST CONCENTRATIONS ARE IN VEGETABLES

mg/100g	NITRATES	NITRITES
Beetroot	329	0.60
Celery	315	0.08
Radishes	258	0.48
Spinach	247	0.38
Lettuce	233	0.06
Beets	203	0.13

mg/100g	NITRATES	NITRITES
Raw ham PDO	0	0
National raw ham	0	0
Choice cooked ham	6	5
Bacon	21	0
Frankfurter of pure pork	13	0
Zampone Modena PGI	0	7
Sausages PDO	1.4	0

From: food content of potentially carcinogenic substances[98].

FOOD CONTENT OF POTENTIALLY CARCINOGENIC SUBSTANCES

in mg/100 grams

THE FOOD CONTENT OF POTENTIALLY CARCINOGENIC SUBSTANCES	PHLP (ng/g)	MELQX (ng/g)	DIMELQX (ng/g)	AC (ng/g)	IQ (ng/g)	MELQ (ng/g)
Fresh beef	0	0	0	0	0	0
Beef grilled (rare)	0-1.2	0-1.1	0	0	0	0
Beef grilled (well cooked)	0-15.0	0-2.2	0-4.3	0-4.15	0	0
Beef grilled (very cooked)	5.7-33.3	1.2-5.8	0.4-1.9	0	0	0
Fried beef	0-23.2	0-8.2	0.1-1.3	0	0-2	0-1.7
Hamburger	0.2-18.4	0.2-1.8	0-0-1	0	0	0
Pork meat (fried or grilled)	0-7.8	0-3.8	0-1.1	0	0-0.7	0-0.1
Chicken meat (fried or grilled)	0-270	0-9	0-4	0-170	0	0
Bacon	0-46.2	0-23.7	0-3.4	0-0.1	0-10.5	0-1.7
Frankfurters	0-0.6	0-0.7	0-0.2	0	0-0.2	0-0.1

From: food content of potentially carcinogenic substances[98].

Protective effect of a balanced diet: vitamin C, vitamin D, folic acid and calcium

The analysis of all this data, which doesn't identify in a clear way a "good" and a "bad", confirm once again that a diet should be considered as a whole and that **the correlation of causes and effects is very difficult, when referring to a single food or food substance**. Some studies have recognised the protective role[99] of **calcium**, milk or whole grains, often associated with a lower risk of colorectal cancer, and there is substantial evidence for the potential chemo preventive effects of **vitamin D**, **folic acid**, fruit and vegetables, also because of their **vitamin C** content.

CONTENT OF POLYCYCLIC AROMATIC HYDROCARBONS

in µg per kg

FOOD	PREPARATION	TOTAL PAH (µg/kg)
Beetroot	raw	14
Cauliflower	raw	2.8
Lettuce	raw	2.6
Courgette	raw	8.9
Apple	raw	8.3
Oatmeal bread	oven	64
White bread	oven	3.2
Breakfast cereals	dried	5.7-59.5
Cereal flour	dried	8.6-38
Pizza	oven	13
Bacon	smoked	6.8
Beef	smoked	9.7
Beef	barbecue	5.7-42.1
Chicken	barbecue	0.6-60.2
Ham	smoked	2.6-9.5
Pork meat	barbecue	3.1-13.6
Salmon	smoked	86.6
Herring	smoked	55-180

Source: Food Content of Potential Carcinogens, EPIC, 2004.

Suggestions

It is clear that every food, including water, every nutrient or food substance presents actual, presumed or potential risks closely related to the quantities consumed, the individual and lifestyle. Meat has high nutritional qualities and its consumption in moderate quantities is linked to proven and consolidated benefits over thousands of years. The benefits and risks associated with the consumption of red and processed meat should not cause dilemmas, if these meats are consumed in moderate quantities as part of a balanced diet[100]. However, there remains considerable uncertainty about the risks associated with specific types of red meat (e.g. pork and beef) and processed meat and, in fact, on which meat to consider processed[101]. It is risky to give credit to information which, on the basis of a hypothesis of risk of a minimum increase in the probability of a disease (such as cancer) leads to **a specific risk of nutritional deficiencies and to the known effects that result at metabolic and cognitive level**. These considerations have an even greater value when they concern the diet of growing individuals, that in subjects of old age or with particular health conditions.

The opinion of the CNSA

The National Committee on Food Safety (CNSA) has made clarity on the IARC report about meat and cancer, sustaining that:

(...) *meat is an important source of high biological value proteins, amino acids, vitamins, minerals and metals (in particular iron and zinc) in human nutrition and, above all, in certain age groups and/or physiological states, as well as in particular health conditions;* (...) and also, (...) *that colorectal cancer, like all neoplasms, is the result of several factors and is triggered by the interaction between environment, lifestyle and genetics; which, in this general framework, are particularly relevant: weight excess, sedentary lifestyle, low fibre consumption, excess calories in the diet, lifestyle as a whole, including food* (...) and it is recommended (...) *to follow a varied diet, inspired by the Mediterranean model, avoiding excessive consumption of red meat, both fresh and processed* (...) *avoiding the excessive consumption of each food*".
(Source: www.salute.gov.it/imgs/C_17_pubblicazioni_2473_allegato.pdf)

5 IS MEAT CONSUMPTION SUSTAINABLE?

The starting point for assessing whether people's food consumption is consistent with the guidelines suggested by nutritionists is to quantify the consumption data per capita per year. Scientific literature offers a lot of information in regard, that however has a limited usefulness due to the many variables in terms of in-depth detail and the boundaries of the analysed phenomena. The following however is a proposed analysis that, although preliminary, provides some interesting information on the consumption of meat and cured meats.

5.1 How people's food consumption is estimated

In general, food consumption can be estimated using two different approaches: the calculation of **food availability** and the **detection** of real consumption.

Availability of food (apparent consumption)

The first method is to estimate a very general picture of the food resources available for human consumption in a country in a given period of time, to the point that its monitoring is normally carried out by major institutional sources (ISTAT, Eurostat, FAO...) showing the relationship between food availability in a country and the number of inhabitants accessing available resources. In the case of meat, the data is given in **equivalent carcass weight** which,

$$\frac{\text{(production + import + initial provisions) - (non-food use + export + final provisions)}}{\text{number of inhabitants of the country}}$$

including non-edible parts (tendons, bones, fat, ligaments), tends to overestimate the real consumption: in this case it is **apparent consumption**. By their nature, this information should not be used to study the relationship between food and consumer health, unless it accepts the enormous overestimation of real meat consumption.

Real consumption

Real consumption is estimated by surveying families or people through specific surveys of well-defined population samples. Although for simplicity in this work the two methods are assimilated, in truth the survey on families is normally conducted analysing the economic expenditure of a given period of time through interviews, while that on individuals involves just the consumption of a given food by a specific sample of people over a given period of time. These methods are used by organisations specialised in the analysis of statistical data, such as CREA, Nielsen, Eurisko, or by scientific studies as in the case of the *European Prospective Investigation into Cancer and Nutrition* (EPIC) project. They are ideal for the acquisition of information useful for the study of the relationship between eating habits and health of people, but they have the defect of being very expensive.

DIFFERENCE BETWEEN APPARENT AND REAL CONSUMPTION

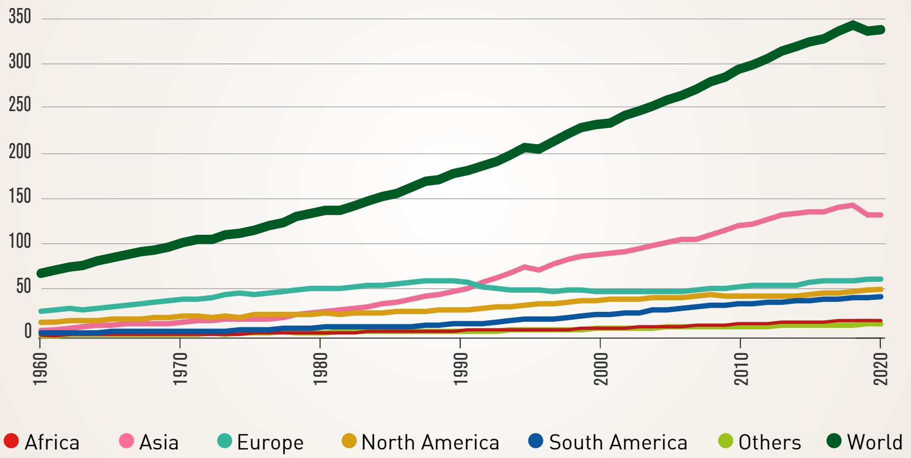
	APPARENT CONSUMPTION	REAL CONSUMPTION	
	FOOD AVAILABILITY (APPARENT CONSUMPTION)	MONITORING FAMILY EXPENDITURE	INDIVIDUAL CONSUMPTION
MODE	Mathematical relationship between quantity of available food and inhabitants.	Detection of expenditure (and sometimes quantity) for the purchase of food by families.	Detection of individual or group consumption in 24 hours or in longer periods by diary or interviews.
TARGET	Know the amount of food available in a country. Compare trends and consumption amongst various countries. Orient decisions on agri-food policies.	Analyse food spending by various sampling of people. Monitor food consumption over time.	Evaluate per capita consumption of food. Studying the relationship between diet and health.
CRITICAL ISSUES	Does not include production for self-consumption. Includes non-edible parts. Difficulty in estimating quantities destined for non-food uses. Includes losses in the different stages of the supply chain. In calculating people, it does not take into account the balance of the flow of tourists as well as non-resident immigrants.	Detects the expense and not the quantity purchased. Does not estimate eating meals outside the home. There is no distinction between the moment of purchase and the moment of consumption. Methodological aspects related to sampling.	The detection can consider weights or number of portions as well as raw or cooked weight. Considers with difficulty waste in the plate. Preparations with different types of ingredients (e.g. meat and vegetables). Methodological aspects related to sampling. Participant reliability. Cost of the method.

5.2 The consumption of meat in the world

In 2020, the world's theoretical meat supply reached about **340 million tons per year** (FAOSTAT data). Over 40% in the Asian continent only. Which, since the early nineties, has contributed more to the growth of the volumes. Europe and North America contribute in a more limited way, with values that measure respectively 27% and 8%. The most consumed species are pork, chicken and beef, although with different annual trends: consumption of beef has been **substantially stable** for over 20 years, while over the same period the consumption of poultry meat has almost doubled. Albeit with some differences between the various species, there is no doubt that the consumption of meat has undergone, over the last 30 years, a clear increase at global level, an increase referring also to the increase in the world population, from about 3 billion in 1960 to the current 8 billion. However, it is worthwhile focusing on the individual regions of the world to see how and where people's eating habits have changed over time. To do this, the theoretical availability data per capita in the same areas already studied are analysed. Also in this case there are substantial differences between the various regions of the world: the countries of North America and Oceania, in fact, register an apparent consumption much higher than that of other continents.

Asian countries, which have become the first global consumers in terms of volume, are in fact amongst those with a lower per capita value, even if they have grown substantially since the end of the 1980s.

APPARENT MEAT CONSUMPTION PER MACRO REGION IN THE WORLD
Millions of t/year



Source: FAOSTAT[102]. The graph shows the apparent consumption (therefore an overestimation of real consumption), elaborated with the food balance sheet method.
The "Other" item includes Oceania and Central America.

Too much meat or too much imbalance between the Countries of the world?

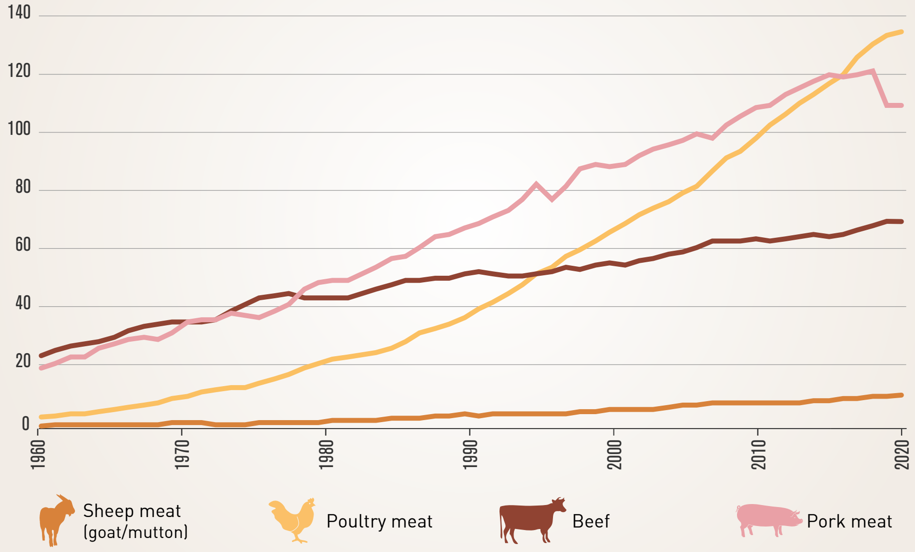
The analysis of world consumption data, but above all their variability from region to region, leads to the consideration that the direct correlation between meat consumption and sustainability is always very critical, without this being contextualised.

Statements such as "**eating too much meat**" or "**meat consumption is unsustainable**" should be contextualised in the light of such data, to understand if this is true at all or if it is true in some parts of the world. Obviously this work offers only a preliminary vision of the problem, which could be explored with a more detailed analysis.

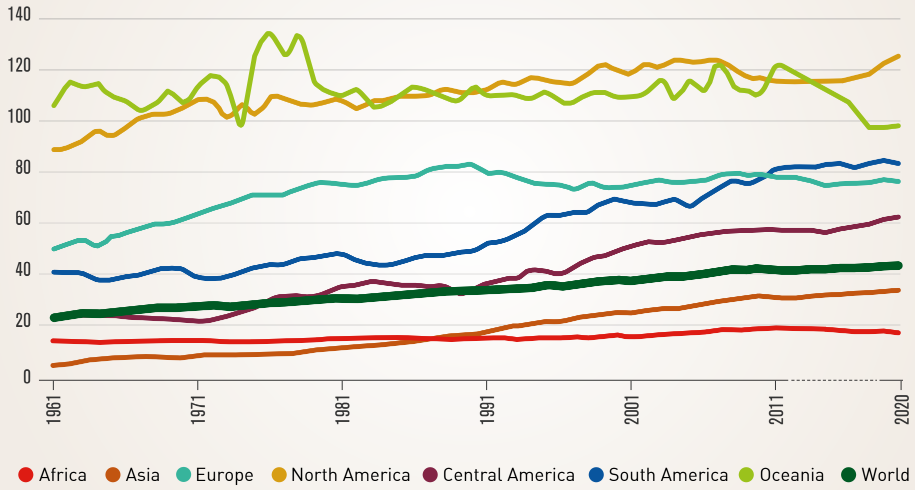
However, it seems clear enough that:

- meat consumption is increasing both due to the higher per capita consumption in some areas of the world, and (and above all) to the **increase of the global population**;
- here is a strong imbalance between regions of the world: the meat consumption per capita in North America is more than 4 times higher than the average African one;
- consumption of **beef in Europe does not show substantial increases since the end of the 1990s.**

APPARENT MEAT CONSUMPTION PER SPECIES IN THE WORLD
Millions of t/year



APPARENT MEAT CONSUMPTION PER CAPITA
kg per capita per year



The graph on consumption by species shows how the consumption of pork decreased in 2019-2020 (both in production and in consumption) due to the multiple outbreaks of African Swine Fever (ASF) spread throughout Asia. Source: FAOSTAT[102].

5.3 Meat consumption in Italy

As for consumption in Italy, it was decided to compare the **apparent consumption data**, available in the ISMEA database and referring to the year 2021, with those **of real** consumption.

To this end, various public sources mentioned in the bibliography were analysed. Despite being rather complex to identify a univocal data of **real or apparent consumption**, the results allow to make some general considerations. Going into detail on the ISMEA data analysed, it is observed that Italians on average consume **about 179 g per day** of all types of meat (chicken, pork, beef).

Real per capita consumption corresponds to slightly more than half of the **apparent** one, a difference moreover consistent with the average yield data between edible meat and animal carcasses. That is, **90 g of meat per day, equal to 630 g per week and 32.9 kg per year.**

This consumption includes all meat, regardless of how (raw, cooked, transformed into cured meats, present in mixed food preparations, canned, etc.) and where (home, restaurants, fast-food, canteens, community centres, stalls, etc.) it is consumed.

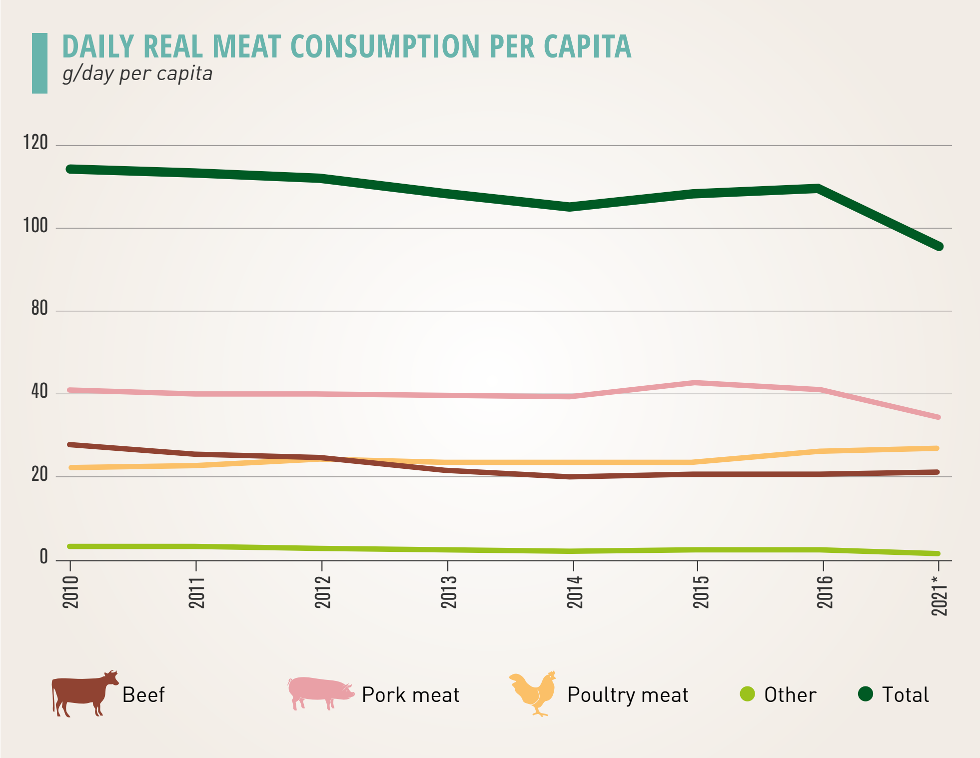
Considering only the consumption of red meat (bovine and pork) and cured meats (therefore excluding white meat), the real consumption stands at **58 g per day**, as far as **beef only is concerned, the real consumption drops to 22.5 g per day per capita**, well below the 100 g per day indicated by WHO/IARC as the threshold, albeit contested (see previous chapter), for cancer risks.

APPARENT AND REAL MEAT CONSUMPTION IN ITALY 2021

kg/per capita per year by species

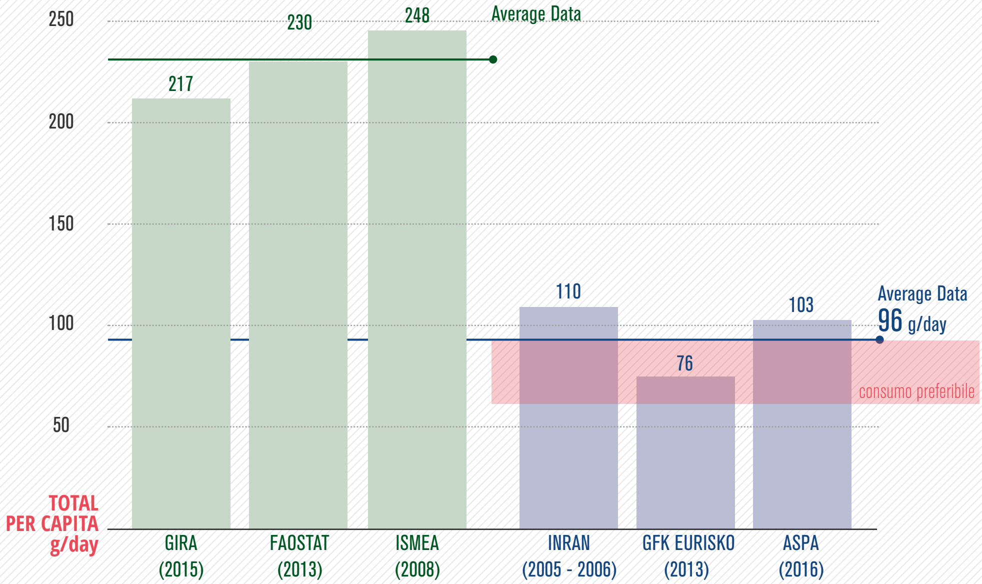
TYPE OF MEAT	APPARENT CONSUMPTION (kg /per capita)	REAL CONSUMPTION (kg /per capita)
PIGS	27.9	13.1
POULTRY	21.4	11.6
BOVINE	16.0	8.2
TOTAL	**65.3**	**32.9**

Source: Processing of Sustainable Meats on ISMEA 2022 data on 2021 consumption. Reprocessing of real consumption with the Preventive Deduction of Losses method: Russo V., et al., 2016. Real consumption of meat and fish in Italy. FrancoAngeli, Milan, 2017.



Source: Russo V. et al., 2017. Real daily consumption (g) of total meat and the main species in the sexennial 2010-2015 Tab. 10, p. 60.
**Re-elaborated by Sustainable Meats based on ISMEA 2022 data on 2021 consumption.*

MEAT AND CURED MEATS CONSUMPTION
IN ITALY



APPARENT CONSUMPTION

Estimated from production data for macro-economic evaluations. It cannot be used for nutritional considerations.

DATA SOURCE USED

- FAOSTAT[102]
- ISMEA[104]
- GIRA
  Data disseminated by the main statistical research institutes.

REAL CONSUMPTION

Based on surveys involving consumers for the purpose of assessing nutritional habits.

DATA SOURCE USED

- INRAN
  The data presented is the average of various scientific studies.[105-106-107-108]
- GFK Eurisko
  The basic data used in this work are those of the Ismea-Gfk-Eurisko database from periodic surveys on purchase behaviour of a sample of 8000 families. Consumption outside the home is not included. The study is cited in the ISMEA document.
- ASPA[109]

FROM APPARENT CONSUMPTION TO REAL CONSUMPTION
THE ASPA STUDY

ASPA (Association for Science and Animal Production) was founded with the aim of promoting the progress of the science and technology that affects livestock production with all the factors of sustainability concerned. Many Italian academic organisations are members of the association who, for their different skills, have the objective of carrying out scientific studies useful for the purpose[109].
*One of the ASPA projects led to the finalisation of a system for the estimation of real meat consumption in Italy[110]: thanks to the in-depth study of all the livestock production chains, the objective of the research was to publish **conversion coefficients useful for transforming the data related to the availability of meat products (apparent consumption) in real consumption by consumers.***
The great advantage of the method proposed was to arrive at the estimate of the actual consumption of meat with a precision comparable to that of a survey on individual consumption, avoiding the high costs of the latter. Starting from the apparent availability data and using the conversion factors resulting from the study of the working group led by prof. Vincenzo Russo, it was possible to calculate the real consumption data, estimating the edible part with respect to the carcass of the single animal species.

CONVERSION COEFFICIENTS OF THE CARCASSES OF THE VARIOUS SPECIES IN SELLABLE MEAT

SPECIES AND CATEGORY (RED MEAT)	CONVERSION COEFFICIENT (K)
Calves	0.524
Male bullocks	0.593
Female bullocks	0.575
Cows	0.507
Piglets	0.494
Light pigs	0.528
Heavy pigs	0.492
Baby lamb	0.573
Adult lamb	0.536
Kids and goats	0.526

SPECIES AND CATEGORY (WHITE MEAT	CONVERSION COEFFICIENT (K)
Chicken meat ‹2kg	0.610
Chicken meat ›2kg	0.620
Turkeys	0.621
Guinea fowls	0.582
Ducks	0.520
Geese	0.520
Quails	0.452
Rabbits	0.553

Source: Russo V. et al., 2016. Conversion coefficients (K) of the carcasses of the various species in consumable meat. Tab. 1, p. 49.

PER CAPITA APPARENT AND REAL ANNUAL MEAT CONSUMPTION IN ITALY

MEAT TYPE	APPARENT CONSUMPTION	CONSUMABLE MEAT	REAL CONSUMPTION	CONSUMABLE ON APPARENT (%)	REAL CONSUMPTION ON APPARENT (%)
BOVINE					
2010	23.8	13.6	12.0	57.1	50.5
2011	22.1	12.6	11.1	56.9	50.4
2012	21.3	12.2	10.8	57.2	50.6
2013	20.2	10.9	9.6	N.C.	N.C.
2014	19.6	9.6	8.5	N.C.	N.C.
2015	17.6	10.2	9.0	57.9	51.0
2021*	16.0	9.2	8.2	57.3	51.0
PORK					
2010	38.4	20.2	17.8	52.6	46.3
2011	37.3	19.8	17.4	53.1	46.7
2012	36.9	19.5	17.2	52.8	46.7
2013	36.7	19.5	17.2	53.1	46.8
2014	36.4	19.5	17.2	53.6	47.3
2015	39.0	20.7	18.3	53.1	46.9
2021*	27.9	14.8	13.1	53.0	47.0
POULTRY					
2010	18.0	10.9	9.6	60.6	53.4
2011	18.6	11.6	10.2	62.3	54.8
2012	19.4	12.1	10.6	62.4	54.6
2013	18.8	11.6	10.2	61.7	54.2
2014	19.5	11.8	10.3	60.5	52.8
2015	19.9	11.7	10.3	58.7	51.7
2021*	21.4	13.1	11.6	61.0	54.0

Source: Russo V. et al., 2017. Apparent consumption (ISMEA), availability of consumable meat and real consumption of beef, pork and poultry (kg per capita/year). Tab. 5-6-7, pp. 55-56.
**Re-elaborated by Sustainable Meats based on ISMEA 2022 data on 2021 consumption.*

BIBLIOGRAPHY

[1] Keys A. et al. (1986), The Diet and 15-year Death Rate in the Seven Countries Study. Am J Epidemiol, 124(6), pp. 903–915.

[2] UNESCO (2010), Representative List of the Intangible Cultural Heritage of Humanity (www.unesco.org/culture/ich/en/RL/00394).

[3] Bach-Faig A. et al. (2011), Mediterranean Diet Foundation Expert Group. Mediterranean diet pyramid today, Science and cultural updates, Public Health Nutr. 14(12A):2274-84, doi: 10.1017/S1368980011002515. PMID: 22166184.

[4] Ros E. et al. (2014), Mediterranean Diet and Cardiovascular Health: Teachings of the PREDIMED Study, Adv Nutr., 5(3), pp. 330S-6S.

[5] Barber T.M et al. (2020), The Health Benefits of Dietary Fibre, Nutrients. 12(10):3209, doi: 10.3390/nu12103209.

[6] Yubero-Serrano E.M. et al. (2019), Extra Virgin Olive Oil: More than a Healthy Fat, Eur J Clin Nutr. 72(Suppl 1):8-17, doi: 10.1038/s41430-018-0304-x.

[7] Savaiano D.A., Hutkins R.W. (2021), Yogurt, Cultured Fermented Milk, and Health: a Systematic Review, Nutr Rev. 79(5):599-614, doi: 10.1093/nutrit/nuaa013.

[8] Phillips S.M. et al. (2015), Commonly Consumed Protein Foods Contribute to Nutrient Intake, Diet Quality, and Nutrient Adequacy, Am J Clin Nutr. 101(6):1346S-1352S, doi: 10.3945/ajcn.114.084079.

[9] Chen J. et al. (2022), A Critical Review on the Health Benefits of Fish Consumption and its Bioactive Constituents, Food Chem. 369:130874, doi: 10.1016/j. foodchem.2021.130874.

[10] Nooyens A.C.J. et al. (2018), Fish Consumption, Intake of Fats and Cognitive Cecline at Middle and Older Age: The Doetinchem Cohort Study, Eur J Nutr. 57(4):1667-1675, doi: 10.1007/s00394-017-1453-8.

[11] Cappuccio F.P., (2013) Cardiovascular and Other Effects of Salt Consumption, Kidney Int Suppl, (2013) Dec;3(4):312-315, doi: 10.1038/kisup.2013.65. PMID: 25019010; PMCID: PMC4089690.

[12] Guasch-Ferré M., Willett W.C. (2021), The Mediterranean Diet and Health: A Comprehensive Overview. J Intern Med. 290(3):549-566, doi: 10.1111/joim.13333.

[13] Del Chierico F. et al. (2014), Mediterranean Diet and Health: Food Effects on Gut Microbiota and Disease Control. Int J Mol Sci. 15(7):11678-99, doi: 10.3390/ijms150711678.

[14] Willcox D.C. et al. (2014), Healthy Aging Diets other than the Mediterranean: A Focus on the Okinawan Diet. Mech Ageing Dev. 136-137:148-62, doi: 10.1016/j.mad.2014.01.002.

[15] Crous-Bou M. et al. (2014), Mediterranean Diet and Telomere Length in Nurses' Health Study: Population Based Cohort Study. BMJ. 349:g6674, doi: 10.1136/bmj.g6674.

[16] Tsigalou C. et al. (2020), Mediterranean Diet as a Tool to Combat Inflammation and Chronic Diseases. An Overview. Biomedicines. 8(7):201, doi:10.3390/biomedicines8070201 Razquin & Martinez-Gonzalez, (2019), A Traditional Mediterranean Diet Effectively Reduces Inflammation and Improves Cardiovascular Health, Nutrients. 11(8):1842, doi: 10.3390/nu11081842.

[17] Tosti V. et al. (2018), Health Benefits of the Mediterranean Diet: Metabolic and Molecular Mechanisms. J Gerontol A Biol Sci Med Sci., 73(3):318-326.

[18] Schwingshackl L., Hoffmann G. (2015), Adherence to Mediterranean Diet and Risk of Cancer: An Updated Systematic Review and Meta-analysis of Observational Studies, Cancer Med. 4(12):1933-47, doi: 10.1002/cam4.539.

[19] Morze J. et al. (2021), An Updated Systematic Review and Meta-analysis on Adherence to Mediterranean Diet and Risk of Cancer. Eur J Nutr. 60(3):1561-1586, doi: 10.1007/s00394-020-02346-6.

[20] Augimeri G. et al. (2021), Nutraceuticals in the Mediterranean Diet: Potential Avenues for Breast Cancer Treatment, Nutrients. 13(8):2557, doi: 10.3390/nu13082557.

[21] Martín-Peláez S. et al. (2020), Mediterranean Diet Effects on Type 2 Diabetes Prevention, Disease Progression, and Related Mechanisms, A Review. Nutrients. 12(8):2236, doi: 10.3390/nu12082236.

[22] Benton D. (2015), Portion Size: What We Know and What We Need to know, Crit Rev Food Sci Nutr, 55(7):988-1004, doi: 10.1080/10408398.2012.679980.

[23] SINU, 2014. Italian Society of Human Nutrition. LARN - Reference Intake Levels of Nutrients and Energy for the Italian population. IV Revision. SICS, Milan.

[24] Pereira P.M, Vicente A.F. (2013), Meat Nutritional Composition and Nutritive Role in the Human Diet, Meat Sci. 93(3):586-92, doi: 10.1016/j.meatsci.2012.09.018.

[25] Nitti F.S. (1958), Scritti sulla questione meridionale, vol II. Laterza, Bari.

[26] Perlès (2007), Le strategie alimentari nell'età preistorica, saggio in Flandrin-Montanari, Storia dell'alimentazione, vol 1, Laterza, Bari.

[27] Grottanelli C., Parise N.F. (1993), Sacrificio e società nel mondo antico, Laterza, Roma-Bari.

[28] Scarpi P. (2005), Il senso del cibo, Sellerio, Palermo.

[29] Flandrin J.L. (1992), Chronique de Platine. Pour une gastronomie historique, Odile Jacob, Parigi.

[30] Zamagni V. (1998), L'evoluzione dei consumi tra tradizione e innovazione, saggio in Storia d'Italia. Annali 13. L'Alimentazione, Einaudi, Torino.

[31] Biondi G. et al. (2006), In carne e ossa. DNA, cibo e culture dell'uomo preistorico, Laterza, Bari.

[32] Ungar P.S. et al. (2008), Dental Microwear and Diet of the Plio-Pleistocene Hominin Paranthropus boisei. PLoS ONE, 3(4), e2044.

[33] Wrangham R. (2009), Catching Fire: How Cooking Made Us Human. Basic Books,Perseus Group, Cambridge, Massachusset, p. 312.

[34] Teleki G. (1981), The Omnivorous Diet and Eclectic Feeding Habits of Chimpanzees in Gombe National Park, Tanzania. In: Omnivorous Primates: Gathering and Hunting in Human Evolution, R.S.O. Harding & G. Teleki (eds.), pp. 303-343, Columbia Univ. Press, N.Y.

[35] Allen J.S. (2009), The Lives of the Brain: Human Evolution and the Organ of Mind, Cambridge, Belknap Press, p. 338.

[36] Eaton S.B. (2006), The Ancestral Human Diet: What Was it and Should It Be a Paradigm for Contemporary Nutrition? Proc. Nutr. Soc. 65(1), pp. 1-6.

[37] Cordain L. et al (2005), Origins and Evolution of the Western Diet: Health Implications for the 21st Century. Am J Clin Nutr. 81(2):341-54, doi: 10.1093/ajcn.81.2.341.

[38] Ruff C.B. (2000), Body Mass Prediction from Skeletal Frame Size in Elite Athletes. American Journal of Physical Anthropology. 113(4):507-17, doi: 10.1002/1096-8644(200012)113:4↓507::AID-AJPA5>3.0.CO;2-F.

[39] Frank S.A. (2010), Evolution in Health and Medicine Sackler Colloquium: Evolution of the Human Lifespan and Diseases of Aging: Roles of Infection, Inflammation, and Nutrition, Proceedings of the National Academy of Sciences U.S.A. 107 Suppl 1(Suppl 1):1718-24, doi: 10.1073/pnas.0909606106.

[40] FAO (2009), The State of Food Insecurity in the World. Rome.

[41] Buccioni A. et al. (2011), Il consumo di proteine animali: la co-evoluzione dell'uomo e della sua dieta, ADI Magazine, 15 (3), pp. 191- 195.

[42] Mele M. et al. (2015), Consumo di Carne e salute umana, In: Alimenti di Origine Animale e Salute, FrancoAngeli, Milano.

[43] Miller V. et al. (2017), Prospective Urban Rural Epidemiology (PURE) Study Investigators. Fruit, Vegetable, and Legume Intake, and Cardiovascular Disease and Deaths in 18 Countries (PURE): A Prospective Cohort Study, Lancet. 390(10107):2037-2049, doi: 10.1016/S0140-6736(17)32253-5.

[44] McNeill S.H. et al. (2012), The Evolution of Lean Beef: Identifying Lean Beef in Today's U.S. Marketplace, Meat Sci. 90(1):1-8, doi: 10.1016/j.meatsci.2011.05.023.

[45] McAfee A.J. et al. (2010), Red Meat Consumption: An Overview of the Risks and Benefits, Meat Sci. 84(1):1-13, doi: 10.1016/j.meatsci.2009.08.029.

[46] DIRECTIVE 2008/100/CE.

[47] Regulation (EC) no. 1924/2006 of the European Parliament and the Council of 20th December 2006 relating to nutrition and health claims made on food products.

[48] Lombardi-Boccia G. et al. (2004), Meat and Meat Products Consumption in Italy: Contribution to Trace Elements, Heme Iron and Selected B Vitamins Supply, Int J Vitam Nutr Res. 74(4):247-51, doi: 10.1024/0300-9831.74.4.247.

[49] IARC (2015), IARC Monographs Evaluate Consumption of Red Meat and Processed Meat, Press release n°240, 26 October 2015, https://www.iarc. fr/en/media-centre/pr/2015/pdfs/pr240_E.pdf.

[50] Provisional Maximum Tolerable Daily Intake (PMTDI): value for iron equal to 0.6 mg/kg of body weight/day (e.g.: 50mg per day for a body weight of 60 kg) as proposed by JECFA (Joint FAO/WHO Expert Committee on Food Additives).

[51] Schmid A. (2009), Bioactive Substances in Meat and Meat Products, Fleischwirtschaft, 89(7) pp. 83-90.

[52] den Hartigh L.J. (2019), Conjugated Linoleic Acid Effects on Cancer, Obesity, and Atherosclerosis:

A Review of Pre-Clinical and Human Trials with Current Perspectives, Nutrients. 11(2):370, doi: 10.3390/nu11020370.

[53] Chmielewska K. et al. (2020), Therapeutic Potential of Carnosine and Its Derivatives in the Treatment of Human Diseases, Chem Res Toxicol. 33(7):1561-1578, doi: 10.1021/acs.chemrestox.0c00010.

[54] Dinu M. et al. (2017), Vegetarian, Vegan Diets and Multiple Health Outcomes: A Systematic Review with Meta-analysis of Observational Studies, Crit Rev Food Sci Nutr. 57(17):3640-3649, doi: 10.1080/10408398.2016.1138447.

[55] Bakaloudi D.R. et al. (2021), Intake and Adequacy of the Vegan Diet. A Systematic Review of the Evidence, Clin Nutr. 40(5):3503-3521, doi: 10.1016/j.clnu.2020.11.035.

[56] McEvoy C.T. et al. (2012), Vegetarian Diets, Low-meat Diets and Health: A Review, Public Health Nutr. 15(12):2287-94, doi: 10.1017/S1368980012000936.

[57] Moughan P.J. (2012), Dietary Protein for Human Health, Br J Nutr. 108 Suppl 2:S1-2, doi: 10.1017/S0007114512003509.

[58] SINU, (2012), Italian Society of Human Nutrition. LARN - Reference Intake Levels of Nutrients and Energy for the Italian population. 2012 Revision. SICS, Milan.

[59] Bauer J. et al. (2013), Evidence-based Recommendations for Optimal Dietary Protein Intake in Older People: a Position Paper from the PROT-AGE Study Group, J Am Med Dir Assoc. 14(8):542-59, doi: 10.1016/j.jamda.2013.05.021. Deutz N.E.P. et al. (2014), Protein Intake and Exercise for Optimal Muscle Function with Aging: Recommendations from the ESPEN Expert Group, Clin Nutr. 33(6):929-36, doi: 10.1016/j.clnu.2014.04.007.

[60] Phillips S.M. (2012), Dietary Protein Requirements and Adaptive Advantages in Athletes, Br J Nutr. 108 Suppl 2:S158-67, doi: 10.1017/S0007114512002516.

[61] Protein Summit 2.0: Evaluating the Role of Protein on Public Health, Am J Clin Nutr., 2015, 101(Suppl), pp.1317S–58S.

[62] Phillips S.M. et al. (2015), Commonly Consumed Protein Foods Contribute to Nutrient Intake, Diet Quality, and Nutrient Adequacy, Am J Clin Nutr. 101(6):1346S-1352S, doi: 10.3945/ajcn.114.084079. Nicklas T.A. et al. (2012), Contribution of Beef Consumption to Nutrient Intake, Diet Quality, and Food Patterns in the Diets of the US Population, Meat Sci. 90(1):152-8, doi: 10.1016/j.meatsci.2011.06.021.

[63] Position Paper SIPPS - FIMP - SIMA – SIMP Diete vegetariane in gravidanza ed età evolutiva. Pediatria Preventiva & Sociale - Year XII - Number 3/2017 Supplement 2. Pages 119-193.

[64] Monk C. et al. (2016), Maternal Prenatal Iron Status and Tissue Organization in the Neonatal Brain, Pediatr Res. 79(3):482-8, doi: 10.1038/pr.2015.248.

[65] Weihrauch-Blüher S. et al. (2019), Childhood Obesity: Increased Risk for Cardiometabolic Disease and Cancer in Adulthood, Metabolism, 92:147-152, doi: 10.1016/j.metabol.2018.12.001.

[66] Hermoso M. et al. (2011), The Effect of Iron on Cognitive Development and Function in Infants, Children and Adolescents: A Systematic Review, Ann Nutr Metab, 59(2-4):154-65, doi: 10.1159/000334490.

[67] Nyaradi A. et al. (2013), The Role of Nutrition in Children's Neurocognitive Development, from Pregnancy through Childhood, Front Hum Neurosci. 7:97, doi: 10.3389/fnhum.2013.00097.

[68] Venkatramanan S. et al. (2016), Vitamin B-12 and Cognition in Children, Adv Nutr. 7(5):879-88, doi: 10.3945/an.115.012021.

[69] Louwman M.W. et al. (2000), Signs of Impaired Cognitive Function in Adolescents with Marginal Cobalamin Status, Am J Clin Nutr, 72(3):762-9, doi: 10.1093/ajcn/72.3.762.

[70] Caro C. et al. (2016), Zinc Deficiency: A Global Problem that Affect the Health and Cognitive Development, Arch Latinoam Nutr, 66(3):165-175, English, Spanish, PMID: 29870603.

[71] Pivina L. et al. (2019), Iron Deficiency, Cognitive Functions, and Neurobehavioral Disorders in Children, J Mol Neurosci. 68(1):1-10, doi: 10.1007/s12031-019- 01276-1.

[72] Jáuregui-Lobera I. (2014), Iron Deficiency and Cognitive Functions, Neuropsychiatr Dis Treat. 10:2087-95, doi: 10.2147/NDT.S72491.

[73] Beard J.L. (2008), Why Iron Deficiency is Important in Infant Development, J Nutr. 138(12):2534-6, doi: 10.1093/jn/138.12.2534.

[74] Krebs N.F. et al. (2006), Meat as a First Complementary Food for Breastfed Infants: Feasibility and Impact on Zinc Intake and Status, J Pediatr Gastroenterol Nutr, 42(2):207-14, doi: 10.1097/01.mpg.0000189346.25172.fd.

[75] WHO (2009b), Infant and Young Child Feeding: Model Chapter for Textbooks for Medical Students and Allied Health Professionals, World Health Organization, Geneva.

[76] Scott S.P., Murray-Kolb L.E. (2016), Iron Status is Associated with Performance on Executive Functioning Tasks in Nonanemic Young Women, J Nutr. 146(1):30-7, doi: 10.3945/jn.115.223586.

[77] Thomas D.T. et al. (2016), American College of Sports Medicine Joint Position Statement: Nutrition and Athletic Performance. Medicine & Science in Sports & Exercise. 48(3):543-68, doi: 10.1249/ MSS.0000000000000852. Erratum in: Med Sci Sports Exerc. 2017. 49(1):222, doi: 10.1249/ MSS.0000000000001162.

[78] Van Staveren W.A. et al. (2012), Nutrition and Ageing. In J. Mann & A.S. Truswell (eds). Essentials of human nutrition, 4th edn. Oxford University Press, New York.

[79] Kouvari M. et al. (2016), Red Meat Consumption and Healthy ageing: A Review. Maturitas. 84:17-24, doi: 10.1016/j.maturitas.2015.11.006.

[80] Landi F. et al. (2016), Protein Intake and Muscle Health in Old Age: From Biological Plausibility to Clinical Evidence, Nutrients. 8(5):295, doi: 10.3390/ nu8050295.

[81] Strasser B. et al. (2018), Role of Dietary Protein and Muscular Fitness on Longevity and Aging, Aging Dis. 9(1):119-132, doi: 10.14336/AD.2017.0202.

[82] Landi F. et al. (2012), Sarcopenia as a Risk Factor for Ralls in Elderly Individuals: Results from the ilSIRENTE Study, Clin Nutr. 31(5):652-8, doi: 10.1016/j. clnu.2012.02.007.

[83] Landi F. et al. (2013), Sarcopenia and Mortality Risk in Frail Older Persons Aged 80 Years and Older: Results from ilSIRENTE Study, Age Ageing, 42(2):203-9, doi: 10.1093/ageing/afs194.

[84] Leong D.P. et al. (2015), Prospective Urban Rural Epidemiology (PURE) Study investigators. Prognostic Value of Grip Strength: Findings from the Prospective Urban Rural Epidemiology (PURE) study, Lancet. 386(9990):266-73, doi: 10.1016/ S0140- 6736(14)62000-6.

[85] Nowson C., O'Connell S. (2015), Protein Requirements and Recommendations for Older People: A Review, Nutrients, 7(8):6874-99, doi: 10.3390/ nu7085311.

[86] McNeill S., M.E. Van Elswyk (2012), Red meat in Global Nutrition, Meat Sci. 92(3):166-73, doi: 10.1016/j.me- atsci.2012.03.014.

[87] Salter A.M. (2018), The Effects of Meat Consumption on Global Health, Rev Sci Tech. 37(1):47-55, doi: 10.20506/rst.37.1.2739.

[88] Lippi G. et al. (2015), Red Meat Consumption and Ischemic Heart Disease, A Systematic Literature Review, Meat Sci. 108:32-6, doi: 10.1016/j.meatsci.2015.05.019.

[89] Roussell M.A. et al. (2012), Beef in an Optimal Lean Diet Study: Effects on Lipids, Lipoproteins, and Apolipoproteins, Am J Clin Nutr. 95(1):9-16, doi: 10.3945/ajcn.111.016261.

[90] English L.K. et al. (2021), Evaluation of Dietary Patterns and All-Cause Mortality: A Systematic Review, JAMA Netw Open, 4(8):e2122277, doi: 10.1001/jamanetworkopen.2021.22277.

[91] Ubago-Guisado E. et al. (2021), Evidence Update on the Relationship between Diet and the Most Common Cancers from the European Prospective Investigation into Cancer and Nutrition (EPIC) Study: A Systematic Review, Nutrients. 13(10):3582, doi: 10.3390/nu13103582.

[92] World Cancer Research Fund (2007), American Institute for Cancer Research: Food, Nutrition and the Prevention of Cancer: A Global Perspective. The Institute, Washington, DC, USA.

[93] Bishop K.S., Ferguson R. (2015), The Interaction between Epigenetics, Nutrition and the Development of Cancer, Nutrients. 7(2):922-47, doi: 10.3390/ nu7020922.

[94] Lippi G. et al. (2016), Meat Consumption and Cancer Risk: A Critical Review of Published Meta-analyses. Crit Rev Oncol Hematol, 97:1-14, doi: 10.1016/j.cri- trevonc.2015.11.008.

[95] IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, Red Meat and Processed Meat. Lyon (FR): International Agency for Research on Cancer; 2018, PMID: 29949327.

[96] Bouvard V. et al. (2015), International Agency for Research on Cancer Monograph Working Group, Carcinogenicity of Consumption of Red and Processed Meat, Lancet Oncol. 16(16):1599-600, doi: 10.1016/ S1470-2045(15)00444-1?.

[97] Ho V. et al. (2014), Meat-derived Carcinogens, Genetic Susceptibility and Colorectal Adenoma Risk. Genes Nutr. 9(6):430, doi: 10.1007/s12263-014-0430-6.

[98] Jakszyn P. et al. (2004), Development of a Food Database of Nitrosamines, Heterocyclic Amines, and Polycyclic Aromatic Hydrocarbons. J Nutr. 134(8):2011-4, doi: 10.1093/jn/134.8.2011.

[99] Song M. et al. (2015), Nutrients, Foods, and Colorectal Cancer Prevention, Gastroenterology, 148(6):1244- 60.e16, doi: 10.1053/j.gastro.2014.12.035.

[100] De Smet S., Vossen E. (2016), Meat: The Balance between Nutrition and Health. A Review. Meat Sci. 120:145-156, doi: 10.1016/j.meatsci.2016.04.008.

[101] Givens D.I. (2018), Review: Dairy Foods, Red Meat and Processed Meat in the Diet: Implications for Health at Key Life Stages, Animal. 12(8):1709-1721, doi: 10.1017/S1751731118000642.

[102] The three graphs of apparent meat consumption in the world are based on FAOSTAT data.

a) Graph on consumption by macro-region and graph on consumption by species

Web site:

"Crops and livestock products" (https://www.fao.org/faostat/en/#data/QCL).

Filter applied for extraction:

Regions (Total) > World, Northern America, South America, Africa, Asia, Europe, Oceania, Central America. - **Items** > Meat pigs - **Items aggregated (Total)** > Meat Total, Beef and Buffalo Meat, Meat Poultry, Sheep and Goat Meat - **Elements** > Production quantity - **Years** > 1961÷2020

b) Graph on per capita consumption

Web site:

"Food Balances (2010-)" (https://www.fao.org/faostat/en/#data/FBS)

Filter applied for extraction:

Regions (Total) > Northern America, Central America, South America, Africa, Asia, Europe, Oceania, World - **Items aggregated** > Meat (Total) - **Elements** > Food supply quantity (kg/capita/yr) - **Years** > 2010÷2019

[103] DOXA study on behalf of COOP Italia, at the link:https://www.bva-doxa.com/cibo-di-oggi-cibo-di-domani- coop-doxa-expo2015/.

[104] ISMEA, Sector Plan, Study on Consumption of Beef in Italy. The figure is part of a historical series from 1938 to 2009, processed by the Chamber of Commerce of Milan in 2010. In this analysis, the most recent available figure was taken into consideration.

[105] Pala V. et al. (2003), Diet in the Italian Epic Cohorts: Presentation of Data and Methodological Issues, Tumori, 89(6), pp.594-607.

[106] Riboli E. et al (2002), European Prospective Investigation into Cancer and Nutrition (EPIC): Study Populations and Data Collection, Public Health Nutr. 5(6B):1113-24, doi: 10.1079/PHN2002394.

[107] Leclercq C. et al. (2009), The Italian National Food Consumption Survey INRAN-SCAI 2005–06: Main Results in Terms of Food Consumption, Public Health Nutrition, 12(12):2504–2532, doi: 10.1017/S1368980009005035.

[108] Turrini A. et al. (2001), Food Consumption Patterns in Italy: the INN-CA Study 1994-1996, European Journal of Clinical Nutrition, 55(7):571-588, doi: 10.1038/sj.ejcn.1601185.

[109] ASPA (Association for Science and Animal Production). List of ASPA commissions available at the link: https://www.assaspa.org/com-missioni.

[110] For more information, see the two studies:

Russo V., De Angelis A., Danieli P.P. (2017), Real Consumption of Meat and Fish in Italy. From Apparent Consumption to Real Consumption with the Method of the Preventive Deduction of Losses, FrancoAngeli, Milano.

Russo V., Sermoneta C. (8/06/2015), Statistical Indicators for the Agri-Food Supply Chain. Meat Consumption: Importance, limits, uncertainties and possibilities for improving the estimates. ISTAT conference, Milan.

FOOD SAFETY AND ANIMAL WELFARE

- THE CONTAMINATION RISK
- CONTROLS AND INFORMATION FOR CONSUMERS
- THE COMMUNITY FOOD ALERT SYSTEM
- ANIMAL WELFARE

 ISBN 9788835155713

Introduction

MEAT AND CURED MEATS ARE COMPLETELY TRACEABLE, A GUARANTEE OF THEIR ORIGIN AND QUALITY

THE ITALIAN HEALTH CARE SYSTEM IS ONE OF THE MOST STRUCTURED IN THE WORLD, WITH 4,500 OFFICIAL VETERINARIANS INVOLVED

ANIMAL WELFARE IS IMPORTANT FOR ETHICAL REASONS, BUT ALSO TO ENSURE THE DEFENCE OF FOOD SECURITY AND IMPROVE MEAT QUALITY

The growing attention to the issues of food and its safety very often leads the media and social media to transform simple news into "food scandals". The reading of these news should always lead to a classification in different spheres: there are the aspects actually related to consumer safety, those concerning economic frauds (e.g. non-organic food sold as organic, but still safe) and those related to animal welfare. Furthermore, when we talk about security, we must distinguish between real or presumed aspects: indeed, very often the ***withdrawal of food products is done according to the precautionary principle*** *because there is a suspicion that food is characterised by potentially dangerous contaminations. In these cases, it is advisable to avoid creating unjustified alarmism because the real danger is normally very low if not zero.*

Italian consumers can rest assured: the quality and the food security, in Italy as well as throughout the European Union, do not represent only a regulatory cornerstone of the Union itself, but the real cornerstone of the community policy for consumer protection. In fact, the European strategy foresees the ***prevention of any risk for food safety along the entire production chain*** *and is based on the so-called "****One Health****" principle*[1]*: an integrated approach that* ***considers the links between animal health, health of products derived from them and human health to be indispensable,*** *to guarantee the latter a high level of life quality by protecting at the same time the health and welfare of the animals. The effectiveness of the controls is further strengthened by* ***traceability****, which allows to reconstruct and follow the path of a food from the consumer up to the primary agricultural production.* ***The Italian health care system is one of the most structured in the world,*** *recognised in Europe as a point of excellence thanks to the approximately* ***4,500 official veterinarians*** *involved in the numerous checks and analyses in the field of meat safety and quality. The issue of security is closely linked to that of* ***animal welfare.*** *Maintaining a state of good psycho-physical health in animals is in fact an indispensable requirement to guarantee them adequate living conditions, but it is also a crucial element in guaranteeing the safety and quality of the food that derives from them. The evolution of public sensibility has meant that starting from the Eighties this theme was widely dealt with by the community and national legislation, that establishes minimum welfare conditions to be respected:* ***in many cases a violation of these rules is considered a criminal offense in Italy.*** *For this reason, it was decided to keep these two aspects, apparently unconnected, in the same chapter of this document.*

1 THE CONTAMINATION RISK

When it comes to contamination, it is important to understand its origin. In general, the phenomena of contamination can be caused by the **use of drugs** in farms or by **chemical and microbiological contaminations** that can occur in the production of feed, in farms, in the transformation and distribution chain.

In the case of drugs, it is essential to divide between those banned and those admitted with a regulated use, also to eradicate some false clichés: the most frequent concerns, for example, the one concerning the use of growth **hormones** that have been **banned for more than forty years** in all of the European territory. Amongst the regulated and widely discussed drugs are **antibiotics** that can be used, **only after medical prescription**, with precise usage amounts and for the **sole purpose of treating sick animals**. Their use must be limited in time; moreover, the animal cannot be slaughtered without having complied with the so-called "**suspension period**", which guarantees respect of maximum residue limits (MRL) in slaughtered meat, established by law.

The presence of chemical substances may derive from possible contamination during the food cultivation phase: for this reason, the European approach to food control is very useful which originates at the beginning of the supply chain and puts under observation every phase of the transformation. Any microbiological contamination, finally, may be due to poor management of the supply chain, distribution or, above all, domestic food preservation.

1.1 Antibiotic drugs

Antibiotics (from ancient Greek: anti, "against", and bios, "life") are molecules originating both from fungal and synthetic species that kill bacteria or inhibit their growth. They belong to the largest group of antimicrobial compounds, used to treat infections caused by microorganisms, including fungi and protozoa.
Since the Fifties of the last century, antibiotics have been a fundamental means for controlling infectious diseases in the veterinary sector, thus contributing to the improvement of animal welfare and product safety of animal origin foodstuffs. The benefits of using antibiotics are also countless for human medicine: many bacterial infections that up to 50 years ago could kill a person, such as pneumonia, are no longer a danger.
However, when the use of these drugs is excessive or not very controlled, it can trigger a phenomena of drug resistance by bacteria.

The phenomenon of the antibiotic resistance

The development of resistance is in itself a normal evolutionary process, a consequence of the genetic evolution to which micro-organisms encounter: when we assist an improper use of antibiotics, however, the phenomenon of resistance accelerates due to the natural tendency of microorganisms to "defend themselves" from active ingredients contained in drugs. "Resistant" bacteria, even if they are harmless, can pass from one organism to another transmitting the resistance to a pathogenic organism of the new guest.

Since the Nineties, the phenomenon has always been more widespread, to the point that in the first Global Report on antimicrobial resistance, published by WHO in April 2014, antibiotic resistance is identified as a "**serious and potential threat to public health**". The development of strains of resistant bacteria makes it indeed difficult to treat an ever increasing range of fairly common infections easy to catch, with the result that also the most common and simple diseases to cure, become potentially a lot riskier for health. To reduce this danger, in 2006 the European Commission **forbade the use of antibiotics** in farms for **non-therapeutic purposes** (i.e. as growth promoters)[2] and has published guidelines for their correct use[3].

Premising that the use of veterinarian drugs is a prerequisite for animal welfare, their use must however be complementary to good barn management and adequate vaccination programs, which allow them to maintain a good state of

EUROPEAN AWARENESS CAMPAIGNS

Various initiatives already taking place in Europe aim to spread messages on the risks related to an inappropriate use of antibiotics as well as to inform about the prudent use of antibiotics primarily for human therapies. Among these, the main ones are the "World Antibiotic Week" promoted by the WHO and the European Antibiotic Day of the European Union, but also national information campaigns developed by individual member states.

Some of these are:

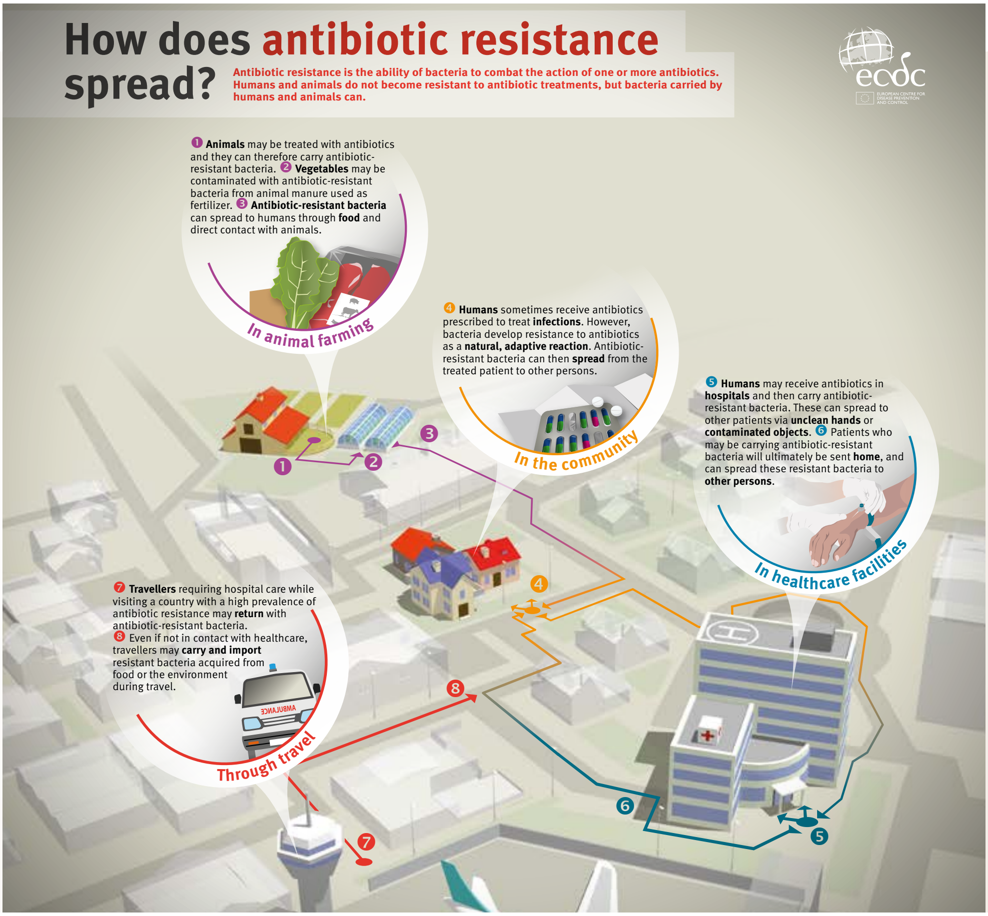
- **AUSTRIA** NAP AMR: The Austrian National Action Plan on Antimicrobial Resistance.
- **BELGIUM** Antibiotics: use them correctly and only when needed!
- **DENMARK** Antibiotics: yes or no?
- **FRANCE** National Antibiotics Information Day.
- **GERMANY** RKI: Antibiotic resistance.
- **IRELAND** Under the Weather.
- **ITALY**
  - *AIFA* (Agenzia Italiana del Farmaco): campaign "Without rules antibiotics do not work".
  - *ISS* (Istituto Superiore di Sanità): Seventh Day of antibiotics: bacteria more resistant in Europe.
- **ENGLAND** "Antibiotic Guardian" Public Health campaign England: toolkit and information material on antibiotics.
- **HOLLAND** Antibiotic resistance.

Not just food: the various areas of diffusion of antibiotic resistance.
Source: European Antibiotics Day.

animal health and minimise the conditions that favour the onset of diseases.
The theme of antibiotic resistance is also at the centre of many **consumer information campaigns** on behalf of various governments and the WHO itself, as well as the object of targeted institutional strategies to promote adequate protocols of antimicrobial drug use.

How many are used

At the moment there are no sources that give precise indications on the quantity of antibiotics administered every year in Europe. To do a preliminary analysis we can however resort to the data provided by the ESVAC project (European Surveillance on Veterinary Antimicrobial Consumption), started in April 2010, with the aim of finding information from all over the European Union on the sale of antimicrobial drugs for animals.
In the Report are collected data related to the sale of antibiotics, the formulations of pharmaceutical products and medicated feed used in animal husbandry collected in 31 countries, including about 95% of the population of animals destined for food-production in the EU/EEA area. Before going into the analysis, however, it is opportune to make two premises. The first is that the **quantities of active ingredients sold do not match precisely the quantities**



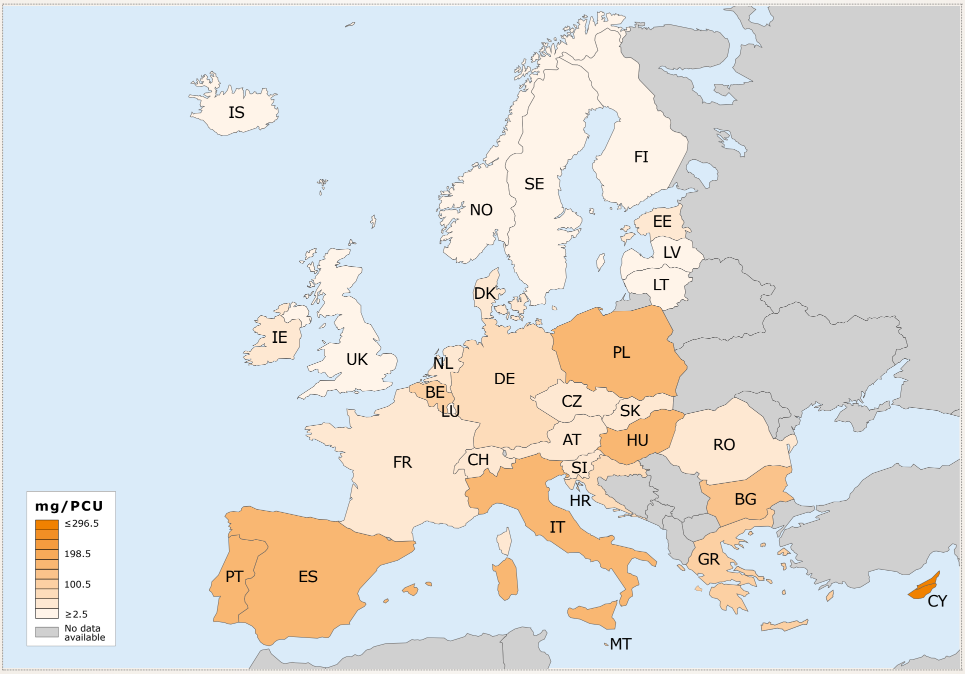
actually administered to animals. The second concerns the management of drugs: while in Italy and in Spain the veterinarians who prescribe the drugs are not authorised to sell them, in other European countries this practice is allowed, but the vets are held responsible for excessive use and, if they do not properly inform the breeder, suffer penalties up to the revocation of the possibility of sale (this is the practice foreseen in the Netherlands, Denmark, United Kingdom, to give some examples).

In order to make data comparable between different member States, the values for amount of antimicrobials sold were normalised by a specific species index called PCU (Population Correction Unit)[4]. The latest report presents data on sales in 2021[5], and includes a chapter on the changes in the use of drugs that occurred between 2011 and 2021. In 2021, there were sold as a whole 5,219.6 t of antimicrobial active ingredients for veterinary use in the 31 countries in question, generally showing a sales decline of about 46.5% compared to 2011 (in the 25 countries with constant collection of data).

Analysing the proportion between the antibiotics sold and the weight of national livestock assets (mg drug/PCU), one no-

MAP OF THE TOTAL SALES OF ALL ANTIMICROBIALS FOR FOOD-PRODUCING ANIMALS

in mg/Pcu



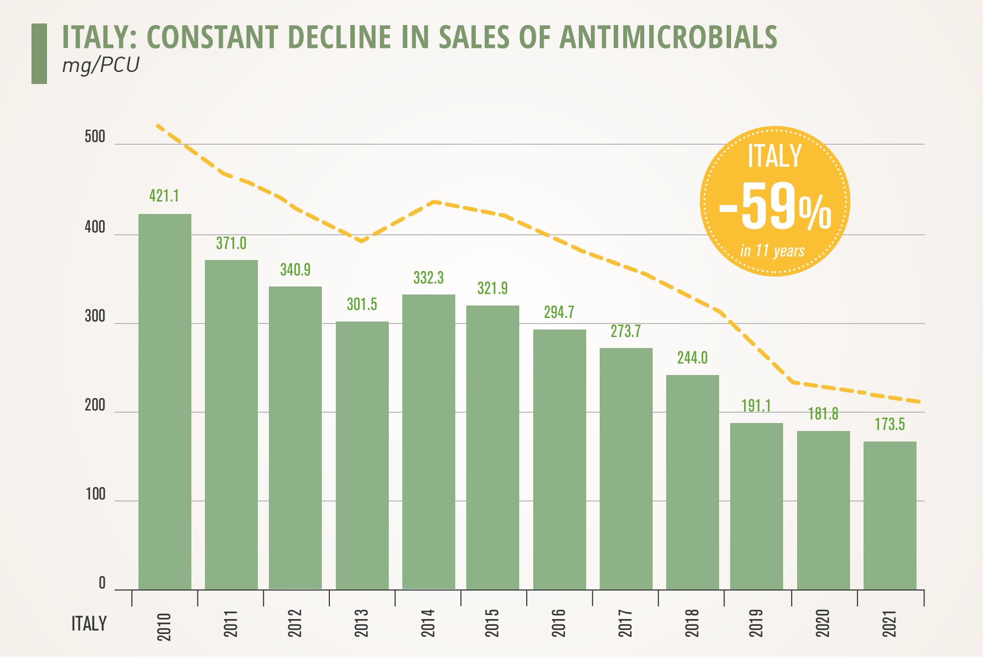
Map of the total sales of all antimicrobials for food-producing animals, mg/Pcu, for 31 countries in 2021. Source: European Medicines Agency, ESVAC, 2022[5].

tices that the highest sales are recorded in Cyprus, followed by Poland and Italy. Italy, although appearing among the first member States for the sale of antibiotics, is the one in which the greatest **reduction is recorded (equal to -59%) between 2010 and 2021 passing from 421.1 to 173.5 mg/PCU.** This reduction in sales is the result of continuous information and awareness raising activities carried out by the health authorities and by producer representative associations to incentivise a responsible use of veterinary drugs. There are still technical difficulties in the comparison of data between countries, as the respective databases are still not aligned. An activity of standardisation is underway that should make comparison more reliable over the next few years, based on standard indicators.

How to reduce risks

The descriptions of practices and dangers are useful to understand what the correct methods for risk reduction are: the cardinal principle for the use of antibiotics, especially in human therapies, can be summarised "***using as little as possible, only when and how much is necessary***"[6].

The administration of antibiotics in animal husbandry, **forbidden for preventive purposes**, is always subject to veterinary prescription and, where possible, should be based on an antibiogram carried out on the bacteria isolated from the animal object of the therapy: this exam allows to check the sensitivity of bacteria to specific antibiotics, thus leading to the identification of a more adequate therapy. In addition to practices related to an adequate use of drugs on farms, the **control of maxi-**



Annual sales of VMP antimicrobials for farm animals, in mg/PCU, from 2010 to 2021.
Source: European Medicines Agency, ESVAC, 2022[5].

mum residue limits (MRL), is crucial, which constitutes the maximum concentration of active ingredients in food legally acceptable **not to put human health at risk.** To ensure compliance with the MRLs, the law establishes **a period of suspension** of drug administration before slaughter or placing foods such as milk, eggs and meat on the market. The control of the presence of antibiotic drug residues in food is entrusted to the National Residual Plan, which will be discussed in more detail in the paragraph on controls and information for consumers.

The Ministry of Health, which is responsible for monitoring, together with the Regions and the competent local health authorities, and supervising the administration of antibiotics to farm animals, has published **guidelines for the correct use of antimicrobial drugs**, in collaboration with the Italian Breeders Association (AIA), Federchimica, Assalzoo and the Italian National Federation Veterinary Order (FNOVI).

The document introduces also the importance of **biosafety**, understood as all those devices useful to avoid the introduction of pathogen micro-organisms into farms (such as attention during the purchase of animals, respect of the rules of hygiene, control of supplies, etc.). The use of vaccination programs and the interaction between veterinarians and breeders are promoted, with the preparation of solid health programs and constant communication between the two parts.

HOW ARE THE MAXIMUM RESIDUE LIMITS ESTABLISHED?

The definition of the maximum residue limits is the result of a process based on 4 successive stages:

1 For each substance, the values of NOEL (No Observed Effect Level) are calculated through laboratory tests, the maximum quantity of a given active ingredient which does not give rise to biological effects when administered in the diet to laboratory animals sensitive to that substance.

2 Starting from the NOEL value the Acceptable Daily Intake (ADI), i.e. the amount of the substance that can be taken throughout the animal's life without the appearance of effects, is established.

3 On the basis of the ADI for animals, one calculates the ADI for humans, that is the amount of a substance that can be taken daily for life by a person without the appearance of any effects. The human ADI is obtained by dividing the animal ADI by a safety factor that varies from 100 to 100,000: in practice it is assumed that the man is at least 10 times more sensitive than the animal species on which the analysis was conducted, and that in the same human species sensitivity can vary up to 10 times.

4 Finally, on the basis of the human ADI and assuming that an individual eats for his whole life exclusively a particular food, the MRL is calculated for that specific substance in that particular food.

EU GUIDELINES ON THE PRUDENT USE OF ANTIBIOTICS

In September 2015, the European Commission published a Communication relative to the Guidelines on the prudent use of antimicrobials in veterinary medicine. These guidelines, which are non-binding, are intended to define the principles for their prudent use in order to combat antibiotic resistance, indicating the measures that member States must consider when developing and implementing national strategies. To turn the guidelines into practice, the document was accompanied by a series of practical examples of their use in the various member States for the implementation of each ingredient.
The Commission highlights the fact that any use of antimicrobials (both in human and veterinary medicine) may result in the development of antibiotic resistance phenomena. The risk increases if antibiotics are used im-

properly, for example in a non-targeted way (collective preventive treatments or using on non-susceptible organisms), at doses below-therapeutic levels, repeatedly or for inadequate time periods). The guidelines provide some general indications, and others more specific depending on the various animals. In general, the goal of a prudent administration is to reduce to a minimum the use of antimicrobials, delineating the use in cases of real necessity. In such situations, the prescription and ***administration of these medicines must be justified by an animal's diagnosis by the veterinarian,*** *and possibly supported by specific tests to determine the most appropriate choice of the antimicrobials.*

The narrow spectrum antimicrobials are, in general, to be preferred to those with a broad spectrum. If an animal or group of animals suffer from recurrent infections that require antimicrobial treatment, one needs to take action to eradicate the strains of microorganisms, establishing why the disease is recurrent and changing the conditions of production, animal husbandry and/or management.

Finally, the use of antimicrobial agents that tend to favor the spread of transmissible resistance should be avoided. The use of ***vaccines*** *and related* ***vaccine protocols*** *are, today,* ***the new frontier in reducing antimicrobials and combating antibiotic resistance.***

PARTICIPANTS
IN THE CHAIN OF CONTROL

The Ministry of Health is responsible for collecting the sales figures of veterinary medicinal products from those responsible for their commerce (AIC). In 2017, with Law n°167, the Ministry introduced the electronic veterinary prescription, which became operational in 2019, with the publication of the D.M. application in the Official Gazette n°89.

The Livestock institutions are involved in monitoring resistance to antibiotics on farms, even offering diagnosis on diseases and zoonosis[7].

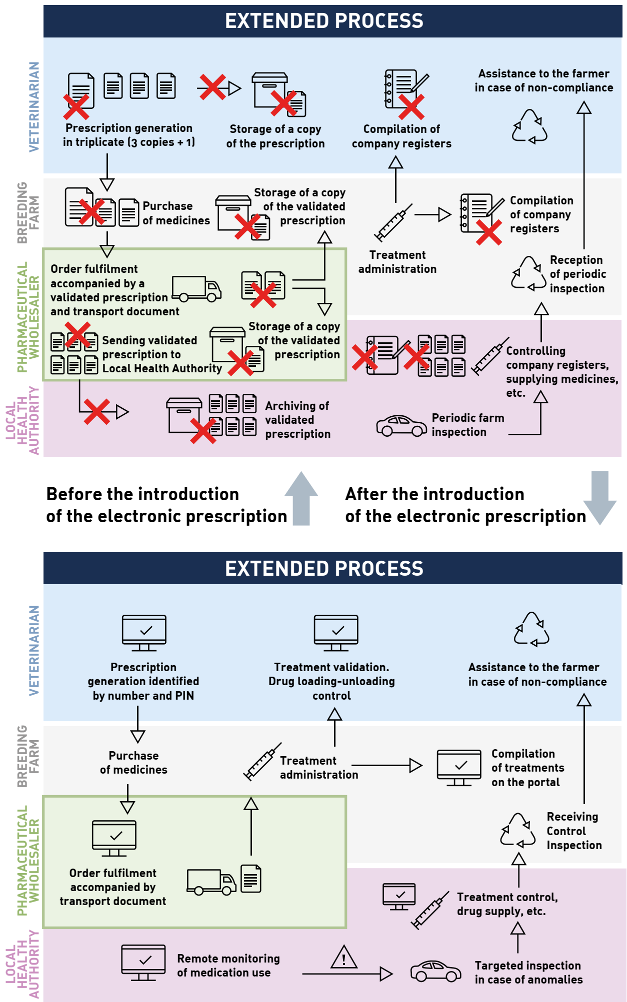
The ASL, within their institutional competencies, constantly monitor compliance with the provisions concerning the prescription of veterinary medicinal products, place the controls provided by the relevant regional medicine surveillance plans and perform inspections of final operators to monitor the records of shipping, delivery and of the stocks.

Finally, in all the Member States of the EU the companies must compulsorily keep for at least five years - regardless of whether the animal is still in the farm or not - the records of all medicines used in animals intended for food production, including the treatments with antibiotics. The records are used to verify the use of antimicrobials in the farm, to observe trends and analyse changes.

THE COMPULSORY ELECTRONIC VETERINARY PRESCRIPTION

By Angelo Gamberini

CHANGES AND SIMPLIFICATIONS MADE WITH THE INTRODUCTION OF THE ELECTRONIC VETERINARY PRESCRIPTION

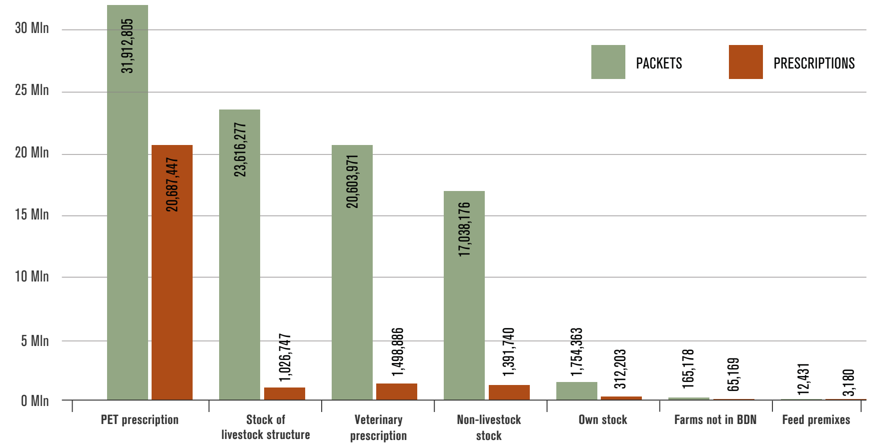


Source: Ministry of Health, National Information System of Drug-Surveillance, Electronic Veterinary Prescription – modified.

Abolition of paper and complete traceability of veterinary drugs. *This was achieved with the introduction of the electronic veterinary prescription, a tool at the service of animal health and consequently also of human health, in adherence to the ONE HEALTH philosophy. Introduced in 2017, by Law n°167, the new prescription format had to await some time to overcome the inevitable difficulties that accompany every novelty and transformation. From 2019, the electronic prescription became operational with the publication in the Official Gazette n°89 of the Decree of the Ministry of Health which establishes the application methods.*

Previously, each veterinarian was required to write the paper prescription in four copies*, one went to the breeder for the order in the pharmacy, the second was destined for the archive of the breeding company, a third for the veterinary's archive and finally the last copy to the local Health Authority of territorial jurisdiction. A complicated procedure to manage and even more to control. Now everything has changed, making the route of the drug simpler, more im-*

NUMBER OF PRESCRIPTIONS AND PACKETS OF VETERINARY DRUGS DISPENSED FROM 2019 TO APRIL 2023 DIFFERENTIATED BY TYPE



Source: Ministry of Health, National Information System of Drug-Surveillance, Electronic Veterinary Prescription – modified.

mediate and above all traceable. In practice, the veterinary surgeon draws up the prescription on his computer connected to the internet (but a tablet or smartphone may be sufficient). The prescription is sent to the veterinary information system of the Ministry of Health (the portal takes the name of Vetinfo) which, ***upon receipt of the prescription, generates a unique number, basically a PIN, from which it is possible to trace the prescribed drug, the farm that will use it, indicating also the animal for which the drug is intended and the veterinarian who issued the prescription.*** *The PIN originating from the Vetinfo system will be the only document needed to collect the drug from the pharmacy, chemist or wholesaler authorised for direct sales.*

The whole world of animal health is involved in the new procedures*, therefore not only veterinarians and breeders, but also feed mills (some drugs are administered with food), up to the owners and holders of* ***PETS, as animals are defined with affection*** *using an Anglo-Saxon term.*

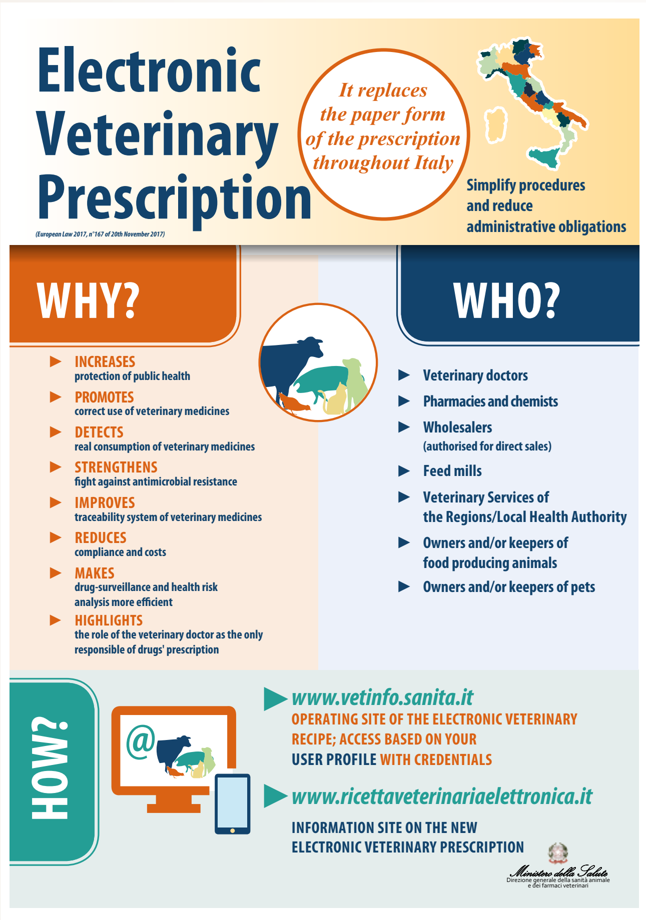
The operation of the system was made possible thanks to a series of IT infrastructures aimed at the timely monitoring of all the national animal heritage. The first step was the creation of the ***Database of livestock registers*** *(BDN), managed by the Livestock Institute of Abruzzo and Molise. All the animals in livestock production and all the companies that hold them are registered here. Connected to the BDN is the Vetinfo system, in which animal health professionals and animal keepers are registered. It is easy to understand how such an articulated system makes it possible to identify with precision and immediacy which drug is being used and on which animal.*

The picture is completed by the introduction, which took place in 2022, of the electronic register of treatments, where the veterinarian and breeder are required to indicate the animals, the quantities of drug used, treatment start and end dates, in different ways depending on whether or not the farm may have stocks of drugs. It is envisaged that the registrations of the treatments are carried out within 48 hours or at the latest within the following 24 hours in the case of demonstrable impediments.

The fact that the system now allows timely verification of the use of veterinary drugs is demonstrated by the data updated daily on the Vetinfo portal, where anyone can check the number of prescriptions issued and the use of the ***prescribed drug****. All types and destinations of veterinary drugs are monitored, both for animals in livestock production and for pets. The high number of prescriptions for the latter (****more than 20 million****) is striking, compared to the modest number (****about 2.5 million****) of prescriptions for farm animals. Similar differences also in the number of packets dispensed.*

A fact that is not surprising if we take into account the presence of numerous animals within the same farm and, on the other hand, the high number of pets that frequent our homes. In Italy ASSALCO (association of companies for pets) estimates that there are around ***64 million PET*** *and it is inevitable that antibiotics are also used for their health, when necessary. This should lead to greater attention when it comes to the fight against antibiotic resistance and a consequent more prudent use of antimicrobials.*

In the field of animal production, the use of antibiotics has gradually decreased, so much so that WOAH (the World Organisation for Animal Health) confirms that between 2016 and 2018, the use of these drugs decreased by 27% at world level. The results achieved in Italy were excellent, where ESVAC recorded a reduction of 38.3% between 2016 and 2020, as can be noted even before the introduction of the electronic veterinary prescription. A responsible behaviour is also desirable in the care of pets, especially if we consider their close coexistence with humans. Still on the subject of antibiotics, similar considerations can be made in the human field, where AIFA, the Italian Medicines Agency, has reported that in 25% of cases there is an improper use of these category of drugs.



Extract from the information brochure on the new electronic veterinary prescription.
Source: Ministry of Health - modified.

1.2 Microbiological and chemical contaminants

A possible threat to consumer safety regards the possible contamination with microorganisms or chemical substances, which may come into contact with food (or with the raw materials such as animal feed) in the many stages of the process. In truth, these types of contamination are not specific to meat, but all fresh food. For this reason, it is essential to have a good management of all distribution phases that occur from the exit of manufacturing sites onwards, including domestic conservation. One risky practice is the poor upkeep of household refrigerators which, if not perfectly clean and not kept at appropriate temperatures, can be a source of contamination.

Microbiological contamination

Microbiological contamination is by far the most frequent cause of food alert. In this category belong contaminations by bacteria (such as Salmonella), parasites (Trichinella), viruses and fungi.

European legislation has intervened to safeguard consumer safety with Regulation (EC) No. 2073/2005[8], which establishes the microbiological criteria applicable to many foods, including all types of meat. It is the basis of the microbiological tests conducted by both official controls and by self-control: in fact, it not only obliges food operators to ensure that food complies with the safety and processing hygiene criteria, but also establishes that **the authorities will monitor** compliance, also through sampling and food analysis in the context of the **supervision activities.**

The goal of self-control of quality management systems and systems developed by the agribusiness companies is that of minimising the risk of microbiological contamination through widespread control of the processes and, in particular, of preservative systems. Even if not included in the 2073, among the microbiological risks are also mycotoxins, toxins produced by certain fungi or moulds in plant foods such as peanuts, walnuts or hazelnuts, corn, grain or soybeans that can enter the food chain through meat or other animal products such as eggs, milk and cheese from cattle that have consumed contaminated feed. In addition to the controls implemented throughout the supply chain, consumer behaviour plays a key role: the best domestic conservation practices and proper cooking of food are fundamental to reduce risks.

Chemical contamination

The chemical contaminants include chemicals in the environment such as pesticides, heavy metals, and other debris that may accidentally enter the food chain during the food production process. **Chemicals such as pesticides** or **medicines used** for animal health are **subject to strict regulations**, and must pass strict toxicity tests for humans and the environment, before being admitted to registration with the European or National Authorities. Also for industrial substances, such as dioxins and heavy metals, there are strict controls, designed to avoid contamination of the environment and to ensure the protection of public health.

THE NATIONAL PLAN FOR THE RESPONSIBLE USE OF VETERINARY MEDICINE AND THE FIGHT AGAINST ANTIBIOTIC RESISTANCE IN POULTRY FARMING

UNAITALIA, the association of reference for operators in the poultry sector, initiated along with the Italian Society of Avian Pathology, a voluntary plan aimed at promoting responsible use of antibiotics in poultry farming. The Plan was promoted by the Ministry of Health, which evaluated beforehand its contents, using a group of experts who will also examine the results.
Specifically, the program aims at reducing the total consumption of antibiotics by 15% by 2015 and by 40% by 2018 compared to 2011.
The results have been fully received, so much so that 2017 has registered a -63% (data certified by a third body, starting from 2015).
Once the first phase was completed, a new plan was drawn up starting in 2018, which brought forward the use of electronic prescriptions, before the legal obligation. In 2021, the result achieved, compared to the reference year, was ***-93.5% for chicken and -83% for turkey.*** *In general, a particular regard is reserved for more problematic antibiotics like fluoroquinolones and macrolides, in addition to the ban on cephalosporin of 3rd and 4th generation since 2013 and, from May 2017, the banning of colistin in chickens and injectable-only use in turkeys.*
Monitoring is planned for antibiotic resistance both in farms and at the slaughterhouse. The strategy is based on the one hand on the promotion of prevention protocols, on the other the continuous updated training of operators. The operational aspects of the reduction scheme are divided into several stages, which include the promotion of best animal husbandry practices, the development of complementary and/or alternative systems that enable the reduction of operations with antimicrobials, the constant monitoring of actual consumption, the exchange of information between operators and their training.
The implementation of the ClassyFarm system, with the voluntary entry of consumption data starting from 2015, together with the electronic prescription, was fundamental for the officiality of the data which show the significant reduction over the years, even compared to the other livestock species.

THE CLASSYFARM SYSTEM: THE UNIQUE RISK CLASSIFICATION AND ANIMAL WELFARE ASSESSMENT SYSTEM

ClassyFarm is an all-Italian innovation, the result of a project wanted and financed by the Ministry of Health and implemented by the Experimental Livestock Institute of Lombardy and Emilia Romagna with the collaboration of the University of Parma.
It is an integrated information system, i.e., a digital model aimed at categorising risk in ruminant, poultry and pig farms, with a further subdivision according to the production category of the species in question.

The idea behind the system is simple but effective: the company veterinary doctors and the appointed evaluators have access to a private section within the platform and record the data relating to their associated farms (these are animal welfare parameters, biosecurity, drug consumption). The system validates them, processes them and finally converts them into a numerical indicator that measures the risk level of the farm and supplies the relative certificate if animal welfare has been assessed. The effectiveness of the system is given by its capillarity on the territory, an aspect that has ***made ClassyFarm the unique system for risk classification and assessment of animal welfare*** *at Italian national level. With its implementation, the collaboration between operators and competent Authorities has emerged strengthened and the programming of official controls has become more effective and targeted. But, above all, ClassyFarm is a valuable tool for the farmer, who is now able to promptly identify any areas for improvement and adopt measures for risk reduction.*

WHY CURED MEATS CONTAIN SALT

The practice of adding substances to foods for easy storage is not a chemical or industrial invention, but is an ***ancient tradition****. Some examples are the addition of an acid juice (such as lemon) to prevent the blackening of a vegetable, as well as the use of smoke from wood, especially ones rich in resin. In the specific case of meat, the* ***use of salt****. In fact, the ancient Romans already had observed that saltpetre was improving the production of cured meats and sausages, avoiding the browning of the meat and especially preventing the proliferation of unwanted bacteria. Precisely for this reason, in the production of* ***some cured meats*** *are added, in controlled quantities, nitrates and nitrites that, inter alia, have the property of maintaining the colour of meat. In 2003, the EFSA – European Food Safety Authority explicitly stated in an important counsel to the European Commission that "in most processed meat products the addition of nitrite (or nitrate)* ***is necessary to prevent*** *the development and production of toxins for C. botulinum"[9]. Also EFSA has confirmed that the level of consumer exposure to foods with added nitrite and nitrate is adequate and does not constitute a danger, if these are consumed with equilibrium[10]. Thanks to the use of the refrigerator and microbiological knowledge, in addition to compliance with hygienic rules and to the exploitation of the bacteriostatic properties of spices and herbs, you can nowadays produce safe cured meat using* ***few preservatives****. In the PDO hams, for example, the* ***prolonged maturing process*** *makes unnecessary the use of nitrites, which in fact are no longer used in these products. As for all substances, also in the case of these compounds an* ***excessive consumption*** *can lead to negative consequences for health. Although it should be noted that nitrates are a component of many plant foods, the* ***nutritional balance****, repeatedly emphasised with the promotion of the Mediterranean Diet, is the way to valorise the benefits of each individual food reducing health risks.*

AGED MEAT:
SAFE LIKE FRESH MEAT. EFSA'S OPINION

By Giovanni Sorlini

The consumption of long-aged meat is as safe as that of fresh meat: this is the conclusion of the European Food Safety Authority (EFSA) in an opinion published on 19th January 2023[1].

In recent years, this type of meat has become increasingly popular in the food industry and catering. "The opinion provides a solid scientific basis for food business operators to produce safe aged meat," said the chair of EFSA's Panel on Biological Hazards, Prof. Kostas Koutsoumanis. According to the European body, this treatment does not present particular microbiological risks compared to fresh meat produced in the traditional way, provided that is carried out in defined and controlled conditions.

The maturation treatment has the purpose of improving the organoleptic characteristics of meat. It is a "controlled ageing" process based on prolonged conservation in special cold rooms, which allows the natural enzymes contained in meat to undertake the proteolysis of collagen and other muscle proteins, with the effects of improving the characteristics of tenderness and flavour. The aging treatment takes longer and requires specific technologies compared to ordinary production, capable of ensuring the constant control of some parameters such as ***temperature, humidity and ventilation of the conservation cells.***

The process involves conservation in dedicated cells lasting 15-30 days, or more in the case of particularly valuable meats. The duration of the treatment may vary in relation to the characteristics of the cut, the breed and the fat content. In standard production, the production cycles are much faster, if we consider that meat arrives on the refrigerated counters of supermarkets and butchers 48-72 hours after slaughtering, i.e., the minimum time necessary to obtain correct cooling and natural acidification of the muscle which ensures its conservation and transformation into meat.

*Aging is obtained through two systems. The first, called "****dry-aging****", provides that the cuts of meat, before being marketed, are matured for at least 15 days at a temperature between 0.5° and +3°C in conditions of low humidity and high ventilation. In this way the combined effect of natural lactic acidification and enzymatic proteolysis is expressed to the maximum, thus enhancing the organoleptic properties of the meat, such as tenderness and flavour.*

*The second system called "****wet-aging****" provides that the meat is vacuum-packed and stored in traditional refrigerator cells. Also, in this case the process can last about 15-30 days. Vacuum maturation allows a prolonged shelf life, even up to 120 days thanks to the natural protective effect of this packaging system. After purchase, vacuum-packed meat can be kept in the refrigerator at home, paying attention to control the temperature (4-5°C) and respect the expiry date. The matured product con also be frozen, provided it is done before the expiry date and in optimal conditions of conservation.*

For the consumer, information on the times and methods of this treatment must be indicated on the label: it is advisable that the label contains further information such as, for example, the breed, origin and provenance of the animals, breeding and feeding methods. Information whose transparency and *truthfulness must be certified by a policy document recognised and authorised by the Ministry of Agriculture. The ageing process must take place in standardised and controlled conditions, with specific technologies: it is not enough for the individual operator to keep the meat in a cold room for a few days to generically declare it as aged. In order for the cuts of aged meat to be of superior quality and truly distinctive compared to traditional cuts, they must come from animals with optimal growth, abundant covering fat and clearly visible marbling, i.e., with the part of fat contained inside muscle bundles evenly distributed. Better if obtained from female animals and older than 24 months. As in the case of the high-quality meats destined for the catering circuit from countries suitable for this type of farming such as Poland, the United States, or Australia. Even in Italy we have adequate breeding circuits, but not sufficient to satisfy the demand from the Catering - HoReCa circuit which represents the main end market.*

[1] *EFSA BIOHAZ Panel (EFSA Panel on Biological Hazards), Koutsoumanis K.,Allende A., Alvarez-Ord´o˜nez A., Bover-Cid S., Chemaly M., De Cesare A., Herman L., Hilbert F., Lindqvist R.,Nauta M., Peixe L., Ru G., Simmons M., Skandamis P., Suffredini E., Blagojevic B., Van Damme I., Hempen M., Messens W. and Bolton D., (2023), Scientific Opinion on the Microbiological Safety of Aged Meat, EFSA Journal 2023; 21(1):7745, 101 pp.https://doi.org/10.2903/j.efsa.2023.7745.*

2 CONTROLS AND INFORMATION FOR CONSUMERS

The quality and safety of food depends on the efforts of all people involved in the agricultural sector: **farming, processing, distribution, storage and even in the consumer phase.** In a nutshell, food safety is a shared responsibility from farm to fork.

To ensure the quality and safety of food throughout the chain, it takes, on the one side, operating procedures to ensure the healthiness of foods, and on the other, monitoring systems to ensure that operations are carried out correctly. The road to security passes through two obligatory stages: the attribution to the production world of the responsibility of safe food production and the execution of appropriate official controls carried out in an effective and coordinated manner among the different competent authorities.

2.1 Traceability and tracking

Often the two terms are used interchangeably, but they are not exactly synonymous, although they represent two sides of the same coin.

- **Traceability** means the ability to describe the path of a raw material or a quantity of production through the passageways from one business entity to another, within the production chain: from production, to processing, up to distribution. In essence, the flow of goods is accompanied by a flow of information, which are adequately recorded and retained at each step.
- **Tracking**, however, implies the possibility to reconstruct backwards the entire path of a product, from its final state to the starting raw materials.

These approaches are essential elements in the management of food security, because they allow the reconstruction of the characteristics and history of a food along the production chain, as well as ensuring a timely withdrawal from the market, when issues appear related to the quality or safety that pose a risk to the consumer. Since 2005, the legislation requires that all food products are properly tracked, involving in this process all the players in the food chain. The obligation of traceability also applies to products of foreign origin (in whole or in part), and permits finding the origins of the raw materials.
In addition to being a fundamental prerequisite for the management of safety and food emergencies, traceability has an important role ensuring the quality of the product: by a careful system of documentation, in fact, all the checks carried out on processes and products can be traced in every production stage.

2.2 Institutional controls

In Italy, the protection of food security is entrusted mainly **official control** activities carried out by the **Ministry of Health**, in compliance with the food safety model introduced in the European Union by Regulation 178/2002[11], Regulation no.

TRACEABILITY AND TRACKING OF MEATS

MAIN CHECKS PERFORMED

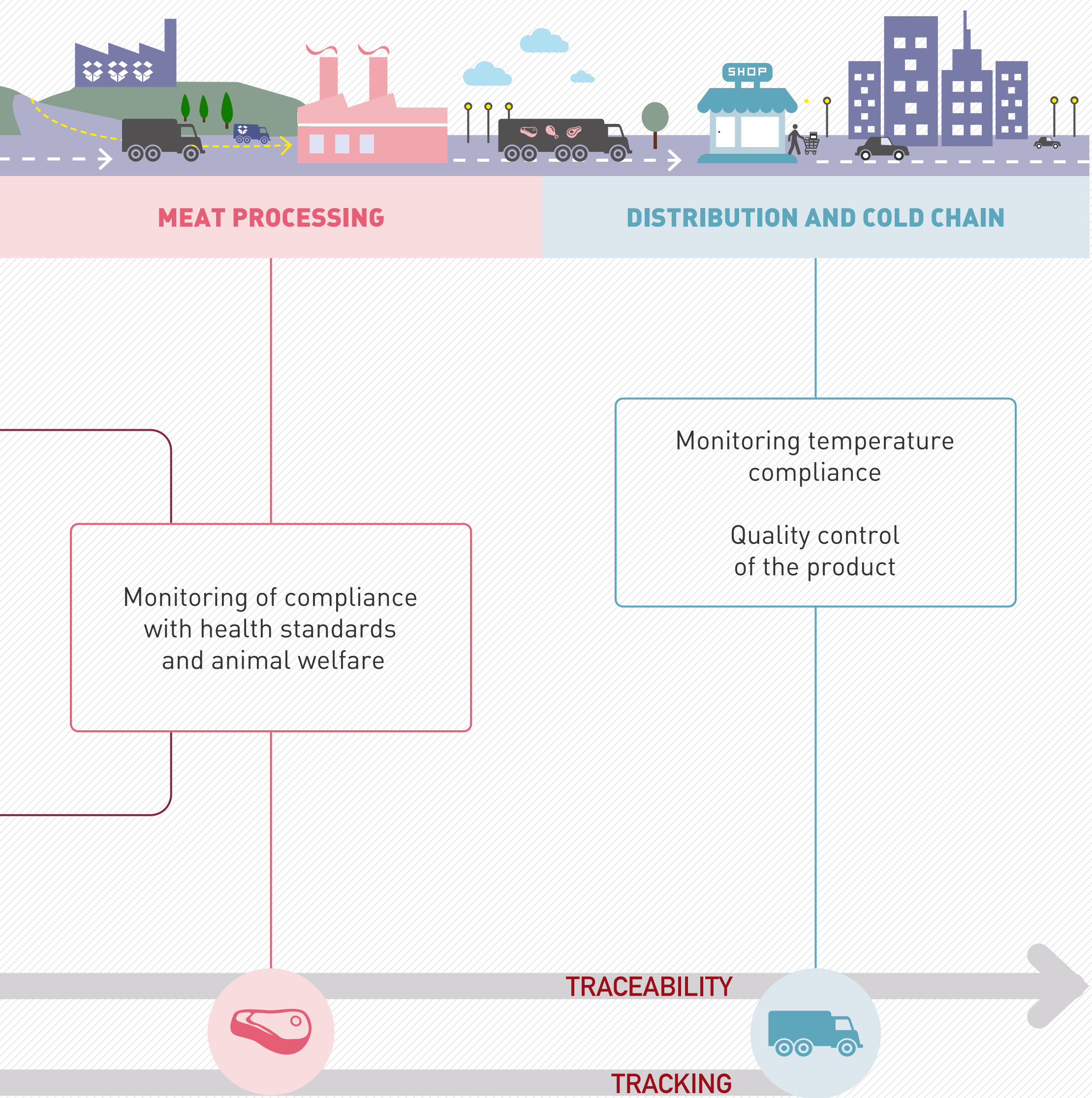
FEED PRODUCTION | **FARM** | **SLAUGHTERING**

Control of accompanying documentation

Analysis on raw materials and/or on the food

Control of possible veterinary therapies

Compliance with animal welfare standards



 ISBN 9788835155713

882/2004[12] and subsequent regulations of the so-called "Hygiene Package"[13].
The Ministry operates at central level, with the General Directorate for hygiene and food safety and nutrition and, at regional level, with its Regional Offices. To these are added the controls of the Regions and Autonomous Provinces of Trento and Bolzano, through their territorial structures, Departments of Prevention of Local Health and public Laboratories of Official Control, such as the Livestock Institutes. The controls are designed to ensure that food and feed on the market comply with the regulations aimed at protecting **consumer's health**, **animal welfare** and prevent **food fraud.** In the first two cases one intervenes to ensure the safety of the consumer, avoiding contamination and preventing situations that could lead to the development of bacterial contamination.

In the case of **commercial fraud**, however, controls verify the conformity of the product with the characteristics declared by the manufacturer about the amount or source, and determine any tampering that could cause danger to human health[14].
In both cases, non-compliant or products considered dangerous are blocked before their arrival on the market, or withdrawn from the market.
The controls, which take place throughout the supply chain, cover both Italian or foreign products to be marketed domestically and Italian products destined for export. In general, the surveys provide a fully investigated product through inspections, sampling and laboratory analysis, or inspections of production processes with controls that may include also the staff assigned to the processing.
As for the meat sector, the controls are focused on farms, with regard to health and animal welfare, as well as slaughterhouses in the processing industries. Continuing along the chain of distribution, attention is drawn to the rules for labelling and compliance with consumer information requirements.
According to regulatory provisions, the controls are programmed on the basis of a risk assessment: the major resources are dedicated to those sectors which involve greater risks for consumer's health. Apart from this, the various competent authorities should operate in an integrated and coordinated manner in order to allow effective actions and reducing to the least the inefficiencies due to any duplications.
Complementing the official controls provided by the legislation, businesses in the food industries have to implement self-control plans in accordance with the principles of HACCP (Hazard Analysis Critical Control Points), which provide for the identification of their critical points and prepare, on them, monitoring and improvement plans.

EUROPEAN AND ITALIAN RULES ON FOOD SAFETY

"Security from the farm to the fork". This is the principle of the strategy adopted by European Union countries for safeguarding health and consumer safety.

In practice this means preparing a system of integrated control between the various subjects involved to guarantee compliance with the requirements of food products and for the welfare of animals and plants, whether they are produced within the EU or imported.

The general principles on which the legislation concerns are[15]:

- *integrated controls throughout the food chain;*
- *interventions based on the Analysis of Risk;*
- *primary responsibility of the industry for each product created, processed, imported, marketed or administered;*
- *traceability of products throughout the supply chain;*
- *consumer as an active part of food security.*

In addition, to ensure a scientific approach to issues related to food, the European Authority for Food Safety was established (EFSA[16]) in 2002, which, in collaboration with national authorities and in consultation with stakeholders, since then provides independent scientific advice and clear communication on existing and emerging risks. EFSA elaborates scientific and expert advice to provide a solid foundation for legislative work and to facilitate timely and effective decisions in risk management.

Especially for meat, the legislation is very detailed, both in the definition of the requirements of the production facilities and for product specifications and related control systems.

IS IMPORTED MEAT LESS SAFE THAN ITALIAN MEAT?

If we were to draw up a list of topics that generate most concern for consumers in relation to food security, the origin of the meat they eat would certainly appear up at the top. It is in fact a quite widespread belief that imported meat is "less safe" than homemade, a hypothesis which in reality is not confirmed by the facts.

Within the EU, the control system is harmonised by Community law and follows the principle of safety "from farm to fork": this means that the cattle are traced at every stage of the supply chain, regardless of the country in which it is bred, and cannot be treated with substances prohibited by the Union (such as, for example, anabolic hormones). Meat coming from other member States, therefore must meet the same requirements as in Italy, and thanks to the obligation of traceability, information can be traced back at any time to specific phases of the supply chain.

As for the non-EU countries, however, the question becomes more complex. In some countries, in fact, the national legislation does not impose the obligation of traceability along the supply chain, giving priority to analytical controls on the product to be placed on the market, rather than supervising pre-slaughter. This does not mean that the products are less safe or controlled, because to obtain the importation authorisation in Europe, the companies must comply with the same requirements in force in the EU market.

Either way, in Italy there are various control points located in places of commercial trade, borders or at ports and airports: the so-called ***PIF (Border Inspection Posts)*** *where the controls on food imported from other countries and the* ***UVAC (Veterinary Offices for Community Compliance)*** *involved in trade between member States are placed.*

P.I.F. and U.V.A.C. are directly connected to the European food alert system: this allows, in the presence of a non-compliant product, to take swift action to prevent the placing on the Community market or eventually its removal.

The agro-mafias insert food into the market without the necessary checks and for this reason they must be prosecuted. The supply chains of meats, instead, spend resources to guarantee to consumers that the product, national or foreign, have the requirements of reliability demanded by the market.

PNR AND CONTROLS
FOR THE DETECTION OF PROHIBITED SUBSTANCES

EU and national legislation lays down control measures for the presence of undesirable substances in food. In particular, each Member State must annually perform the ***National Plan for the detection of Residues (PNR),*** *a structured program which aims at overseeing and monitoring the presence of residues of substances for livestock use, both illicit and authorised, and environmental contaminants in live animals and the feed from which they originate. The PNR consists in a series of samples prepared at national level adapted to the regional situation and carried out by the National Health Service, both on farms (primary production) and in the establishment of initial processing (slaughterhouses or the milk collection centres).*

The analyses to reveal the presence of illegal substances are carried out by the laboratories of the ***Istituti Zooprofilattici Sperimentali.*** *The substances to be researched fall into the two categories:*

- ***Category A:*** *includes unauthorised substances for the treatment of farm animals. For example growth hormones.*
- ***Category B:*** *includes the veterinary medicinal products, for which the EU defines a maximum residue limit that cannot be exceeded in consumer products; and environmental contaminants such as heavy metals.*

In the event that the administration of prohibited substances is detected, or the content of residues of authorised substances or environmental contaminants were higher than the established limits, the application of sanctions would be implemented to protect the consumer such as the recall of dangerous products, the ***application of administrative and criminal sanctions****, the conducting of epidemiological investigations to determine responsibilities and uncover any further treatments. For some substances, such as growth promoters, the PNR also adds other specific controls. The use of low concentrations means that the residues of these substances present in animal tissues are difficult to reveal by laboratory analysis. In this case, we resort to specific histological examination, i.e. tissue analysis, carried out directly on the carcass after slaughter operations: the use of growth promoters, in addition to increased enhancement of the animal, in fact also determines the alteration of some organs (sex glands, gonads, thymus etc.) whose analysis can highlight situations that deviate from the norm and, accordingly, permits the use of illicit substances to be suspected.*

THE RESULTS OF THE 2021[17] PNR

In 2021, the implementation of the PNR led to the analysis of ***30,263*** *samples, of which 49.6% for the research for substances belonging to category A and the remainder for the research for category B substances. The samples that provided irregular results due to the presence of residues were a total of 12, equal to* ***0.04%*** *of the total samples analysed. Few cases therefore, despite the accuracy of the analysis allowed by current laboratory technologies, capable of verifying an enormous range of substances, even in minimal traces. The conclusions demonstrate once again that meat, milk, eggs (and their derivatives) offer excellent guarantees of safety.*

2.3 The self-control system of companies

According to European regulations[18], any activity that operates in the food industry has an obligation to prepare a plan of self-control according to the HACCP (Hazard Analysis and Critical Control Points). This method provides that each operator performs an analysis of potential risk factors for health resulting from its operations, and define one or more measures for the control and prevention of the risks. The HACCP Manual must be validated by the Health Authority (ASL) which oversees its implementation.

The HACCP self-control plan is based on seven principles:

1. Identify any hazard to be prevented, eliminated or reduced.
2. Identify the critical control points (CCP – Critical Control Points) in the phases in which it is possible to prevent, eliminate or reduce a risk.
3. Establish, for these critical control points, critical limits which separate acceptability from unacceptability.
4. Establish and implement effective monitoring procedures at critical control points.
5. Establish corrective actions if a critical control point is not under verification (exceeding the established critical limits).
6. Establish the procedures to be regularly applied to verify the effective functioning of the measures taken.
7. Prepare documents and records commensurate with the nature and size of the food business.

The plan must be applied and finalised at preventing problems and must provide for appropriate corrective actions to minimise risks every time there is a non-compliance. The plan includes general and specific measures. Those "**general**" are represented by common rules that apply to all processing areas and are inherent to the hy-

INFORMING THE CONSUMER WITH THE PRODUCT LABELS

The labelling of meat, which became mandatory for beef as early as the 2000s (EC Regulation 1760/2000) and then extended to other meats over the last 10 years, is a system that requires the producer to provide information to consumers about the product they are about to buy.
At European level, the matter is currently governed by Regulation 1169/2011, which establishes common rules for the labelling of the various species and serves as a coordination between the various sectors, ensuring consistency of the information contained in the different labelling systems.
Although there are subtle differences between the various species, in general the information concerns the **country of breeding**, **slaughtering** and, if applicable, **processing** of the product. This information can help the conscious choice of consumers during the purchase

giene of operators, premises, equipment, processes and products, as well as the application of verification measures of the rules.
Those "**specific**", defined for each type of production process, aiming at the identification, evaluation and control of the specific **risks of a biological, chemical and physical** nature which could affect the safety of food products.
The dangers are evaluated according to the principles outlined in the "**Codex Alimentarius**" and the national and international legislation.

2.4 An all Italian safety: supply chain and the protection consortium

The Italian food system presents some peculiarities that, in addition to determining a strength in terms of quality and value, permits excellent safety levels to be guaranteed.
A first aspect concerns the presence of effective and wellcoordinated **supply chains.** A product is made "in the food chain" when all the players involved in the production process are integrated and coordinated with each other: in this way an additional control, direct and complete, of agricultural and industrial production systems is possible on behalf of those who have product liabilities towards the market.
The purpose of the chain is to make transparent the relationship between the subjects involved in the production and processing of the final product, by developing a relationship of trust, with shared objectives between the parties involved. An added value to the chain is to minimise risk by simplifying the control plans. Products relating to controlled supply chains allow a better understanding of quality and food safety data, generally more detailed than the minimum requirements of the law, better control of product standards with respect to the expectations of the con-

DOP E IGP IN ITALY

Italy holds the European record for the number of PDO and PGI awards, with more than **319 quality products** recognised[19]. Due to the international importance of these designations, the awarded products are subject to strict and specific controls, in addition to the routine checks laid down by European and national legislation. In Italy, the PDO and PGI products of the pig production chain are subject, as well as inspections of the national health system, to the annual inspections at farms, slaughterhouses, processing plants, ham and cured meats companies, carried out by two independent institutions designated by the Ministry of Agriculture, Food and Forestry.

These organisations certify the quality of raw materials and in particular compliance with the rules of production materials: a system which guarantees the acquisition of high quality products, made according to traditional recipes. About a third of European PDO and PGI meat based products are Italian. In addition, the first 4 PDO Italian products for export volumes and market share belong to livestock chains: Parma ham, San Daniele ham, Grana Padano and Parmigiano Reggiano cheese.

sumer and greater recognition through dedicated brands. In Italy it is estimated that about half the beef and the pork are produced in the supply chain, while for poultry meat in the production chain is almost complete.

A second aspect concerns the presence of numerous products identified internationally as gastronomic excellences such as those protected by the geographical indication trademarks.

The European Union protects the typicality of some food products through the recognition of **PDO (Protected Designation of Origin) and PGI (Protected Geographic Indications)**. These designations, recognised throughout Europe, are awarded only to those high quality products whose production takes place in defined geographical area, and for which there is a causal link between the geographical area and the quality or characteristics of the product and the characterising aspects of the production process[20].

In other words, the product should show a strong link to the territory, to whose name must be traced certain characteristics of the product itself. The function of these trademarks is threefold: to protect quality products from misuse and imitation; give consumers reliable information about the products they purchase; contribute to the protection of rural areas, whose socio-economic system often depends on the development of typical agricultural food production and quality.

VOLUNTARY LABELLING IN THE POULTRY SECTOR

Italian legislation foresees the possibility, for operators who wish to do so, to provide voluntary and additional information on the label other than that required by law. To achieve this, however, a particular set of voluntary labelling procedures must be followed, which are recognised by the Ministry of Agriculture: in the poultry sector, the first and most comprehensive is the one developed by UNAITALIA, representative of 99.98% of the producers who use voluntary labelling.

In addition to the information prescribed by the law, the guidelines state that you can enter specific information relative to:

- the food: for example, no GMO, free of animal flour and/or added animal fat, vegetable food etc.);
- the kind of farming adopted: raised on the ground, outdoor, extensive covering, etc.;
- the genetic type;
- animal welfare measures: more space in breeding areas respect to the legal limits, the presence of natural light in infrastructure dedicated to breeding, presence of straw bales or perches to encourage natural behaviour;
- absolutely no use of antibiotics at all, in any phase of the animal's life.

3 THE COMMUNITY FOOD ALERT SYSTEM

To notify risks (real or potential) in real time for the health of consumers, a system of Community rapid alert (RASFF) was established, which, through a network of spreading information, permits a rapid and coordinated action. In practice, the RASFF constitutes a network of "contact points", identified in the European Commission, in the EFSA (European Food Safety Authority), the ESA (Supervisory Authority of the EFTA - European Free Trade Association) and at national level, identified by the authorities in individual member Countries.
All parties involved exchange information in a clear and structured way by means of protocols that ensure the homogeneity of the reports: the Ministry of Health is the Italian point of contact. In case of serious and immediate risk (for example, of a toxin such as botulinum), further to providing immediate seizure of the products, the emergency procedure can be supplemented with press releases to inform the public on the risks linked to the consumption of a particular product and the mode of delivery of the food to the competent local Health Authority.

3.1 Different levels of alert: when is it right to worry?

The Alert System foresees **four types** of communications that are sent to the member States depending on the severity of the situation:

- The **Alert Communications**: are sent when food or feed which present a serious risk are on the market and where action is needed quickly for their withdrawal or recall. The RASFF member that identifies the problem and takes proper action (e.g. product recall) starts the alert with the objective of giving all members the information to verify whether the product in question is on their markets, so that they can take the necessary measures.
- **Informational Communications**: are used when a risk is identified in respect of a food or feed on the market, but other Member States are not required to take rapid action. This is because the product has not arrived or is no longer present on their market or because the nature of the risk simply does not require such action.
- The **rejections at the border**: concern consignments of food and feed undergoing an exam and rejected outside the EU borders (and the EEA, the European Economic Area) when a health risk is detected. Notifications are sent to all EEA border posts.
- The **News**: all information feed that have not been sent as a warning, but which also contain useful news for the safety of consumers.

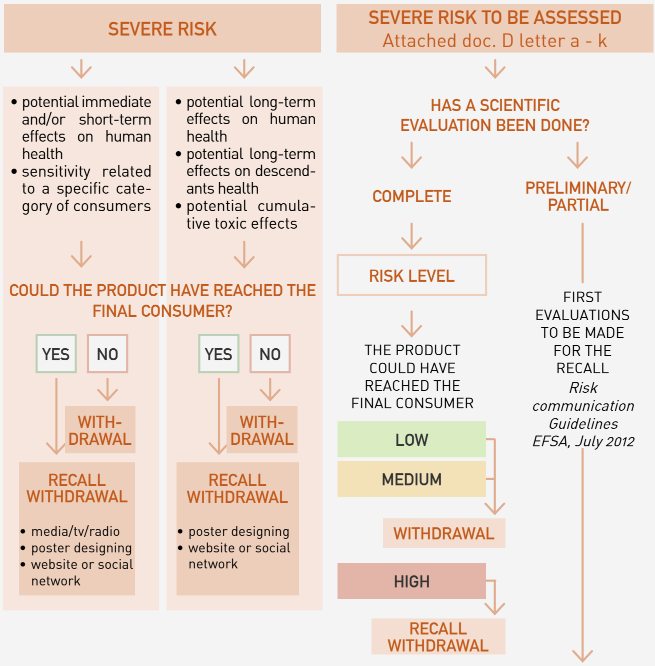
+ *Detailed study*

NOTIFICATIONS
TO CONSUMERS

Consumers are explicitly warned (with direct and multi-channel communications) if a dangerous product, which has already been sold to consumers through the distribution network, is to be recalled from the market.

CRITERIA FOR THE RECALL

State-Regional agreement
2008 November, 13
"WARNING SYSTEM GUIDE LINES"



	RISK LEVEL	IMPACT	ESPOSURE
WITHDRAWAL	LOW	Little impact on public health / lack of public interest	None
	MEDIUM	Low/medium impact on public health / Low/medium lack of public interest	Slight
RECALL	HIGH	High impact on public health / high/medium lack of public interest	Widespread/ specific groups
	UNKNOWN	Unknown, to be evaluated	Unknown

Source: Ministerial note - Procedures for the recall by OSA of non-compliant products, www.salute.gov.it/portale/temi/p2_6.jsp?lingua=italiano&id=4633&area=sicurezzaAlimentare&menu=vuoto.

3.2 What are the risks that generate alerts?

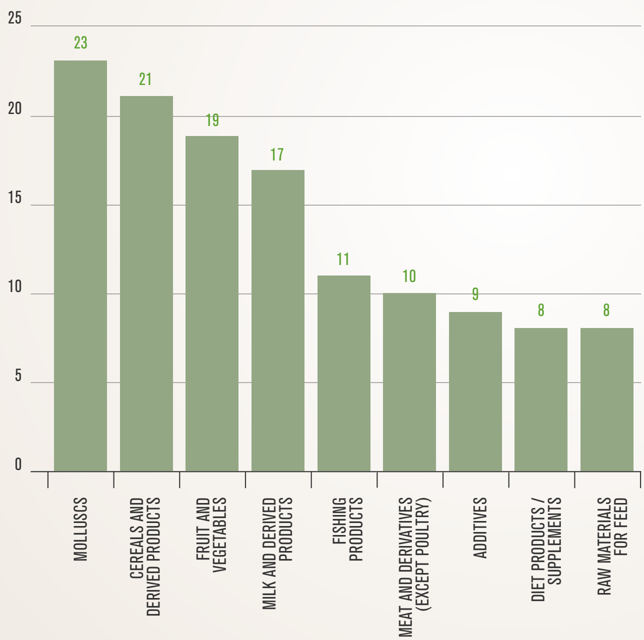
Each year the results of the notifications to the RASFF system are collected in a report published by the European Commission and then translated by the various Member States. The annual report represents an extremely useful tool for getting immediate information on which food categories were most subjected to criticism during the course of the year, as well as the type of risk detected.

From the analysis of the report dated 2021[21], it emerges that notifications are gradually decreasing, while most warnings concerned the contamination by the presence of residues of pesticides (1,251), phatogenic micro-organisms such as Salmonella (774), mycotoxins (449) and non-compliant coposition (343).

NOTIFICATIONS IN ITALY

Overall in 2021, in Europe, there were **4,588** notifications[21], compared to 3,783 the previous year. The comparison with previous years reveals (after a constant decrease from 2011 to 2016) an increase in alerts, which went from 2,925 in 2016, to 3,759 in 2017, to 4,000 in 2019 and finally to 4,588 in 2021. In particular, the increase from 2020 to 2021, is mainly attributable to the **ethylene oxide** emergency, found both in **vegetables** and in spices and additives.

Looking at the situation in our country, Italy has proven to be the **fourth member state for the number of notifications sent** to the European Commission, thereby demonstrating intense and thorough monitoring activities throughout the country, with a total of **387 notifications** (equal to 8.4%), while in 2020 the notifications issued by Italy were 300 (7.9%).



Italy is the tenth in the ranking for the number of notifications received, with a total of **172 national products reported as irregular** (compared with 125 notifications in 2020). The type of irregular products is heterogeneous: the highest number of notifications concerned bivalve **molluscs** (mussels and clams), followed by **cereals**, **bakery products and fruit and vegetables**.

4 ANIMAL WELFARE

4.1 The foundations of animal welfare: five freedoms

The interest for animal welfare, as we understand it today, can be traced to **1965**, the year the **Brambell report** was published, the first scientific paper on the subject commissioned directly by the British government. The document is specifically related to farm animals and sets out the **"five freedoms"** to be protected to ensure animal well-being, not only as absence of disease, but as a state of good overall physical and mental health. These conditions, taken and "institutionalised" in 1979 by the Farm Animal Welfare Council (FAWC), are still the basis of international legislation on animal welfare.
The five freedoms recall the respect for the fundamental and basic needs of each animal, the protection of which is vital especially in captive conditions.
Although these requirements are still the basis of Community legislation, in reality the debate on this topic has not yet found a clear definition.
Most experts agree to see animal welfare as a balance between the individual and the environment that surrounds it, where "environment" refers to a heterogeneous group of factors including the physical environment (facilities, density, microclimate etc.), interaction with other animals and humans, the absence of disease or predators[22]. The adaptation to these factors can vary in intensity from case to case: the animal can be, for example, in a good level of wellness compared to some factors such as the farming structure, but in a low level for others, such as the health status.
From this consideration emerges that one cannot talk about health only in terms of its presence or absence, but also that wellbeing varies from very bad to very good[23]. To testimony the strong interest on the subject in recent years various pro-

FIVE FREEDOMS

1. FROM HUNGER, THIRST AND MALNUTRITION
by ensuring the animal access to fresh water and a diet that maintains full health

2. TO HAVE AN ADEQUATE PHYSICAL ENVIRONMENT
giving the animal an environment including shelter and a comfortable resting area

3. FROM PAIN, INJURY, DISEASE
foreseeing them or diagnosing and treating them quickly

4. TO EXPRESS THEIR SPECIFIC BEHAVIOURAL CHARACTERISTICS
of their species providing the animal with sufficient space, proper facilities and the company of other animals of their own species

5. FROM FEAR AND DISTRESS
ensuring the animal conditions and care that do not involve psychological suffering

jects have started to measure the level of animal welfare, based on specific and objective indicators that can reflect the psychophysical condition and the level of stress of animal health: some of these are the Welfare Quality® and the RIBECA project. Also in the Rural Development Programmes animal welfare has found ample space. In particular, Measure 215, relative to payments for animal wellbeing, financially supports the dissemination of methodologies and farming conditions with high animal welfare content, more than the minimum limits imposed by specific regulations, with the aim of increasing the competitiveness and profitability of livestock farms.

Although the scientific community has established the characteristics of animal welfare and its measurement mode, in the public opinion the perception of well-being is far from unique and maintains a strong characteristic of subjectivity, due to ethical considerations. In other words, if for science there is a substantial agreement on how to define the state of animal welfare, in common understanding the conditions considered "adequate" vary according to the conception of the animal itself and the adopted perspective.

4.2 Animal welfare in modern livestock

As with all food products, also livestock production is constantly increasing and this involves, on the part of the operators a constant search for efficiency. This, one should admit, has over the years resulted in some critical situations regarding some aspects of sustainability, such as animal welfare, which have been put into second place compared to the economic factor, which has always been the main driver of a productive enterprise.

It is also necessary to observe, however, even though not always at the same speed among the various industrial sectors, that things are changing and many entrepreneurs have started considering animal health among the subjects relevant to the sustainability of their business, especially when the vision is far-sighted: it is only in medium or long-term horizons that investment without immediate return, such as those of animal welfare, give their fruits.

In the case of livestock, the principles laid down by the five freedoms should be guaranteed mainly by paying attention to the **rearing phase**, **but also to transport and slaughter**. To regulate these and other factors the legislation, first Communitarian and then National, intervened establishing specific criteria that represent minimum thresholds to be respected. Intervention in legislature has been joined, with a remarkable growth in recent years, by the development of a large number of standards and voluntary initiatives, brands and certifications to ensure compliance with certain characteristics in breeding, permitting, among other things, a higher level of well-being. It is for example the case of awards for animal welfare and standards for breeding proposed by nongovernmental organisations such as Compassion in World Farming and the RSPCA, or product standards such as organic, for the attainment of which are provided stringent requirements for farming conditions.

NATIONAL QUALITY SYSTEM FOR ANIMAL WELFARE (SQNBA)

By Angelo Gamberini

*Named the **National Quality System for Animal Welfare** and its Italian acronym, **SQNBA**, is intended to label animal origin products whose production respected optimal breeding conditions, even superior to those envisaged by current regulations on this matter. This is what is envisaged by the Decree of the Ministry of Agricultural Policies (today the Ministry of Agriculture and Food Sovereignty) published in the Official Gazette n°279 of 29th November 2022. This is only the last step, in chronological order, of a long journey of animal welfare protection that has its roots in the final years of the last century. Compared to then, when the greatest attention was paid to calf breeding, much progress was made to protect animals in livestock production, from bovine to pigs to poultry and further. SQBNA is a further step forward, which began in 2020, with the introduction in the "Relaunch Decree" (law decree n°34 of 19th May 2020) of article 224 bis, which established new objectives in terms of animal welfare and, if you look more closely, to relaunch and enhance the Italian livestock system. In a nutshell, it is **a certification system, with voluntary participation, which aims to encourage practices of excellence** in the management of farms with respect not only of animal needs but also of the environment. As specified by the same decree, it "establishes the procedure for the definition of animal health and welfare requirements, higher than those of the relevant European and national standards, aimed at qualifying the management of the farming processes of animals intended for food production".*

Among other things, the 13 articles and annexes that make up the regulation provide for the definition of a certification body, which must be registered in the appropriate list of the agricultural ministry.

*Furthermore, the establishment of an "Animal welfare scientific technical committee" is envisaged, which will have the task of defining the certification requirements and harmonising and coordinating the technical standards already recognised and used for other certifications. This committee will include representatives of the Agricultural Ministry, the Ministry of Health, the regions and autonomous provinces, the Italian accreditation body **Accredia**, and obviously also animal welfare experts. To achieve the objectives set, the **SQNBA project will be able to rely on ClassyFarm**, the system developed by the Ministry of Health to "categorise" farms based on risk. In this case we are also dealing with an initiative (already operational for some time) with voluntary participation, which by collecting farm data and information makes* *it possible to evaluate their efficiency and safety, suggesting the necessary corrective measures if necessary. Joining **ClassyFarm** thus becomes a necessary step for subsequent animal welfare certification.*

*To enter the operational phase, SQNBA requires further demanding steps to define the technical aspects to be applied in the field, whose compliance will be supervised by the certifying body. To seal the excellence of the animal products thus obtained, a logo will be prepared, presumably inspired by the acronym SQNBA, to be affixed to the final product and to the preparations contained within. The entry into force of the decree, which must be accompanied by the necessary implementing decrees, is however subject to the conclusion of the notification procedure to the European Commission, which has the final say. In Italy, compliance with the rules on animal welfare, as well as attention to their health, is the usual practice on behalf of farms, with the awareness that it is a fundamental prerequisite for the success of the livestock enterprise. The SQNBA project raises the bar of animal welfare towards even more ambitious levels, which could however involve higher production costs. As participation is on a voluntary basis, it is therefore legitimate to take into consideration the attractiveness of the project. The launch of a communication and promotional campaign for these products, which we could define as "with high animal welfare", can be an incentive to join the project. A further stimulus to participation arises from the consumer's propensity to give their preference to products that respect animal welfare and the environment. In this case, the difference would be the higher price on sales' shelves. An important incentive could also come from European resources and the new **Community Agricultural Policy (CAP)** for the period 2023-2027. This envisages that each nation provides for the definition of a Strategic Plan for the CAP (SPC), with particular regard to interventions in favour of the climate and the environment. To this end, **the SPC of Italy has defined five eco-schemes**, the first of which concerns animal husbandry, which receives the most significant part of the economic resources (363.3 million Euro out of a total of 875.5). The eco-scheme intended for farms has two levels: the first aimed at encouraging the reduction of the use of veterinary drugs and the second at favouring commitments on the animal welfare front. For the latter, the award is conditional on compliance with some specific obligations that concretise in joining the SQNBA system.*

For both levels, community aid concerns all UBA (adult livestock units) and is disbursed annually as an addition to the basic payment. The amount for level one (that concerning the reduction of veterinary drugs) provides for 66 Euro per UBA in the case of dairy cattle and buffaloes and 54 Euro per UBA for other bovines (meat). Sheep and goats receive 60 Euro per UBA. For all types of pigs, the payment stops at 24 Euro per UBA. The premiums destined for level 2, that for animal welfare, are decidedly higher, reaching 240 Euro per UBA for cattle (milk and meat), rising to 300 Euro per UBA in the case of pigs.

Adherence to the SQBNA system is not an indispensable condition for obtaining support for level 2 eco-schemes, but it represents an accelerator of the verification process for the envisaged obligations. Whilst not mandatory, SQBNA as a consequence offers a privileged way to access community benefits conditioned by compliance with specific requirements. Opportunities which, together with the advantages of product certification, will encourage wider participation by farms and the entire supply chain.

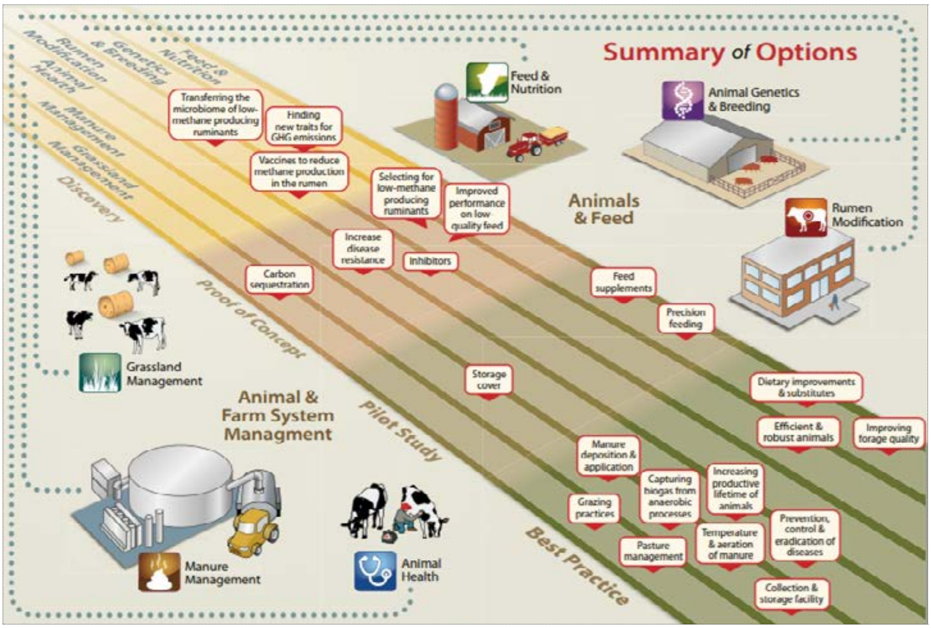
THE SAI PLATFORM
(SUSTAINABLE AGRICULTURE INITIATIVE)

*In order to catalyse a change in the food industry, some producer companies of wide consumption goods have established, in 2002, the platform for "Sustainable Agriculture Initiative" (SAI Platform). Today the initiative involves more than 170 companies in the food and drinks industry. Their goal is to increase knowledge of sustainable agriculture and communicate with an increasing number of stakeholders. Among the various initiatives there is the standard **"Farmer Self-Assessment" (FSA)** that was designed for analysis and improvement of sustainability on farms.*

The standard, designed for the analysis of the European context, has been the subject of a pilot project to adapt it to the Italian reality focusing attention on the aspects considered relevant. This test had main players such as INALCA, DQA - Agri-Food Quality Department and Coldiretti and has permitted to identify possible improvement actions as well as any measurement tools.

*A second, important initiative at European level is the **"European Roundtable for Beef Sustainability" (ERBS)** project focused on the sustainability of beef. The ERBS objectives fall into 4 areas of intervention: environment, animal welfare, antibiotics, breeding management. Each of the countries that have currently joined the project (Italy, France, Germany, Ireland, Poland and the United Kingdom) has created its own national platform and is required to submit a periodic report on all the activities implemented.*

FLOW OF THE MAIN ACTIVITIES OF SAI PLATFORM



Source: SAI Platform.

SURVEY ON THE MAIN ASPECTS OF SUSTAINABILITY
FOR ITALIAN BREEDERS AND STAKEHOLDERS

One of the preparatory activities for the improvement of sustainability in the livestock sector is aimed at examining and, where possible, measuring the perception of the sector's operators on the topic. For this purpose, the collaboration of Coldiretti with INALCA allowed to engage a heterogeneous sample of farmers in the beef industry as well as public subjects and private individuals of particular importance (MASAF, McDonald's, COOP, Barilla...), with the aim of understanding the aspects and related practices of sustainable management of most interest. The themes touched from the survey are those mainly involved in sustainability issues such as company management, environmental impacts, animal well-being, ethical and social aspects. In practice every stakeholder was asked to assign a score that allowed to quantify applicability or relevance of that aspect compared to its presence in the bovine supply chain. The elaborations have identified that among the most relevant topics are to be found ***animal welfare, the management of the company, ethical and social aspects.*** *On some themes the two samples offer very discordant results. An example are the related questions to the reduction in use of antibiotic drugs and fight against illegal hiring: both the questions registered a high interest score for stakeholders (companies and public institutions) and very low for breeders. This dichotomy highlights how some themes related to sustainability are interpreted and lived completely differently inside the supply chain. This discrepancy underlines once more the importance of drawing up transversal and integrated guidelines at all levels of the livestock supply chain for sustainable development at all levels of the livestock supply chain.*

Questionnaire questions (● Animal welfare ● Company management ● Ethics and social)	**Breeder results**	**Stakeholder results**
What value is attributed to the correct management and improvement of animal welfare	4.64	4.73
Importance of management and decrease in the use of antibiotic drugs	4.13	4.73
Importance of fighting illegal hiring and, in general, the respect of collective agreements at work	3.77	4.73
Importance of financial stability and investment planning	4.43	4.55
Importance of a balanced diet for livestock and adequate space for animals	4.62	4.45
Importance of correct management of company safety and health care	4.45	4.36
Importance of fair remuneration and freedom of association	4.40	4.36
Importance of the company's environmental impact *(consumption of water. emissions and management of manure. maintenance of biodiversity)*	4.06	4.18
What value is attributed to the transparent management of company ethics?	4.36	4.18
Importance of the company's ability to integrate local communities (job creation) and to support the territory	3.68	4.18
What value is attributed to the culture of corporate and managerial improvement of the farm?	4.23	4.00
What value is attributed to the management of environmental aspects?	4.15	4.00
Importance of energy efficiency management and use of renewable sources	3.87	4.00
Importance of proper staff training through the organisation of specific courses	3.68	4.00
Importance of an improvement plan in the selection of suppliers *(animal genetics. food outsourcing and national origin)*	3.89	3.91
Importance of a commercial positioning and access to the company market through the definition of contracts	4.23	3.73
Importance of the choice of sustainable supplies and raw materials	4.02	3.73
Importance of the company's ability to adhere to production chains aimed at conserving traditional breeding and processing systems with reduced environmental and climatic impact (e.g. designations of origin)	3.72	3.64
Importance of management and improvement of well-being during transport	3.45	3.64
Importance of management control and access to finance	3.85	3.55

Results of the questionnaire sent to stakeholders and breeders, complete with all the questions ordered according to the priorities expressed by the interviewees (1 minimum - 5 maximum). The topics of greatest interest were highlighted, mediated on the basis of the results of the analysis of the questionnaires compiled by breeders and stakeholders.

Extensive or intensive farming?

Today the issue of animal welfare is directed especially towards intensive farming, generally accused of offering lower conditions of animal welfare and respect in comparison to more "traditional" and extensive forms.

Behind this statement there is a complex issue, namely the inability to objectively define what are the characteristics of an "intensive" or "industrial" farm.

Although the term "intensive" is commonly used both in legislation and in common language, there is actually not a unique and precise definition. One of the few references is in the **European Convention for the Protection of Animal Husbandry** of 10th March 1976 which defines intensive farms, "*that primarily employ technical installations managed principally by means of automatic devices*". A definition both broad and vague. A second suggestion, more specifically, is provided by **INEA** (National Institute of Agricultural Economics) in a report from 2012, in which it identifies the intensive rearing livestock as a way in which man has the control of both of space available and of animal resources. However, even in this case, there is some ambiguity: as in the case of "pasture grazing" farms when the animals are sheltered in warehouses when there is intense cold or snow: in this case one necessarily turns to food rations, thus the "resources" available to the cattle, and the space to be assigned to each of them are controlled.

When the judgement of the well-being is based on the conditions and on the place of farming, one tends to look favourably on pasture grazing in preference to those in the barn, considered more "industrial" and less respectful of standards of animal welfare. In reality, **both methods have advantages and weaknesses**, and it is important to remember that they refer to different farming requirements, which are derived from the characteristics of the territory and the fertility of the soil, but also the economic sustainability of companies.

In the case of **confined** livestock farming (barn, sheepfold, pigsty, henhouse, etc.) which obviously provides less space, the management of the animal is more **precise** and **accurate**: the animals are checked daily, with the possibility of a timely detection of problems of various associated nature,

COMPARISON BETWEEN EVENTS THAT OCCUR TO AN ANIMAL IN NATURE AND IN A FARM

(the + are positive scores offset by the –)

Events	Nature	Farm
Hunger	–	++
Thirst	–	++
Illness	–	++
Predation	–	+++
Predation	++	+/–
Fear	–––	+/–
Total	-5	+10

Source: Pulina G. (2019) - Carnipedia. Appunti per una piccola enciclopedia della carne.

for example, in diseases or nutritional problems. In this case, also, it is easier to prevent any harmful infectious diseases for livestock or humans, important especially in highly humanised environments.
In farming in the **open** (pasture grazing, open-air) typical of northern European countries or America, which have large agricultural areas,the animal is left in the open, even in the wild in the case of ruminants and pigs, for most of its life. In this case there is certainly more freedom of movement, but you must consider that the production cycles are getting longer and the degree of control in the event of illness, **bad weather or predator attack** is less. It is therefore clear that the choice **between extensive and intensive is not so distinct**, both because there are no fixed definitions, and because both farming models have advantages and disadvantages that need **to be judged with a global vision** that takes into account many aspects. Therefore, in general, the type of livestock farming is not the only criterion on which to base the measurement of well-being: it is not the case that a structure with high densities, but handled scrupulously, providing an environmental enrichment and innovative infrastructures, necessarily offers conditions of wellness worse than one with a lower density, but handled with less care.

What the law says: minimum criteria to be respected

A first step in the evolution of the legislation is represented by the Amsterdam Treaty of 1997, in which animals are defined as "**sentient beings**" and are no longer considered only food. Subsequently, in the White Paper on Food Safety published in 2000, the Commission proposed a set of standards by highlighting the close relationship between animal welfare and food safety.

The significance of the issue of animal welfare at legislative level, finally, is also found in the Common Agricultural Policy (CAP), which has included since 2007 animal welfare among the criteria required to be met in the context of so-called "**conditionality**", subordinating the economic support for farmers with compliance to a series of sustainable requirements that specifically concern animal welfare[24]. **In Italy, starting from 2022, the protection of animals enters the Constitution of the Italian Republic.** With the approval of the amendment of **articles 9 and 41 of the Constitution,** the Constitutional Law that protects animals and the environment came into force **on 9th March 2022**. In particular, article 9 mentions: "*The Republic promotes the development of culture as well as scientific and technical research. It protects the landscape and the historical and artistic heritage of the nation. It protects the environment, biodiversity and ecosystems, also in the interest of future generations. State law regulates the methods and forms of animal protection*".
Within the complex **body of legislation** currently in **force**, it is possible to distinguish **horizontal and vertical legislation**. The first dictates the lines of appropriate behaviour in all species of food-producing animals, while the second enters into the specifics of certain animal species.
With regards to horizontal legislation, amongst the acts developed by the European Commission these should be remembered:

- **directive 98/58/CE** disposes the minimum standards for the protection of all animals on farms, containing provisions regarding animal control, freedom of movement, livestock buildings, automatic systems, feed and mutilation;

- **regulation (CE) No. 1/2005** on the protection of animals during **transport**, which lays down the provisions concerning the liability of operators and the training of animal handling personnel and the controls based also on the use of new technologies, space during transport, the duration of the journey and the pauses, the rules for long journeys and for animal handling operations during their loading and unloading;
- **regulation (CE) No. 1099/2009** on the protection of animals during **slaughter**, which instructs on the provisions on the responsibilities of the slaughter house, staff training, housing modes in the lairages and animal movement, innovative systems of stunning and killing the animals and the verification of their efficiency.

The vertical legislation concerns the **different species of animals for income** and, in particular, the following categories of production: breeding and **fattening pigs**, **calves** (i.e. bovine from 0 to 8 months of life), **laying hens and broiler chickens.** These rules aim to establish criteria relating to the management and structural aspects finalised at protecting the animals, setting

	FARM	TRANSPORT	SLAUGHTER
EGG LAYING HENS	DIRECTIVE 98/58/EC, concerning the protection of animals on farms. DIRECTIVE 1999/74/EC and DIRECTIVE 2002/4/EC, concerning minimum standards for the protection of laying hens.	REGULATION (EC) No. 1/2005 of 22nd December 2004 on the protection of animals during transport and related operations.	1099/2009 of 24th September 2009 on the protection of animals at slaughter.
CHICKENS FOR MEAT	DIRECTIVE 98/58/EC, concerning the protection of animals on farms. DIRECTIVE 2007/43/EEC laying down minimum standards for the protection of chickens kept for meat production.	REGULATION (EC) No. 1/2005 of 22nd December 2004 on the protection of animals during transport and related operations.	REGULATION (EC) No 1099/2009 of 24th September 2009 on the protection of animals at slaughter.
PIGS	DIRECTIVE 98/58/EC, concerning the protection of animals on farms. DIRECTIVE 120/2008/EEC laying down minimum standards for the protection of pigs confined for rearing and fattening.	REGULATION (EC) No. 1/2005 of 22nd December 2004 on the protection of animals during transport and related operations.	REGULATION (EC) No 1099/2009 of 24th September 2009 on the protection of animals at slaughter.
CALVES	DIRECTIVE 98/58/EC, concerning the protection of animals on farms. DIRECTIVE 119/2008/EEC laying down minimum standards to protect calves confined for rearing and slaughter.	REGULATION (EC) No. 1/2005 of 22nd December 2004 on the protection of animals during transport and related operations.	REGULATION (EC) No 1099/2009 of 24th September 2009 on the protection of animals at slaughter.
BOVINE	DIRECTIVE 98/58/EC, concerning the protection of animals on farms.	REGULATION (EC) No. 1/2005 of 22nd December 2004 on the protection of animals during transport and related operations.	REGULATION (EC) No 1099/2009 of 24th September 2009 on the protection of animals at slaughter.

minimum requirements for the elements that affect the welfare conditions of the different species, such as housing density, environmental control, paving, supply of food and water, etc.

The crime of animal mistreatment

The acknowledgement of Community indications means that Italy is in line with other European countries in terms of safeguarding the minimum conditions of animal welfare. A peculiar aspect of Italy, however, is made up of the larger number of controls resulting from the presence in the Criminal Code of the **offense of cruelty to animals.** Article 544-ter of Law 198 of 2004, amended by Law 201 of 2010, states that there is a crime when an animal is subjected to injury, abuse, unbearable conduct or hardships, or to treatments from which cause damage to its health or moreover when it is subjected to the administration of prohibited substances. The offense is connected with the **exercise of the profession**, and all persons who come into contact with the animal in the farm, transport and slaughter are punishable.

The inclusion in the Criminal Code leads to a **widening of the prohibitions** with respect to the provisions of the Community legislation (any act involving unjustified suffering to the animal is potentially punishable), but also to a widening of the spectrum of the persons responsible for monitoring. Any supervisory body active in the sector of food business operators (from the traffic police to the NAS – Italian Food Anti-sophistication police) can in fact carry out controls and file a complaint. It should also be remembered that in Italy a "National Plan for Animal Welfare" has been active since 2010; it defines the criteria and monitoring programs by the competent Sanitary Authority with the aim not only to verify the application of national and Community legislation concerning the **protection of animals on farms**, but also to provide information, explanations and guidelines for the breeding of various species.

The pursuit of excellence: standard and voluntary criteria

For more virtuous operators maintaining animal welfare is not a "plus" accessory, but the daily modus operandi, and results in a number of specific practices well-integrated into the business management system. Not only, in addition to the practices established by law, the most sustainability-conscious organisations have **voluntarily** decided to implement action protocols or to adopt additional protections on the welfare of farm animals. In this context, in Italy, there are many initiatives, promoted both by institutional entities and associations, to improve farming conditions further: obviously these excellences **only represent the "best practices"** to which the industry is leaning towards (or should lean), with time tables and effectiveness which vary from case to case. Among the notable initiatives there are certainly those of a few international non-governmental organisations, who have rallied to ask producers to ensure additional measures of animal protection than those provided by law. One of these is **Compassion in World Farming (CIWF)**, an NGO present at global level since 1967 that promotes more respectful animal wellbeing farming systems. Since 2007, Italy has started an **Animal Welfare Award** program, through which it promotes the use of voluntary measures to protect specific-species animal welfare. The measures vary from award to award, but can be attributed in general to the following main areas: a **density** of less breeding within the limits of the law, the absence of systematic **mutilations**, the presence of **environmental enrichments** and adequate space so that the animals behave naturally.

Another case is represented by brands and voluntary certifications, such as **organic**, for the attainment of which certain animal welfare criteria must be met. In general, **organic livestock production is closely tied to the land**, and the number of head to rear depends on the area available to the farm. The farming method should meet the ethological and physiological needs of the animals, thus allowing the expression of natural behaviour and ensuring adequate living conditions. The facilities for livestock farming must also ensure sufficient free space available to the animals and allow outdoor access, even in winter. Animals must be fed with vegetable products obtained by the organic production method, possibly grown on the farm. As for veterinary treatments, remedies should aim to stimulate the immune system of the animal. A maximum of two drug treatments per year are permitted. Finally, there are many companies that, despite not joining standard or special certifications have voluntarily developed additional protocols containing measures to protect animal welfare.
The most common interventions include maintaining the animal outdoors for part

MANUAL FOR THE WELFARE EVALUATION OF THE IZS CATTLE FARM OF BRESCIA

The "Manual for the welfare assessment and bio safety in cattle farming for meat", prepared by the National Reference Centre for Animal Welfare (CRENBA) and published by the Livestock Institute of Lombardy and Emilia Romagna, addresses the need for creating a balanced and objective assessment system, easy to apply, that also allows comparisons between different farms on the basis of the measurements themselves, ensuring greater objectivity of the assessment provided.
According to the developed methodology, the evaluation of the welfare level of a farm includes both aspects relating to the structures and management (evaluated through the so-called "non-animal based measures" - N-ABMS), and those linked to the animals' reactions to their living conditions (measured through the "animal-based measures" - ABMS).
The choice of the aspects to be evaluated fell on those easily measurable by objective surveys in almost all the Italian beef cattle farms. The ultimate goal is to compare the different farms on the basis of these assessments, ensuring a greater objectivity to the assessment provided.

The assessment on farm animal welfare and bio-security is done through a checklist consisting of 56 items, divided into 5 areas: corporate and personal management; facilities and equipment; animal based measures (ABMs); bio-security; great risks and alarm systems. The result of the evaluations is a numerical value expressed on a scale from 0 to 100, capable of identifying the general conditions of well-being of animals.
The system is evolving in order to be integrated with the proper management of the veterinary drug, an indissociable part in the judgement of animal welfare.

or all of its life cycle, the offer of environmental enrichment and maintaining a farming density less than the legal limits. Another case is constituted by the supply policy of manufacturers or the GDO, according to which suppliers are only accepted whose products fulfil certain criteria of well-being: for example, the choice of some distributors and processing companies only use eggs from free-range hens.

BIBLIOGRAPHY

[1] For more information, refer to the website of the One Health Initiative organization (www.onehealthinitiative.com/).

[2] Regulation (EC) 1831/2003.

[3] Commission Communication 2015/c 299/04, Guidelines on the prudent use of antimicrobials in veterinary medicine.

[4] The Population Correction Unit is a theoretical value determined on the basis of the average weight of the livestock on which the treatments and number are carried out animals slaughtered in the year in question, taking into consideration imported and exported animals exported to be fattened and slaughtered.

[5] European Medicines Agency, European Surveillance of Veterinary Antimicrobial Consumption (2022), 'Sales of Veterinary Antimicrobial Agents in 31 European Countries in 2021'. (EMA/795956/2022).

[6] AIA, AISAM ASSALZOO, FNOVI. Good practice for the use of antimicrobial drugs in animals intended for food production.

[7] Zoonosis are infections or diseases that can be transmitted directly or indirectly between animals and humans, for example through the consumption of contaminated food or contact with infected animals. In humans these diseases can have different severity, depending on the type of pathogen and the physical condition of the infected person, with clinical pictures characterised by mild symptomatology up to potentially lethal diseases.

[8] Commission Regulation (EC) 2073/2005 European Union of 15th November 2005 on microbiological criteria applicable to foodstuffs, OJL 338 of 22.12.2005, pp. 1-26.

[9] Opinion of the Scientific Panel on Biological Hazards on a Request from the Commission Related to the Effects of Nitrites/Nitrates on the Microbiological Safety of Meat Products, 2003, The EFSA Journal, 14, pp. 1-34.

[10] The risk assessment explained by EFSA, 2017. Nitrites and nitrates added to food.

[11] Regulation (EC) 178/2002 introduced the current food safety model, marking the start of a real reorganization process of the relevant Community legislation.

[12] Regulation (EC) 882/2004 represents the framework regulation for the organization of official controls on food, feed, health and animal welfare.

[13] For more information on the regulations of the Hygiene package, please refer to the Ministry website of Health (www.salute.gov.it/portale/temi/p2_6).

[14] Food frauds (health and commercial) (http://www.izsalimento.izsto.it/palimenti/. *Path:* Home › Shopping › Food fraud).

[15] Reference legislation on food safety (https://www.salute.gov.it/portale/home.html. *Path:* Home › Topics › Food security› Food safety › Safety from farm to fork).

[16] Autorità Europea per la Sicurezza Alimentare, EFSA - European Food Safety Authority.

[17] Ministry of Health, 2022. National plan for research on residues (PNR) - Results for the year 2021, available on the web page: https://www.salute.gov.it/imgs/C_17_pubblicazioni_3247_allegato.pdf.

[18] Regulation (EC) 852/2004.

[19] Mipaf List of Italian denominations, filed in the Register of protected designations of origin, of protected geographical indications and of the traditional specialties guaranteed (EU regula¬-tion n. 1151/2012 of the European Parliament and of the Council of 21st November 2012) (updated to 21/11/2021).

[20] For more information, see: AICIG, Association Italian Consortia Geographical Indications

[21] Ministry of Health. Rapid Alert System for Food and Feed - Annual Report 2021.

[22-23] INEA, 2012.

[24] Regulation (EC) 1782/2003.

ECONOMIC AND SOCIAL ASPECTS OF MEAT CONSUMPTION

- THE SIZE AND ECONOMIC TREND OF THE SECTOR
- ORGANISATION OF THE COMPANIES IN ITALY
- THE COST FOR CONSUMERS

Introduction

THE MEAT CHAIN CONTRIBUTES TO ABOUT 15% OF THE ENTIRE ECONOMIC RESULT OF THE ITALIAN FOOD INDUSTRY

THE ORGANISATION OF AGRICULTURAL OPERATORS IS FUNDAMENTAL FOR THEIR ECONOMIC SUSTAINABILITY IN THE MIDDLE AND LONG TERM

WHEN MEAT IS INSERTED IN A BALANCED DIET IT DOES NOT INVOLVE EXCESSIVE COSTS FOR THE CONSUMER

The economic and social theme in meat production is extremely complex because it takes into consideration very different and apparently distant topics.

The macroeconomic aspects linked to the performance of the sector in the world and in the various geographical areas must in fact be accompanied by a ***territorial analysis*** *that examines how the companies that make up the sector are organised. Although many people associate the (relatively few) brands of the meat processing industry to the meat industry, it is important to remember how the* ***livestock supply chain lays the foundation of the many companies*** *that manage the farms and, increasingly, the cultivation of foods.*

This aspect is particularly relevant ***in Italy*** *where the reality of production is characterised by a* ***large number of family-sized, or slightly larger****, companies which give continuity to the tradition over generations in a complex and heterogeneous system highly linked to the rural dimension. On the one hand, these peculiarities have the advantage of passing on quality over time (which is why Italian food is world famous), but on the other hand they make economic sustainability of the companies precarious, increasing, among other things, the risk of abandonment of the territory by the farmers and their families.*

For this reason, ***the tendency towards aggregation and forms of stable partnership between companies of various sizes must be seen in a positive way****, as the goal is to ensure* ***economic sustainability****, whilst maintaining the original identity. This trend, highly developed in countries that make wealth out of agriculture, allows the organisation of supply chains for better product control. A fundamental aspect of* ***an "organised" system*** *is the possibility of better integrating with the various related production systems (meat, milk, cereals), increasing productive efficiencies as much as possible. Last but not least is the analysis of the cost for the consumer who is increasingly attentive to food choices. Meat and cured meats are products that are normally placed in a medium-high cost segment but, as shown by the construction of the* ***"economic hourglass"****, even in this case the equilibrium pays off: an adequate consumption consistent with nutritionists' indications does not incur excessive costs for consumers.*

In reality the trend that the producers are starting to take into account is ***"less but better"*** *that is moving purchase preferences towards products of a superior quality, perceived or real, even if higher costs are incurred.*

1 THE SIZE AND ECONOMIC TREND OF THE SECTOR

Despite the data over the last 50 years shows a general growth of the sector in the world, a detailed analysis allows us to observe how this growth is neither constant nor homogeneous.

1.1 Evolution in the world

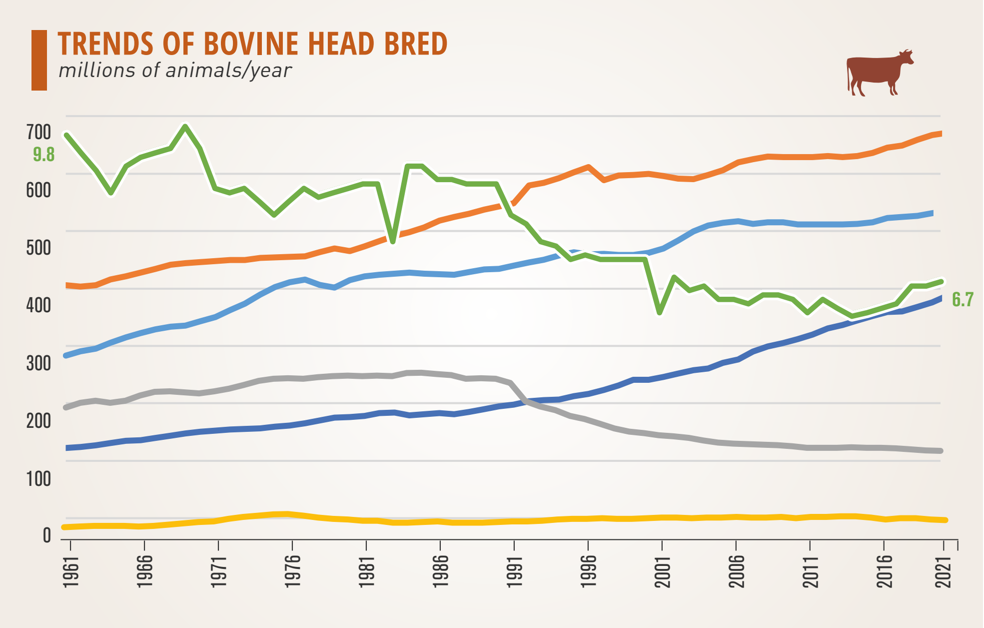
To get a general overview of the sector's performance worldwide it is possible to take into account the data of the historical series of the FAOSTAT database regarding the number of animals bred of the main species (bovine, pig and poultry) in the various regions of the world[1].

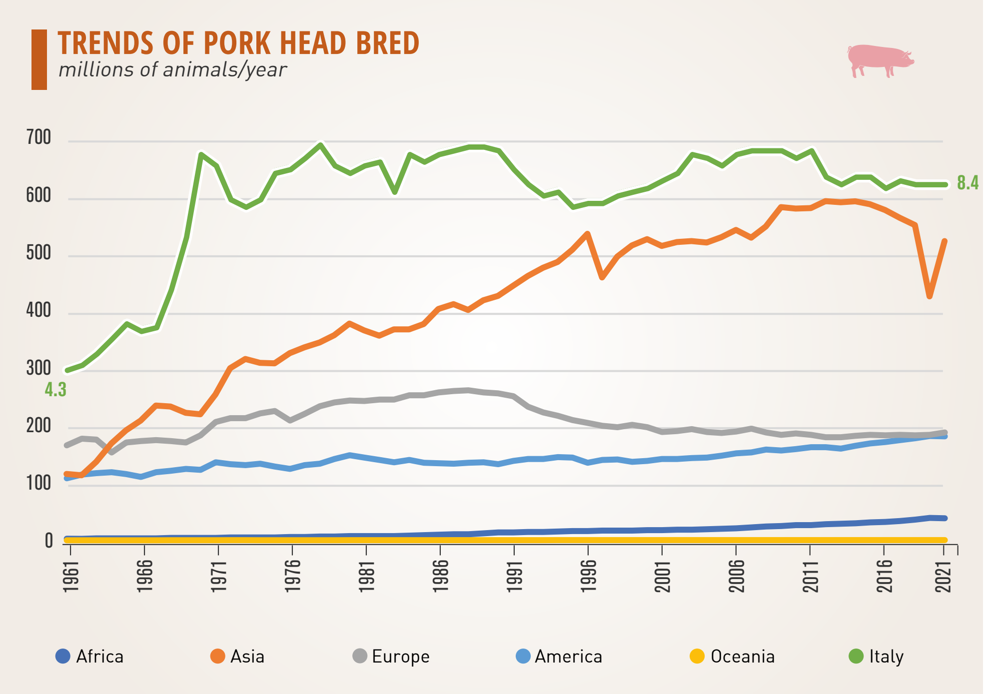
As for the **bovine species** in the world there are raised about 1,733 million head with a growth of about 67% over the last sixty years. Asia and America, with 1,200 million head, are the are the areas with the highest number bred and with constantly growing trends. **The trend in Europe is in the opposite direction, which today has 115 million bovine head** against 193 million in 1961, **equal to a decrease of 40%.**

In **Italy** alone, the **cattle** population from 1961 to 2021 was **reduced by approximately 30%**, with **6.7 million head** and resulting in the abandonment and consequent depopulation of the countryside.

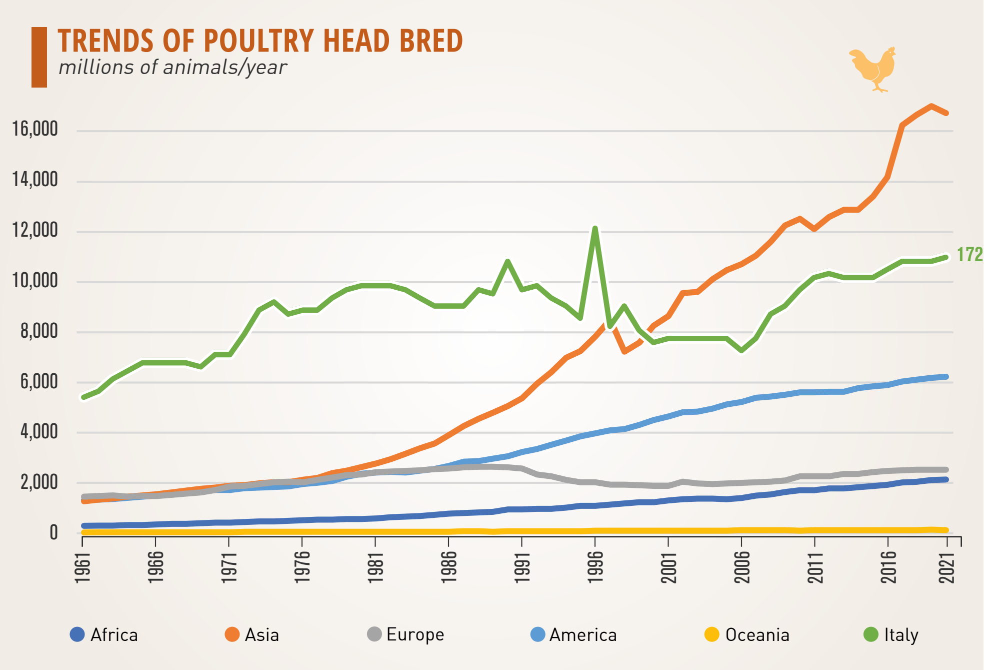
The production of **pork** is dominated by Asia, where more than 50% of the 975 million heads bred annually in the world are found. The growth trend for this continent shows an increase of 370% compared to the 1960s, equal to an overall worldwide increase of 140% for the same period. As with cattle herds, pigs also show substantially stable figures over the last decade. **The pig herd** in **Italy**, in 2021, amounted to **8.4 million head.**

Unlike the other **species** for which the data are much more heterogeneous, the values for **poultry farming** show a widespread increase since the Sixties. The overall production has in fact increased by 525% in the sixty years between 1961 and 2021 and today it counts more than **27.611 million heads**: also in this case Asia is the region where the increase is greatest. Europe confirms itself as the region which, with alternating trends, has seen constant growth since the 2000s, with production reaching 2,450 million head in 2021. In **Italy**, the animals raised were equal to 172 million per production cycle, for a total of **over 600 million chickens** raised per year. Notwithstanding the fact that the data of the head bred does not closely coincide with the consumption of meat in the same areas due to the phenomena of commercial exchange, this information can help to understand the phenomenon of sustainability in the livestock supply chain and, consequently, help the investment of resources and technologies to mitigate environmental impacts and to better manage the topic of food safety and animal welfare.





Average head on the farm.
The Italian trend is out of scale *compared to that of other regions of the world. In the graph relating to pigs, a decline in 2019-2020 production can be seen due to multiple outbreaks of African swine fever (ASF) spread throughout Asia.*
Source: FAOSTAT (Live Animals, Stocks, Cattle and Buffaloes and Pigs, 1961-2021).



Average head present in farms per production cycle.
The Italian trend is out of scale compared to that of other regions of the world.
Source: FAOSTAT (Live Animals, Poultry Birds, 1961-2021).

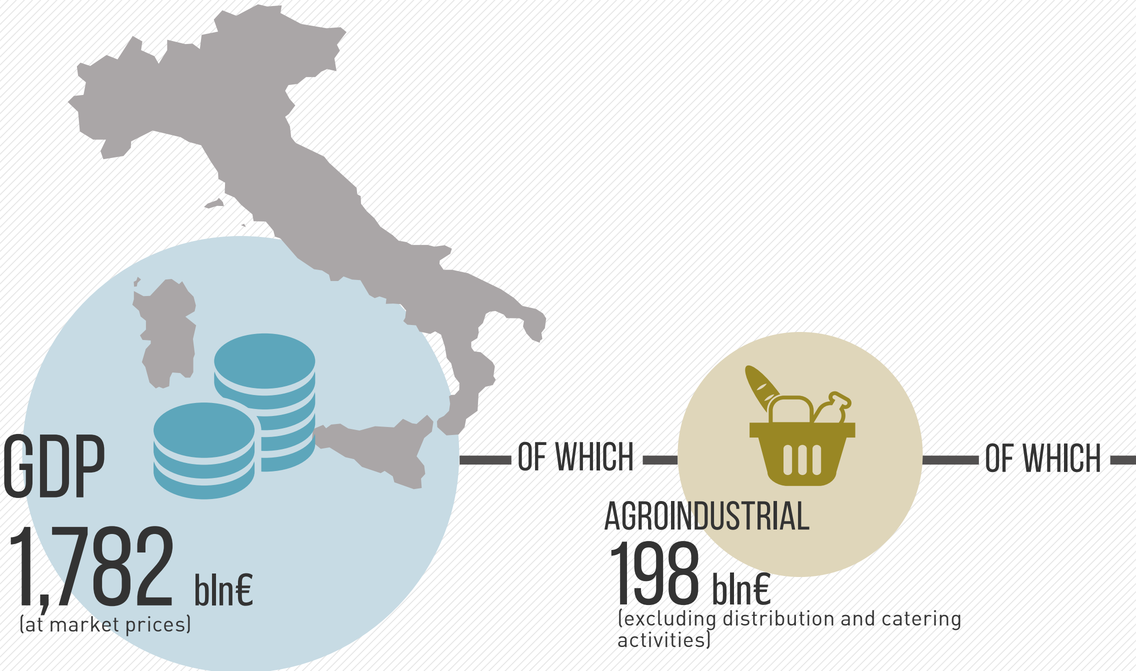
1.2 The Italian situation

The average values of the last few years[2] confirm the agri-food sector as one of the cornerstones of the Italian economy.
If we consider the first phases, agricultural and industrial, of the Italian agri-food system, we obtain a contribution of **198 billion Euro, 11% of the national GDP**[3].
Of these, around **30 billion** come from the **meat sector**, of which 1/3 from the agricultural sector and the remainder from the transformation sector, excluding catering and distribution[3].
In terms of quantity consumed at home, the most requested fresh meats (thus excluding cured meats) are poultry (**42%**), followed by beef (**36%**) and pork (**22%**)[4]. The substantial differences between the three main supply chains lie in the **commercial balance** as well as in the division of value between the agricultural and industrial supply chains.

In the case of **bovine**, the trade balance is negative: Italy is in fact a strong importer of live cattle for fattening and beef (fresh, chilled or frozen, for consumption or subsequent industrial processing).
The self-supply rate of our country, obtained from the ratio between production and apparent consumption, is around 47%[4].
As regards the **pork supply chain**, the degree of self-sufficiency is equal to 62.1%[4]. Most of the economic value is generated by the processing industry above all thanks to the production of cured meats which, among other things, allow Italy to export products of high qualitative and economic value.
Unlike the others, the **poultry supply chain** makes Italy self-sufficient with a production slightly higher than requirements (108,8%)[4]. The economic value is generated mainly by transformation with a trend of growth.

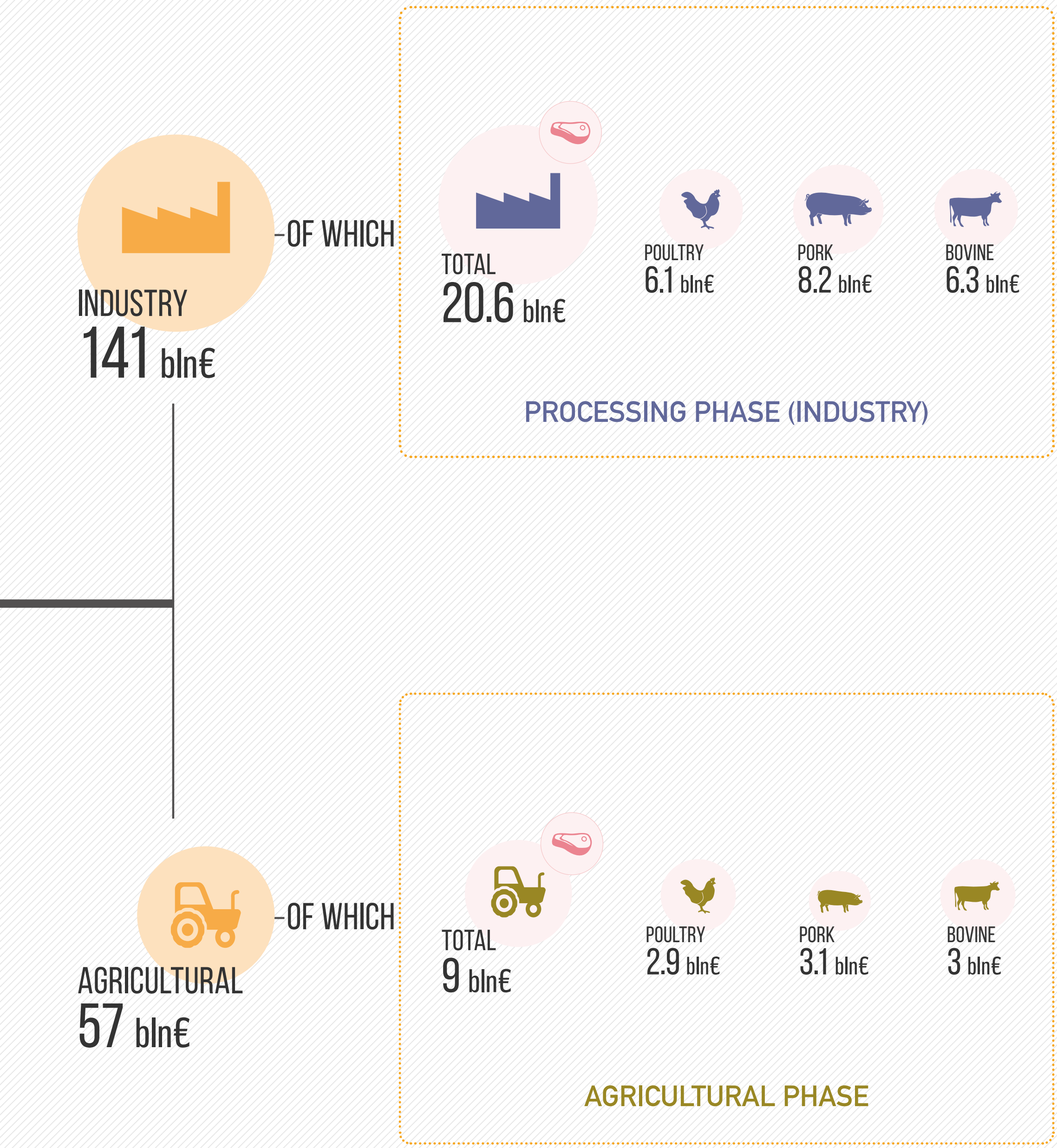
MEAT AND CURED MEATS IN ITALY
ECONOMIC DIMENSION OF THE SECTOR

DATA IN BILLIONS OF € PER YEAR (2021)



Macro-economic dimension of the meat sector in Italy. The information presented has the purpose of providing a general indication and is the result of reprocessing statistical data published by ISMEA and ISTAT** that is recommended to consult for any further information or details. *www.ismeamercati.it/carni **www.dati.istat.it/.*

ITALIAN MEAT AND CURED MEATS SUPPLY CHAINS (2021)



Source: Ismea (2022).

HEAD BRED AND NUMBER OF COMPANIES IN ITALY

	2020		2021		2022	
	COMPANIES	HEAD	COMPANIES	HEAD	COMPANIES	HEAD
TOTAL CATTLE	141,125	6,045,867	138,129	6,064,541	133,595	5,925,896
TOTAL PORK	31,853	8,795,979	30,730	8,751,736	29,398*	8,448,579
TOTAL POULTRY	6,716	666,000,000	6,804	631,000,000	6,797	600,000,000
TOTAL	179,694		175,663		169,790	

Source: data provided by the BDN of the Livestock Registry set up by the Ministry of Health at the CSN of the G. Caporale Institute of Teramo.
The data refer to the annual number of bovine (including buffaloes), pigs (including wild boars) and poultry farms (farms with a capacity of ›250 head).
**Family-run businesses are excluded.*

2 ORGANISATION OF THE COMPANIES IN ITALY

As is the case in many Italian goods sectors, the agri-food sector is also very articulated and organised into structures, often **family-run, of a medium-to-small size**. In reality, the trend is slowly changing and the market is moving towards companies of gradually larger sizes and better organised. These are "weak" but unequivocal signals, recordable not only in Italy but also in other territories of the European Union. The growth in size is largely determined by the reduction in the number of active companies that affected both the agricultural sector and that of the first and second industrial transformation[5].

Fewer farms but with larger agricultural areas

The abandonment of the countryside and the consequent depopulation of rural territories over the last 60 years has determined and is determining an inexorable concentration of agricultural activities in ever larger and better organised farms.

According to data from the latest General Census of Agriculture[6], in 2020, there were **1,133,023 active farms in Italy**. Between 1982 and 2020, almost two out of three farms disappeared in our country and, starting from 2000, this trend has become even more accentuated: in the last twenty years the number of farms has more than halved, going from **2.4 to 1.13 million**.

The trend relating to the Utilised Agricultural Area (UAA) and the Total Agricultural Area (TAA) was different, which in the same period (1982-2020) showed a more contained decline, of -20.8% and -26.4% respectively, compared to the number of farms.

In fact, in the last 38 years, the average size of farm area has more than doubled,

TOTAL FARMS, UTILISED AGRICULTURAL AREA AND TOTAL AGRICULTURAL AREA

	ABSOLUTE DATA (THOUSANDS OF HECTARES)			AVERAGES PER FARM (HECTARES)	
YEAR	NUMBER OF FARMS	UAA	TAA	UAA	TAA
2020	1,133,023	12,535	16,474	11.1	14.5
2010	1,620,884	12,856	17,081	7.9	10.5
2000	2,396,274	13,182	18,767	5.5	7.8
1990	2,848,136	15,026	21,628	5.3	7.6
1982	3,133,118	15,833	22,398	5.1	7.1

Farms, utilised agricultural areas (UAA) and total agricultural areas (TAA), from 1982 to 2020. Absolute values, average size.
Source: ISTAT, 7th General Agricultural Census.

FARMS AND UTILISED AGRICULTURAL AREA (UAA)

UUA CLASSES (HECTARES)	FARMS			UTILISED AGRICULTURAL AREA (THOUSANDS HECTARES)		
	NUMBER		% DIFFERENCE	UAA		% DIFFERENCE
	2020	2010	2020/2010	2020	2010	2020/2010
UNTIL 0.99	240,980	498,620	-51.2	128	275	-53.5
DA 1 A 1.99	209,662	326,032	-35.7	292	452	-35.3
DA 2 A 2.99	128,381	171,344	-25.1	307	410	-25.2
DA 3 A 4.99	147,320	186,324	-20.9	561	709	-20.9
DA 5 A 9.99	160,133	186,145	-14.0	1,119	1,295	-13.6
DA 10 A 19.99	109,545	120,115	-8.8	1,521	1,663	-8.6
DA 20 A 29.99	45,118	46,687	-3.4	1,091	1,129	-3.4
DA 30 A 49.99	41,167	40,915	0.6	1,569	1,557	0.8
DA 50 A 99.99	32,487	29,214	11.2	2,226	1,994	11.6
FROM 100 ONWARDS	18,230	15,488	17.7	3,722	3,370	10.4
TOTAL	1,133,023	1,620,884	-30.1	12,536	12,856	-2.5

Farms and utilized agricultural area (UAA), by UAA class. Years 2020 and 2010.
Absolute values, percentage variations.
Source: ISTAT, 7th General Agricultural Census.

both in terms of UAA, which went from 5.1 to 11.1 average hectares per farm, and of TAA, from 7.1 to 14 .5 average hectares per farm.

Livestock Farms

On the livestock front, the number of farms with livestock recorded a lesser decline than the number of farms as a whole. The UAA and TAA values of livestock farms, in 2020, are respectively equal to 5 million and 6.5 million hectares, or 40.4% and 51.9% of the respective national totals, of which 3.1 million hectares are permanent meadows and pastures.
From the national database of the Livestock Registry (BDN) of Teramo it emerges that, in 2022, the number of **companies with livestock farms** was equal to **169,790 units**: the greatest presence of livestock is found in the northern regions, in particular Lombardy, Veneto, Emilia-Romagna and Piedmont.

2.1 The importance of the “agricultural” dimension in Italian agri-food

The statistical data does not reveal the unmistakable characteristic of the Italian agricultural heritage: its “agricultural dimension”, the cultural values, identity, traditions and social membership that it represents.

Farmers by tradition

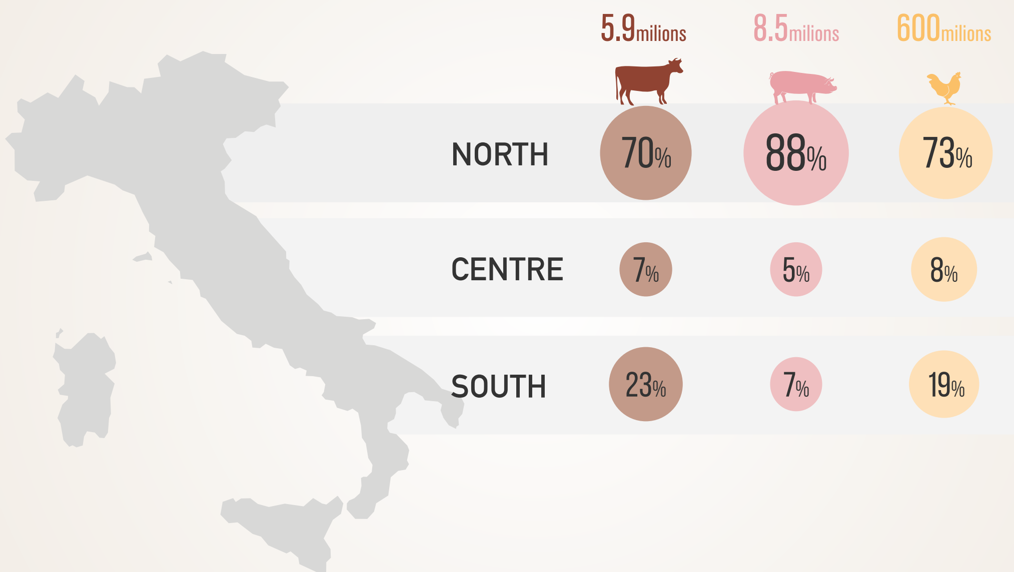
The Italian territory is historically characterised by a plurality of agricultural systems with a great diversity of landscapes, agro-ecosystems and socio-economic conditions, that over time have produced a multiplicity of economic realities, production facilities and relative markets. **In Italy, 93.5% of farms are managed as individual or family businesses**, a slight decrease compared to 2010 (96.1%). In the last decade there has been an increase relating to partnerships, which went from 2.9% to 4.8%, of joint-stock companies, from 0.5% to 1% and to a lesser extent for "other" legal forms, from 0.1% to 0.2%. **Individual or family farms continue to represent the most widespread juridical profile in Italian agriculture.** This diversity and ubiquity represents the Italian specificities, on which rests the heritage of great wealth and agricultural biodiversity production that also represents the safest method to maintain the mountain and hill areas.

Some peculiar characteristics of farmer agriculture are fundamental: the different ways of **family run businesses, the communities and cooperatives** related to the work of land, local roots and the various conservative and sustainable agricultural practices, the control of the reproductive cycle through the reproduction of local seeds, traditional varieties and native breeds. Practices and methods that are now found in many forms of agricultural reality, of family tradition or new settlement, in every Italian region.

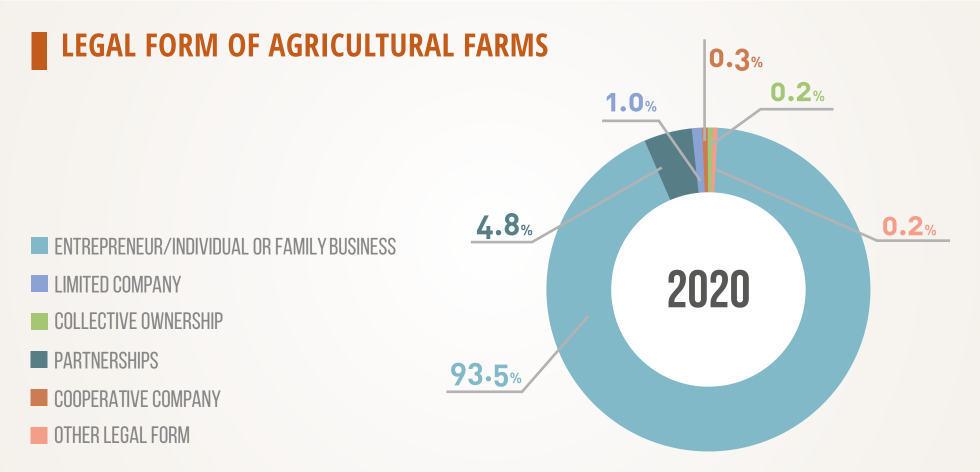
Land protection

The presence of these realities is very important and serves to guarantee the preservation and protection of the territory, reducing the continuing depopula-

LIVESTOCK PRODUCTION IN ITALY BY GEOGRAPHICAL AREA



Livestock production in Italy and relative distribution (million head).
Source: data provided by the BDN of the Livestock Registry established by the Ministry of Health at the CSN of the G. Caporale institute of Teramo year 2022.



Farms by legal form in 2020. Percentage compositions.
Source: ISTAT, 7th General Census of Agriculture.

tion of agricultural areas by bringing back work and employment, thereby reducing the environmental costs (**hydro-geological system, the maintenance of the soil and the protection of biodiversity**), reconstructing the social and rural landscapes, ensuring the presence of people in places that might otherwise be abandoned.

Land conservation is achieved mainly by using a wide variety of farm protection policies: it has been seen that severe hydro-geological instability increased when those agricultural activities that were carried out in full harmony with the territory stopped. **The cultivated land, in fact, along with forests**, play an essential role in stabilising and consolidating the slopes and holding back the river banks, thanks to their high absorption capacity, helping to prevent landslides and land erosion.

The protection of the territory by the farmer, whose maintenance work is essential especially **in the marginal areas of the hills and mountain**, must therefore be guaranteed by a proper environmental protection policy, supporting and promoting the activities of the farmer. **In the mountains cattle and sheep farming is an excellent way for monitoring activities through the careful management of pastures.** Since there is a plurality of patterns of agriculture, for the purpose of proper land management, depending on the different production realities, appropriate and diversified measures are necessary, recognising agriculture as a socio-economic model and consequently identifying standards that are appropriate for it.

European agricultural policy (CAP) - the set of rules that the European Union, since its inception, has sought to create, by recognising the central role of agriculture for an equal and stable development of its member countries[7], **is specifically intended to help farmers not only to produce food but also to protect the environment, improve animal welfare and to maintain rural communities economically alive.**

The profession of agriculture

The fragmentation of farms makes economic sustainability difficult for them and the entire food farming sector, with the risk that farmers and their families abandon the land. For this reason, the tendency to organise themselves into **coopera-**

tives or small and big industries must be judged positively, since the objective is to ensure the economic sustainability of the companies themselves, while maintaining their original identity. This trend is highly developed in countries that make agriculture a source of wealth, and allows for the **organisation of supply chains** which, as can be seen, are those that provide the most **control over the products.**

Finally, a fundamental aspect of an "organised" system is the ability to better integrate the various related production systems (e.g. Meat, milk, cereals), thereby maximising production efficiency.

This agriculture, "by profession", is the most representative of the main supply chains for meat production in Italy.

Meat sector employees

In addition to the important contribution to the creation of value within the Italian Gross Domestic Product, the meat supply chains have a decisive **social role in terms of employment.** The total number of employees in the sector, including livestock farms and those of industrial transformation, in fact amount to over **513,000**[8].

As far as the processing **industry** is concerned, there are **around 62,000**[9] workers, adding together all the sectors of poultry, pork and beef.

There are over **451,000 employees in livestock farms**. It is interesting to note that the family workforce is the majority (53%) and is present in 98.3% of farms and livestock farms, even if the last General Census of Agriculture (2020) certified a significant increase in incidence of non-family labour, up by 38.1% compared to 2010.

This confirms, on the one hand, the enormous social value of the work of farmers, as well as that of the primary meat processing sector, which today in Italy has a structure of over 1,227 slaughterhouses for beef, 2,034 for pork and 253 for poultry[10].

Digitisation of farms

According to the latest General Census of Agriculture[6], in the last 10 years, **the computerisation of farms has almost quadrupled** (+193.7%). In the decade under examination (2010-2020), the increase in digitisation involved all Italian regions: in particular, it was much more intense in

NUMBER OF EMPLOYEES IN ITALY (2020)
in livestock farms and in the processing industry

Reworking of Sustainable Meats on ISTAT data and the 7th General Census of Agriculture and BDN Livestock Registry.

TOTAL MANPOWER PRESENT IN ITALIAN FARMS

LABOUR CATEGORY	PEOPLE				
	NUMBER (THOUSANDS)		COMPOSITIONS %		VAR% 2020/2010
	2020	2010	2020	2010	
FAMILY LABOUR	1,460	2,933	53.0	75.8	-50.2
NON-FAMILY LABOUR	1,296	938	47.0	24.2	38.1
TOTAL	2,755	3,871	100.0	100.0	-28.8

Labour present in farms by labour category. Years 2020 and 2010. Absolute values, percentage compositions, percentage variations.
Source: ISTAT, 7th General Agricultural Census.

the South (+247.0%), in the Islands (+241.9 %) and in the North-East (+205.5%), while in the other regions it remained below the national average.
Despite the significant increase in Italian digitisation, today the average of farms that use computers or other IT or digital equipment for business purposes is only 15.8%. The degree of computerisation is strongly linked to the size of the company (in terms of Work Unit - AWU) and varies between North and South. In fact, **78.2% of large companies are computerised, 44.7% of medium-sized companies and just 8.8% of the small ones.**

At regional level, there is still a strong gap between the digitisation of farms in the South and those in the North: in fact, only 6.7% of farms in the South are computerised, against 10.3% in the Islands and 16. 1% of the Centre, while computerised farms in the North-West and North-East rose respectively to 32.9% and 33.5%, the latter percentage driven by the autonomous provinces of Trento (52, 8%) and Bolzano (60.8%).

THE ITALIAN LIVESTOCK LANDSCAPE

The landscape, understood as the result of the interaction between the needs and activities of human society and the opportunities and constraints that the territory offers and poses to them with its natural abiotic and biotic components, is in continuous, inevitable evolution. If on the one hand it cannot be embalmed, on the other it is necessary that its evolution be directed positively, by understanding the role played by the various human activities and orienting them appropriately. Large rural areas of the country are, in fact, characterised by morphological and climatic conditions which make them suitable, rather than for crops, for farming, on which architectural modules, cultural models and methods of use of the agri-forestry surfaces that have created real ***"livestock landscapes"***[1]*. In fact,* ***a significant share of the Italian rural landscape is livestock landscape.*** *Animal farming is practically widespread throughout the Italian territory, with an intensive character in the Po valley regions of Lombardy, lower Veneto, eastern Piedmont, southern Emilia and Campania, semi-intensive and extensive in almost all the other regions. This situation is reflected in the livestock loads which are concentrated in the regions with a prevalent livestock vocation (Piedmont, Lombardy, Sardinia), but also in Campania due to the concentration of buffalo farming, in which, in addition to shaping the landscape, constitute one of the most significant environmental impacts of agriculture. The* ***livestock landscape*** *and, in particular, the* ***pastoral*** *landscape is profoundly influenced by* ***forage crops, such as grasslands, permanent and alternating meadows and pastures****, used exclusively in farm contexts in which ruminant species are bred. 27% of the Italian agricultural area is intended for grazing, with a clear prevalence of pastoralism in the regions of Valle d'Aosta, Trentino-Alto Adige, Sardinia, Liguria and Abruzzo, with values ranging from over 95% to 40% of utilised agricultural surfaces; the regions with the highest livestock intensity, on the other hand, are Veneto, Lombardy and Campania with a load indicator per unit of forage area exceeding two units and more than double*

compared to the national figure which stands at 1.34 ALU (adult live unit) per ha[2]. The Italian livestock landscape is also the result of impressive transformations that have affected vast rural areas of Italy[3]. The loss in competitiveness of traditional animal husbandry has pushed towards the intensification of production models in favourable areas and towards the abandonment in less favourable ones. The consequences for the landscape have been many: the loss of architectural identity and of the territorial-breeding-product link, the occurrence of problems of excessive releases of nutrients and/or degradation of the grazing facies in the areas of intensification, the extensive renaturation in abandoned ones, with significant effects, often unfavourable, on the aesthetic quality and on the plant and animal biodiversity and on the hydro-geological stability of the steep slopes. Recently the ***livestock landscape*** *has been enriched with* ***systems for the production of renewable energy.*** *From the diffusion of biodigesters in intensive and semi-intensive farms, useful also for the reduction of climate-altering gas emissions and for the recycling of the nutritive elements N, P and C, we are witnessing the transition towards agri-solar and agri-wind, with the installation of photovoltaic panels and low-power turbines, capable of inverting the energy demand of the livestock supply chains. Their landscape compatibility, as well as agronomic and environmental, is one of the most significant challenges that the planning of livestock territories will have to face in the years to come. To recreate the functional link between animal husbandry and landscape, and guarantee its sustainability, the research for a livestock landscape will have to combine a territorial approach to the study of the interactions between animal husbandry, cultural landscape and biodiversity with the identification of new technical and economic solutions.*

[1] Ronchi B., Pulina G., Ramanzin M. (edited by) (2014), The Italian Livestock Landscape, FrancoAngeli, Milan.

[2] Pulina G., Manni C., Battacone G. (2018), The Italian Livestock and Pastoral Landscape. In: "Rural Landscapes, Research Perspectives" [edited by Balestrieri M., Cicalò E., Ganciu A.], FrancoAngeli, Milan

[3] Ramanzin M., Battaglini L. M., Morbidini L., Pauselli M., Pulina G. (2009), Evolution of Livestock Systems and Landscape Transformation. Ital. J. Agron. / Rev. Agron., 2009, 3 Suppl.:19-23.

HISTORICAL AND SOCIAL ASPECTS OF MEAT CONSUMPTION IN HUMAN HISTORY

By Massimo Montanari and Giovanni Sorlini

The history of man has been, first of all, to continually search for answers to his food needs, at a time when food was the essential reason for survival, the first and unavoidable daily necessity. How can we not think of the vivid images of cattle in the French caves of Lascaux, whose meat was already at that time probably the main source of livelihood for the European primitive man?

At some point in history, however, the pure need for food transforms into pleasure, an element constituting a particular social affiliation; a radical transformation of its original function to the exact opposite, represented by the research of hedonism and cultural belonging. This dual polarity, or rather the change in the function of meat, unfolds a complex history, closely linked to power relations and social inequalities that went with it. The history of this food is closely interconnected to mankind's history, which constitutes one of the basic elements, in each case either the cause or the effect of human events.

When trying to identify some of the stages that we consider particularly significant, the first that seems appropriate to recall is the fall of the Roman Empire: during the centuries III-VI AD, the dissolution of this millennial cultural horizon has indeed given way to the establishment of new political and administrative realities, the turbulent mixing of peoples and cultures, the depopulation of the countryside and the breaking up of the patterns of production and food distribution, present at the time.

In this moment in history we are witnessing the depletion of the food model based on the cultivation of the fields, determining the general conditions of food scarcity and, with them, an unquestionable period of hunger. In this period of history in fact the testimony of war, famine and pestilence are widely documented by historians of the period and with them especially the general demographic decline of the European population.

The European man of the III-VI century, from consumer of products obtained from the cultivation of the fields, the typical model of the Roman period, differentiated himself, by significantly using products from the forests, which in those centuries grew heavily at the expense of agricultural land, often not able to be used due to the demographic imbalances of that difficult period. The need to develop a new model of consumption that combined the traditional model of the cultivated ager with the exploitation of uncultivated areas typical of the barbaric matrix (the so-called saltus, a term used by the Romans, not without a pejorative connotation towards the peoples *beyond the Alps), determined the process of more food supply systems which together formed the foundations of a food model in which we Europeans still recognise ourselves today.*

For meat, we can say that the controlled production model typical of the Romans and based primarily on the rearing of small ruminants in confined spaces, is combined with the spontaneous model of Germanic and Celtic matrix, based on the exploitation of virgin nature and uncultivated spaces, ideal for example for hunting, or the natural farming of wild pigs.

In this historical phase, in which various food supply systems in different and distant historical and cultural origin are integrated and the cultivation of the fields becomes more difficult because of demographic imbalances, meat becomes once again a mainstream food, the food value "par excellence".

If the Latin doctor Cornelius Celsus considered bread to be the absolute best food, the icon based on the cultivation model of the fields, his colleague Antimo of the sixth century did not hesitate to consider meat as the "king of food", showing a particular sensitivity to pork; so dear to the powerful of the time, the court of Theodoric in Ravenna. In other words, Antimo was already influenced by food supply models based on the exploitation of uncultivated areas, particularly important in that historical period. Again ager versus saltus.

In later centuries, characterised in Europe by the consolidation of Christian thought and, with it, the symbolism of oil, wine and bread as food symbols of purity and rectitude, meat however does not lose its core value. In the Europe of the post barbarian invasions, in fact, there seems to finally have been determined an unprecedented and definitive integration between the culture of bread and that of meat, so that both end up enjoying the statute (no less ideological than material) of primary and indispensable food.

In the Christian era, the polarity between the Roman and barbaric model overlaps with that of the "monastic" and "aristocratic" model: between them they play for the leading role of cultural hegemony. A comparison with many different sides and meanings, where social ethical values clash with those of religious morality, the reasons for fasting with those of power and strength.

How can we not consider Charlemagne to be the archetype of this cultural tension? The first emperor who contributed to the modern picture of Europe left us a historical trace, constantly torn between warlike images of abundance of food, that hinged on the consumption of meat and the Christian ethic of moderation. The first monarch who made meat consumption an element of his powerful iconography, without denying the values of frugality and moderation in food consumption of the Christian religion that he had embraced, and that animated his political actions.

From the start of the eighth-ninth century, thanks to this successful integration between the agricultural food model and that based on the exploitation of forests, the demographic curve starts to *rise again, and with it, deforestation, land reclamation and the colonisation of uncultivated areas to build new agricultural settlements. Again, a new intensive agriculture at the expense of forestry was the inevitable reaction to the growing demand for food, especially proteins, and, with it, a demand of civilization and progress: from then on, the concepts of natural and wild related with regards to the food industry are relegated to the margins of production and its dominant ideological values.*

It is the beginning of a big boom, which probably continues to this day. But agrarian expansion brings with it new tensions and social inequalities, conflicts born from the search for fertile lands, duties claims and property rights, as well as natural disasters, as frequent then as today.

Here the countryside-cities model is born, with all the implications related to the distribution and the storage of food on a large scale. It is a model that ensures stability and the balance of noble protein sources and culminates in the thirteenth century, especially after its progress in agricultural production techniques and more favourable weather climates. This nutritional well-being, the abundance represented by the new wide availability of meat, reaches such a level that even the Pope Innocent III feels the need for an indictment against the sin of gluttony and the new delicacies that the insane passion of men has managed to invent.

"Wine, beer, or the good things that come to us from the trees, the earth, the sea, the sky are no longer enough: you want spices and perfumes".

It is in this century, in fact, that gastronomy is born and its written codification of food recipes, due precisely to the abundance of flavours and gastronomic delights that the cultivation techniques and the expansion of the spice and food markets allowed.

Over the centuries of food abundance meat consump-

Agostino Verrocchi, Rome 1585-1659, Oil painting on canvas, Private collection, Modena.

tion represents a status symbol, particularly in the fourteenth century, during which there was a reduction in cereal crops in favour of pasture and forage crops.
It is in this period that farms specialised in livestock farming are born, with its focus on the short and long-range meat trade. It is the so-called carnivorous period of Europe, like the lucky definition that Braudel has accustomed us to call it. A period of happy and individual life, which will last until the XVI century.
*The repeated pleas of the ecclesiastical community to eat less, at least in certain periods of the year, more than being a deterrent, indirectly confirms the centrality of the role of meat in the food system of the time. In modern times, with the emergence of the middle classes and the industrial revolution, meat reaches larger sections of the population. In the wider horizon of a new **food democracy**, the concept of **quality and industry standards were born**; with the progress of scientific knowledge, the nutritional properties of meat and its relationship with our health were better associated.*
In the past century of efficiency and technology, in a context of even greater food availability, the new model of thinness as the ideal beauty of a powerful body, with perfect productivity, speed and efficiency is finally imposed; even in this new context, the unstoppable rise in consumption of meat continues, without losing the symbolic value of a conquered dignity to social classes who once were hungry.

And today? Meat is always at the centre of this story of hunger and abundance. Forgotten the famine of the past, we live with abundance and its problems.

In this polarisation between two extremes that have always chased each other in history, today the real challenge is that of moderation and balance. The rediscovery of the original value of the meat as a good and necessary nourishment and, with it, the word "diet": a term invented by the ancient Greeks to designate the daily food regimen (but more generally the rule of life): knowledge necessary for a conscious, varied and balanced food consumption, that each individual has to build on their personal needs, attitudes and knowledge of himself. Unlike today, where this word expresses, more superficially, the simple restriction or deprivation of particular foods, often following trends or models imposed by consumer society.
This is the role of meat in the modern diet, a precious and irreplaceable food that finds its rightful place in the Mediterranean Diet, as intended by the wise fathers of our civilisation and not that of some propagators of today, who are more interested in market dynamics rather than our true cultural identity.

3 THE COST FOR CONSUMERS

At a time when the economic crisis is the protagonist of everyday life for businesses and households, we have tried to present a brief insight into the importance of the cost of food in household consumption. It is indeed interesting to note that the proportion spent on food has declined significantly over the past forty years, at the expense of items such as housing or recreation.

In the context of food consumption, meat contributes to about 19-22% of the total monthly "bill" of an average family.

In this context it is interesting to look for a relationship between spending and the adoption of "sustainable" diets, such as, for example, the Mediterranean nutritional model. Income levels are indeed often used to determine the quality of life and the type of food eaten.

Many authors[11] have developed scientific studies in this regard and in this document too, we also decided to present a reinterpretation of the public data in order to provide an additional perspective.

Using the same approach as with the environmental information, the amount of daily food recommended by INRAN (now CREA - Food and Nutrition) has been multiplied by the average prices of individual product categories, as reported for the month of October 2022 by the Observatory for Prices and Tariffs[12].

The conclusion to which it arrives, which is clearly shown in the "economic hourglass" graphic is one that, by following a diet with the "correct portions", the meat category does not have higher costs than fruit and vegetables, for which the unit cost is lower, but suggested consumption is greater.

	2020		2021	
MEDIAN MONTHLY EXPENDITURE	€ 1,962		€ 2,048	
AVERAGE MONTHLY EXPENDITURE (=100%)	€ 2,328	%	€ 2,437	%
FOOD PRODUCTS AND NON-ALCOHOLIC DRINKS	468 €	20%	470 €	19%
NON-FOOD PRODUCTS	1,861 €	80%	1,967 €	81%
ALCOHOLIC DRINKS AND TOBACCO	43 €	2%	44 €	2%
CLOTHING AND FOOTWEAR	88 €	4%	100 €	4%
HOUSING, WATER, ELECTRICITY AND OTHER FUELS	893 €	38%	912 €	37%
FURNITURE, HOUSEHOLD ARTICLES AND SERVICES	104 €	4%	112 €	5%
HEALTH SERVICES AND EXPENSES	108 €	5%	118 €	5%
TRANSPORT	217 €	9%	241 €	10%
COMMUNICATIONS	54 €	2%	54 €	2%
RECREATION, SHOWS AND CULTURE	93 €	4%	99 €	4%
EDUCATION	14 €	1%	14 €	1%
HOSPITALITY SERVICES AND CATERING	79 €	3%	100 €	4%
OTHER GOODS AND SERVICES**	167 €	7%	174 €	7%

Median expenditure and monthly average of the sample households

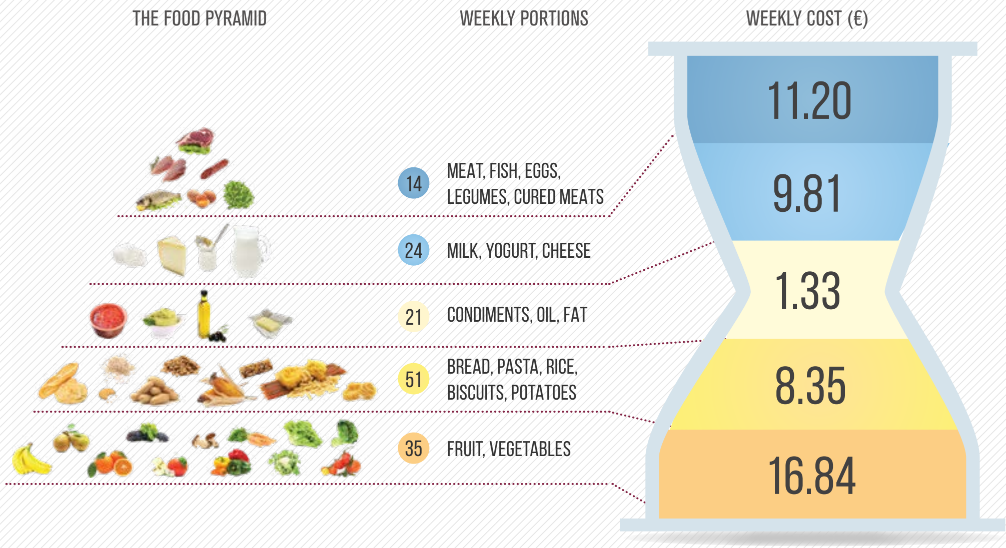
** Median monthly expenditure: the consumption expenditure value that divides the frequency distribution into two equal parts (50% of households have a lower consumption expenditure value or equal to the median, 50% higher). Since consumer spending has an asymmetric distribution, the median is always lower than the mean value.*

** Average monthly expenditure: calculated by dividing the total expenditure by the number of households residing in Italy.

*** Other goods and services: entry which includes goods and services for personal care, personal effects, social assistance services.

Source: ISTAT, 2021. Year 2021 - Household consumption expenditure.

THE ECONOMIC HOURGLASS



Economic Hourglass expresses the weekly cost of the diet suggested by INRAN guidelines (now CREA – Food and Nutrition), in analogy to what was described for the construction of the environmental hourglass's scenario B (intermediate). The weekly economic expense has been elaborated on the basis of the data provided by the Observatory for Prices and Tariffs, relating to the cities of Turin, Milan, Naples and Palermo, in October 2022.

BIBLIOGRAPHY

[1] Data extrapolated from the FAOSTAT website (www.fao.org/faostat/en/#data), going to the item 'Production Crops and livestock products'.

The filter applied for the extraction is the following:

Countries > Italy - **Regions (Total)** > Africa, Americas, Asia, Europe, Oceania. - **Items** > Pigs. - **Items aggregated** > Cattle and Buffaloes, Poultry Birds - **Elements** > Stocks - **Years** > 1961÷2020.

[2] ISMEA markets: https://www.ismeamercati.it/carni.

[3] Reprocessing of Istat and Ismea data.

[4] Ismea data (2022).

[5] CREA, 2021. Yearbook of Italian agriculture 2019, volume LXXIII. ISBN: 9788833851044.

[6] ISTAT, 7th General Census of Agriculture.

[7] The agricultural policy (CAP) of the EU (www.europa.eu/pol/agr/index_it.htm).

[8] Processing of Sustainable Meats based on Istat data, the national database of the IZS of Teramo.

[9] Istat data (2020).

[10] Data provided by the BDN of the Livestock Registry set up by the Ministry of Health at the CSN of the G. Caporale Institute of Teramo.

[11] Among the most active authors Drewnowski can be mentioned, who in his works relates the cost of food, nutritional aspects, people's income and lifestyles. By way of example, the following publications are noted:

Drewnowski A., Eichelsdoerfer P. (2009), The Mediterranean Diet: Does it have to cost more? Public Health Nutr., 12 (9A), pp. 1621-1628.

Drewnowski A., Monsivais P., Maillot M., Darmon N. (2007), "Low-Energy-Density Diets Are Associated with Higher Diet Quality and Higher Diet Costs in French Adults", Journal of American Dietists Association, (107), pp. 1028-1032.

[12] Consumer Goods and Services, Prices Surveyed for Food, Fish and Fruit and Vegetables - October 2022. Last accessed: October 2022 (https://osservaprezzi.mise.gov.it/prezzi/livelli/beni-e-servizi-di-consumer goods/ archive-surveys-goods-and-services-of-huge-consumption).

FOOD WASTE

- WHAT IS FOOD WASTE
- WHERE AND HOW MUCH FOOD IS WASTED
- WASTE IN THE MEAT SUPPLY CHAIN

Introduction

IT IS APPROPRIATE TO INTRODUCE THE CONCEPT OF SOCIAL VALUE TO IDENTIFY CORRECTLY FOOD WASTE

THE MEAT SECTOR IS AMONG THE MOST VIRTUOUS, NAMELY ONE WHICH GENERATES THE LEAST WASTE

CONSUMER AWARENESS IS CRITICAL FOR LIMITING WASTE IN THE DOMESTIC CONSUMPTION PHASE

IN THE EU EACH YEAR ABOUT 87,6 MILLION TONS OF FOOD ARE THROWN AWAY, FOR AN AVERAGE OF 173 KILOS PER PERSON

It is estimated that around one third of the food produced each year in the world is lost before consumption. *At European level, waste has reached 87.6 million tons of food, for an average of* ***173 kilos per person*** *(data referring to the EU-28)*[1]*. The causes of waste are to be found in combined effects, which belong* ***both to the world of consumption (more than 50%) and to production (over 30%)****. The remainder refers to catering services, wholesale and retail distribution. EU countries, through the Green Deal, are committed to meeting the UN Sustainable Development Goal of* ***halving per capita food waste*** *at sale and consumption* ***by 2030*** *and reducing food losses and waste along the production and supply chains, through* ***prevention, reuse, recycling and recovery.*** *Without prejudice to the final objective of reducing waste, the in-depth analysis of the available information makes it clear that trivial errors must be avoided, such as for example that of* ***including both the actually wasted food and the inevitable non-edible scraps in the waste.*** *A correct interpretation of the concept of waste and the related data should take into consideration* ***the social value of food****, to separate what is recovered for human consumption from what is instead recovered as a resource. Italy was the first country in Europe that chose to adopt a regulatory instrument to combat food waste with the law n. 166/2016 ("Gadda law") which provides for a series of measures to reduce the production of waste and extend the life cycle of products for reuse and recycling purposes, as well as encouraging the redistribution of food surpluses. Today, research on food waste, both nationally and internationally, still has several information gaps due to the different standards of detection and measurement. From the re-elaboration of the available data, however,* ***the meat sector is one of the least subject to the phenomenon of waste, both in terms of production and consumption****. Despite the intrinsically degradable nature of the marketed product, in fact, the meat supply chain has the least social waste.*

The reasons for this virtuosity are due to the structure and organisation of the supply chain, which allows the processing of by-products in secondary processes (circular economy), but also to the economic, cultural and social value attributed by consumers to these foods.

1 WHAT IS FOOD WASTE

The European Commission has defined waste[2] as:

"The quantity of rejected products from the agri-food chain that, for economic or aesthetic reasons, or because of the proximity of the sell-by date, although still edible and therefore potentially usable for human consumption, in the absence of a possible alternative use, are removed and disposed of, producing negative effects in environmental terms, economic costs and lost earnings for companies".

1.1 Waste and scraps: what they are and why they are important

Food waste along the supply chain is generated and managed in many different ways. For this reason, especially in English-language literature, the phenomenon of waste is referred to using two distinct concepts: Food losses and Food waste[3]. **Food losses** indicate a decrease in the quantity of edible foods caused by efficiencies in the production and transformation processes. In other words, these are "food losses", which occur in the early stages of the food chain. On the other hand, when we talk about food waste, we are referring to real **food waste**. In other words, it is a decrease in the quantities of edible foods in the last stages of the supply chain (distribution, catering and domestic consumption) attributable to the behaviour of retailers and consumers. In this document, where it was not necessary to make this distinction, the term waste has been used to indicate both concepts.

For the sake of completeness, it should be noted that other scholars[4] include the overeating of individuals in the definition of waste, i.e., the difference between the amount of food a person consumes and what they would really need according to the recommended caloric needs, also including overweight and obesity (and the consequent pathologies) within the debate. However, it was decided not to deal with this approach as it is closely linked to nutritional aspects whose in-depth analysis goes beyond the objectives of this chapter.

A critical issue concerns the quantification of the phenomenon. Despite the "official" definition of the European Commission, there are in fact various interpretations and understandings that lead to different estimates of the amount of food wasted in the various stages of the food chain. In fact, as better described below, **one of the greatest problems associated with the management of food waste is precisely the absence, on a global level, of a single approach.** Despite the big efforts of supranational agencies and institutions and of research bodies involved in measuring food waste, there is in fact neither a globally shared definition/classification of the various types of waste, nor even a single methodology for their monitoring over time. This double criticality is inevitably a cause of confusion, with negative repercussions on the operational management of waste territorially.

1.2. Waste management at international level

The reduction of waste along the supply chain obviously offers various economic, social and environmental advantages[5] and is therefore an aspect on which not only international organisations but also institutional subjects, the world of research and companies are focusing. Among the most relevant initiatives, the 2030 Agenda of the United Nations and various projects at European level are certainly worth mentioning.

Worldwide initiatives

In 2015, with the United Nations Agenda 2030[6], goal number 12.3 was defined *"By 2030, halve global food waste per capita at the retail and consumer level and reduce food losses along food chains of production and supply, including post-harvest losses".*

European initiatives

EU countries, through the Green Deal, are committed to meeting the United Nations Sustainable Development Goal. Already in 2016, the Council of the European Union adopted conclusions outlining initiatives to reduce food waste and calls on the Commission and the Member States to:

- improve monitoring and data collection, in order to better understand the problem;
- focus on the prevention of food loss and waste and the increased use of biomass in future EU legislation;
- facilitate the donation of unsold food products to charitable organisations, in order to ensure greater food safety.

Although there are still many information gaps, **the study and management of the Waste problem in Europe is one of the most advanced in the world**. The activities of the Commission and, successively, of the member states are based on the results of **two research projects** focused on the measurement of food waste, as shown in the table below.

In addition to the two projects, the European Commission in 2016, established the **EU Platform on Food Loss and Waste**[7], which brings together EU institutions, national experts and relevant stakeholders with the aim of intensifying efforts to halve food waste by 2030. The platform's role is to define the measures needed to avoid food waste, share best practices and evaluate progress over time.

Fusions project (2012-2016)	**Refresh project** (2015-2019)
It represents the first attempt to dimension the phenomena for each phase of the supply chain in Europe, and as such it incorporates **strong limitations** and criticalities. In fact, the data put into the system by Fusions do not come from a process of harmonisation of statistical information, but rather represent an initial collection of data from different sources, which use different definitions of food waste and different estimation methodologies, with different time references.	It represents the current reference in the institutional and scientific fields. It aims to develop strategic agreements, pilot projects and experimental approaches to reduce food waste with the collaboration of governments, and involving stakeholders from **four pilot countries** (Spain, Germany, Hungary and the Netherlands). The aim is to develop **practical and easily implementable approaches for measuring** food waste at different stages of the consumption lifecycle, **so as to support policy implementation at national level**.

Regarding the results of these efforts, unfortunately little information is available. In fact, despite what has been established by the European Commission[8] to standardise the collection and reporting of data at national level, most of the Member States have not yet implemented[9] a methodology compliant with EU provisions. Defining a baseline (data to be used as a starting point for monitoring improvements over time) is another step that most Member States have yet to complete. In many cases, however, partial results referable to individual production sectors are available.

1.3. Waste management at Italian national level

More and earlier than in the rest of Europe, Italy has matured a significantly more marked sensitivity on the subject of food surpluses, recovery and waste: thanks to the long regulatory process started with the law n.155/2003, known as the Good Samaritan, which made it possible to start food donations and recovery programs. For this reason, Italy has promptly implemented the stimuli from international institutions - the 2030

Source: Council of the European Union, General Secretariat, 2021.

Agenda of the United Nations and the conclusions of the Council of the European Union - and was the first country in Europe that chose to adopt a regulatory tool to combat food waste. With the **Gadda Law against food waste** (Law n.166/2016), the reference regulatory framework that regulates the donations of unsold food was reorganised with simplification, harmonisation and incentive measures. But, above all, the priority of recovering food has been established, to be donated to citizens in conditions of poverty.
As regards the study of the waste phenomenon on the Italian territory, the most complete academic references from a methodological and empirical point of view are two and are shown in the table below.

Finally, at an institutional level, there is **a round table for the fight against waste and for food assistance**[12] envisaged by the Gadda law, to quantify the waste phenomenon at a national level in an unambiguous and scientifically based way, with the final objective of ensuring the necessary technical-scientific support to policy makers. The first-year report (2018) is the result of the research and development work carried out by CREA in collaboration with Ref Research and focused on the collection and dissemination of information, statistics, policies and good practices on surpluses, recoveries for human consumption and on food waste along all stages of the supply chain.

The black book of waste in Italy[11] (University of Bologna, 2011)	**Feed the hungry**[11] (Milan Polytechnic, 2012)
The work examines and makes coherent a series of sources, from those of an institutional nature (e.g., ISTAT for agricultural production) to some original surveys carried out with the help of Last Minute Market, a spin-off of the University of Bologna (processing and distribution stages). The setting favours an **environmental and economic logic of the phenomenon**, translating the Italian waste of CO_2 emitted. The university spin-off Last Minute Market has also permanently launched a public awareness campaign (**Zero Waste**) and the first national waste observatory (**Waste Watcher**) with which annual monitoring is conducted on domestic food waste and the habits of Italians in relation to the management and use of food.	The most innovative and interesting aspect of the research is given by the **change in the perspective of investigation**, with a focus not on waste but on food surplus. With **surplus** we mean the set of edible food products which for various **reasons do not reach the subjects for whom they were produced**. An example of surplus are products which - due to errors in forecasting demand or qualitative defects that reduce the perceived value of the product (e.g., damage to the packaging) - are sent to charitable organisations or the animal feed industry. It follows that by **waste** we mean that portion of surplus which is not recovered for human consumption (social perspective), for animal feed (livestock optics), for the production of goods or energy (environmental perspective).

2 WHERE AND HOW MUCH FOOD **IS WASTED**

There is a lot of information in literature and databases. However, due to the different hypotheses that underlie the survey methodologies used, these are not always comparable. For example, in Italy the first survey on the subject was carried out by the University of Bologna[10], leading to an estimate of an average annual waste equal to 27% of consumption, with an economic value of around 1,700 Euro per family. Only a year later, the Polytechnic of Milan[11] led to an estimate of waste equal to 16% of consumption.

Although obtaining quantitative data is not easy (due to the criticality in the collection of reliable information and in statistically significant numbers) **the information available is already sufficient to frame the phenomenon, to understand its causes and, ultimately, to outline strategies to reduce it over time.** In this sense, it is particularly useful to analyse the Italian phenomenon starting from the results obtained by the two research groups, a summary of which is provided in the following pages.

2.1. Where does waste occur along the supply chain

The agri-food chain is divided into numerous stages which include agricultural and/or industrial operations characterised by different degrees of efficiency and types of losses and waste.

Starting from the losses of the primary sector and those of the food processing industry, we move on to the waste that occurs during distribution, in collective and commercial catering, up to that of domestic consumption.

PRIMARY SECTOR

Includes the phases of growing food and livestock.

In the agricultural phase the greatest losses are caused by the weather or by plant diseases, which cause deviations from the standards required by the market.

TRANSFORMATION

The first and second transformations lead to the creation of food products ready to be placed on the market.

During these phases, the losses are caused mainly by the failure of the product to meet quality requirements and products returned by the market.

Waste can take place during **production** (including distribution), or during **consumption.**

However, it is to be noted that flows considered as waste may have very different destinations; while it is very likely that waste produced during the production and the distribution is intended for animal feed or in any case recycled (e.g. energy as biogas or transformation into compost), it is equally likely that the food wasted during the consumption stages is destined for disposal with significant impacts on the environment.

> "THE AGRI-FOOD CHAIN IS DIVIDED INTO SEVERAL STAGES WHICH INCLUDE AGRICULTURAL AND INDUSTRIAL OPERATIONS CHARACTERISED BY DIFFERENT TYPES OF LOSSES AND WASTE."

CATERING

One of the methods of final consumption is represented by the catering sector (collective or commercial) which is becoming increasingly important, given the growing number of meals eaten outside the home.

The waste generated in this phase is due to the non-consumption of the prepared food.

DISTRIBUTION

The third stage is connected to food distribution, either wholesale or retail.

In this context, much of the waste is due to food remained unsold for reasons related to the quality or consumer preferences.

FINAL CONSUMER

In the phase of domestic consumption wastes are mainly due to the over abundance of food bought, inability to consume within the expiry-date or proper food conservation.

Regarding the destination of these food flows, the approach adopted in the publication "Feed the hungry"[11] is of particular interest because, although dated, it provides a technical distinction of the three possible paths:

- **DIRECT FOOD CONSUMPTION.** Edible component of those foodstuffs that reach consumers to satisfy their dietary needs.
- **FOOD WASTE.** Inedible component, and therefore discarded, of foodstuffs. It cannot be considered as waste food as it could not be destined for human consumption under any circumstances (e.g., bones, fruit pits).
- **SURPLUS FOOD.** Food goods suitable for consumption but which – due to errors in forecasting demand or qualitative defects that reduce the perceived value of the product (e.g., damage to the packaging) – remain unsold. The surplus can in turn be divided according to the way it is managed and its intended use:

  -***Human consumption***: used to satisfy human needs, through sale to secondary markets, charities, food banks, etc.;

  -***Animal feed***: used to satisfy animal needs, through sale to kennels or zoos, or transfer to companies dedicated to the production of feed;

  -***Valorised waste:*** used for the production of fertilisers or for conversion into energy;

  -***Unvalued waste****: it represents the most serious waste, i.e., the excess quota that has not been recovered either for human consumption (social perspective), or for animal feed (livestock perspective) ... but not even for the production of goods intended for technical purposes, such as fertilisers, or for energy (environmental perspective). This excess portion is then disposed of in landfills.*

As better shown in the figure on the following page, **the surplus intended for human consumption is the only one that does not represent a social waste**, as it was recovered in time and destined for the purpose for which it was produced (human).

2.2. How much food is wasted

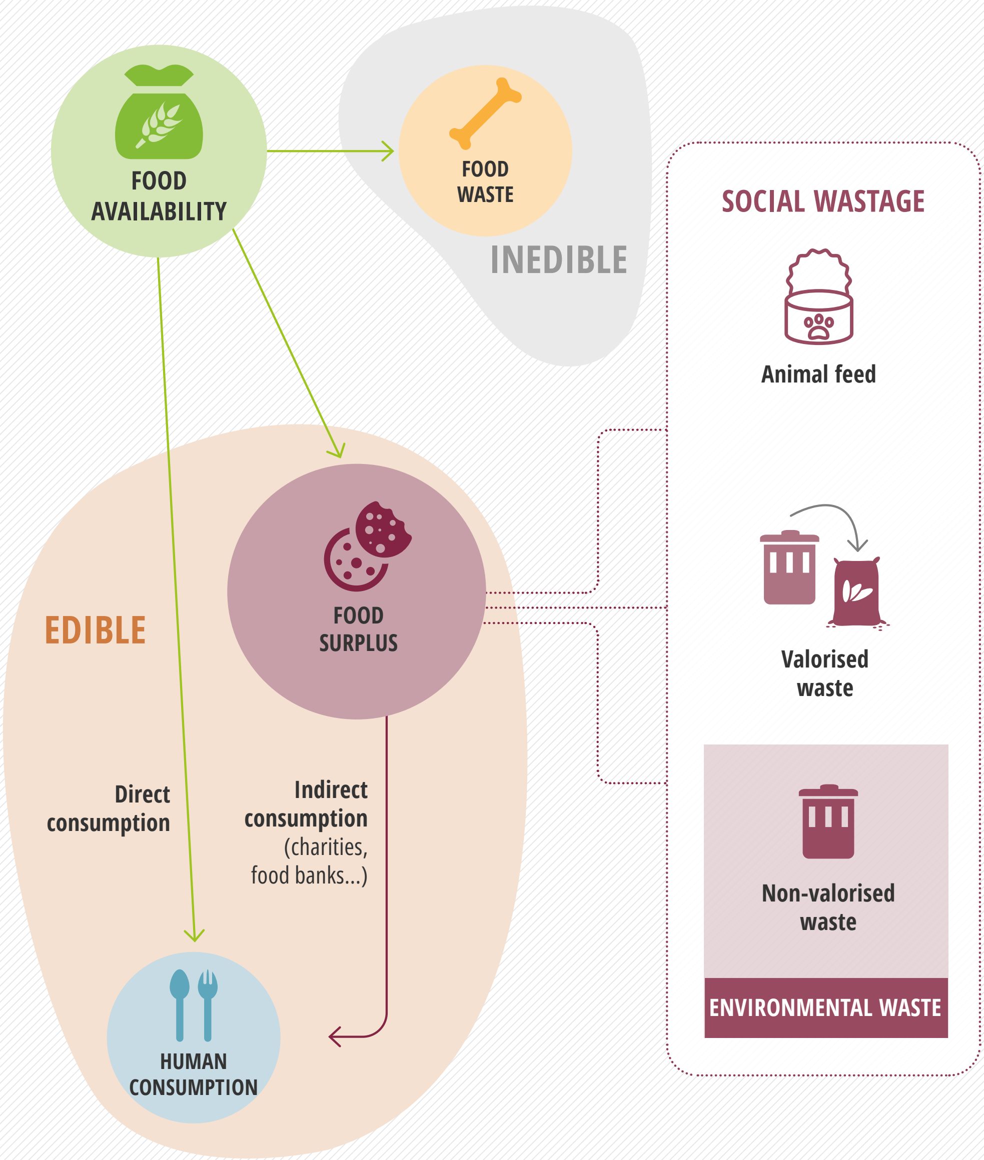
An initial analysis can be made by observing the efficiency in the recovery and valorisation of food in each segment of the supply chain. As detailed in the figure, **the food surpluses that are not recovered for human consumption - and which therefore represent a social waste - are particularly low in the livestock supply chain**, but very high in all the other primary sector supply chains. Processing (except frozen foods) and delivery to distribution centres have good efficiency on average, while waste in stores and restaurants fluctuates in the range of 85-95% and reaches 100% in the domestic consumption segment.

However, to give each phase the right weight, it is important to compare the waste of each segment with the overall waste of the entire supply chain, which was estimated at around 5,500 thousand tons per year. In doing so, it emerges that, in absolute terms, **the critical points of the supply chain are the primary sector** (especially the fruit and vegetable, cereal and fishing sector) and **the domestic consumption phase**. On the other hand, waste in the distribution and catering phases is clearly reduced.

Given the importance of the domestic contribution, a large part of the research efforts is aimed precisely at investigating the causes of waste in this phase of the supply chain. In this regard, recent stud-

Infographic

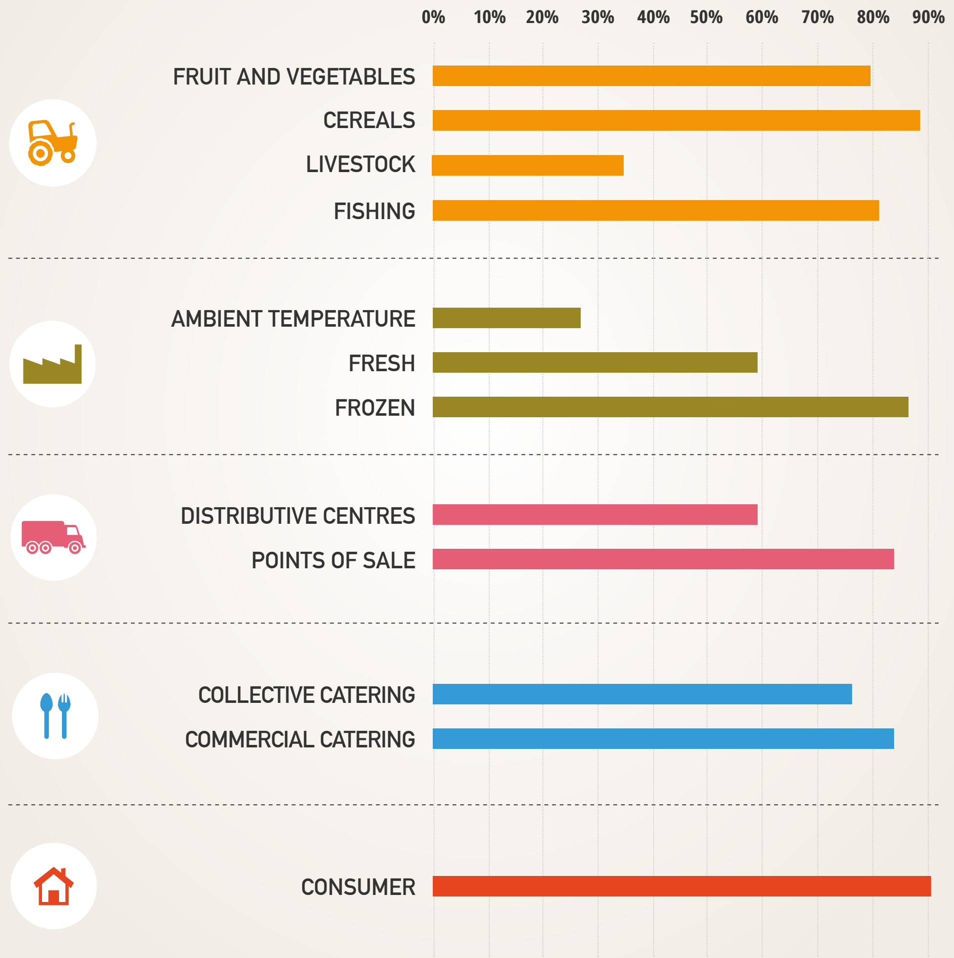
FOOD SURPLUS



Food waste identifies the edible part of food not consumed by humans.

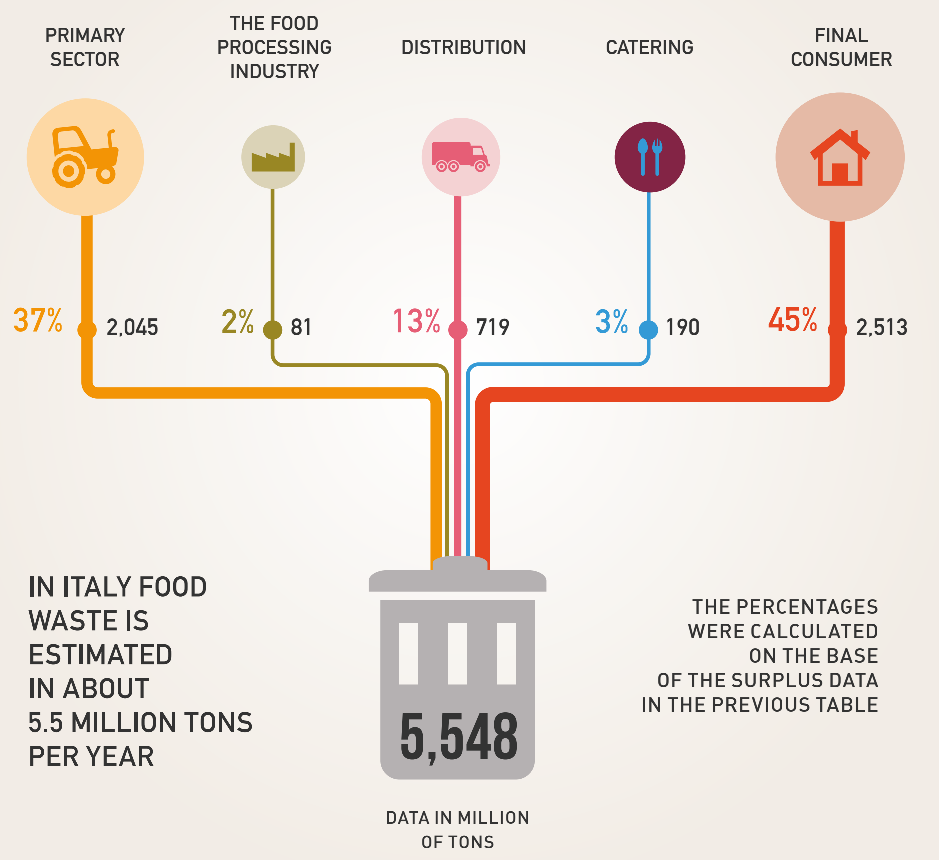
ies show that Italy registers a quantity of domestic waste similar to that found in other European countries, i.e., **on average 370 grams per week per family** (CREA study, with the collaboration of REF Research and the support of the analysis by GFK-Italy)[13].

SOCIAL WASTE: REPRESENTS HOW MUCH SURPLUS FOOD IS WASTED



Among the "less wasteful" categories there are foods derived from livestock as well as those included in the "ambient temperature." category (i.e. less perishable) in the transformation chains (Source: Based on data available in Garrone, 2012[17].

WHO WASTES MORE



Source: processing of data relating to Italy and available in Garrone, 2012[11].

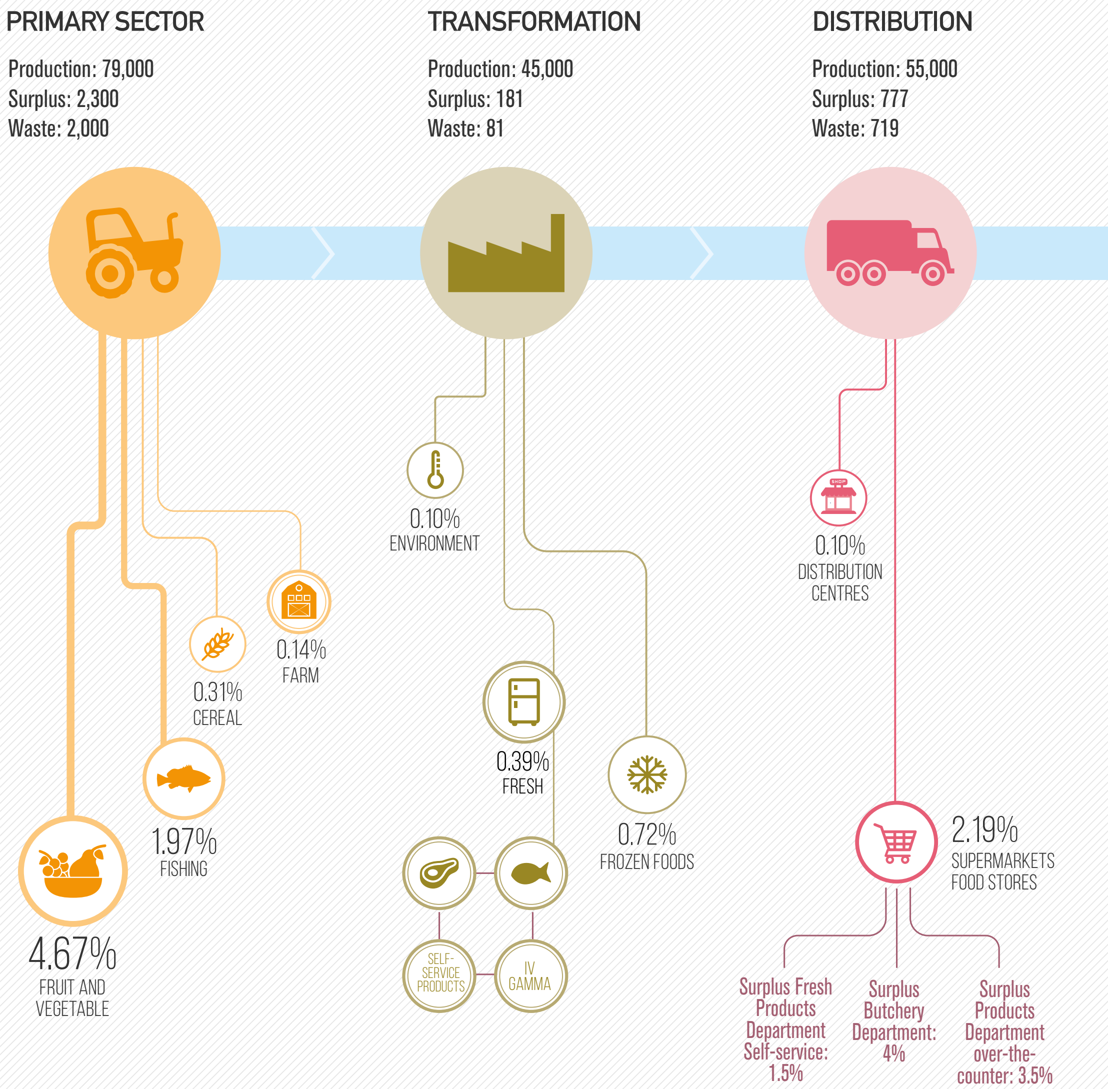
WEEKLY HOUSEHOLD FOOD WASTE IN FIVE EUROPEAN COUNTRIES

Country	Food waste (g/week per family)	Sample size
Spain	534	1,020
Germany	425	841
Hungary	417	464
Italy	**370**	**1,142**
The Netherlands	365	1,029

Source: MIPAAF-CREA, 2019[13].

WASTE
IN THE FOOD SUPPLY CHAIN

*DATA IN THOUSANDS OF TONS



THE PERCENTAGE INDICATES, FOR EACH STAGE OF THE SUPPLY CHAIN, THE ACTUAL SOCIAL WASTE ON TOTAL PRODUCTION

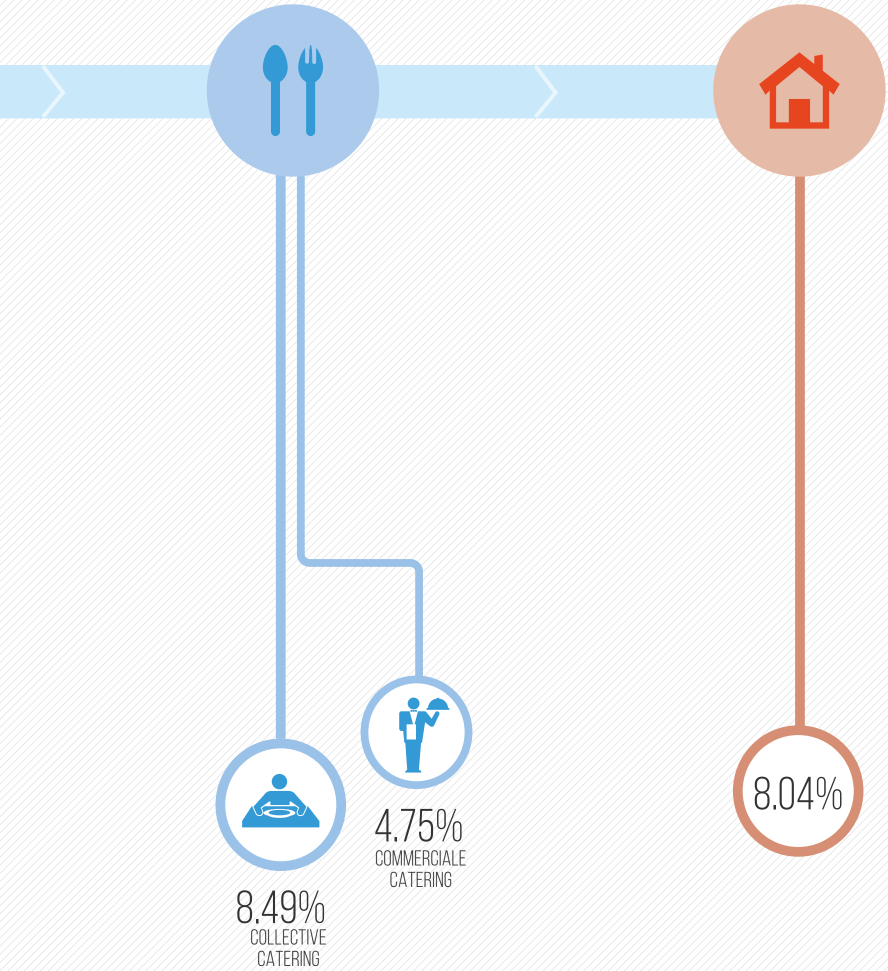
SURPLUS: edible component of food that is not sold or consumed.
SOCIAL WASTE: part of the surplus that is not used for human consumption.

CATERING

Production: 3,000
Surplus: 209
Waste: 190

FINAL CONSUMER

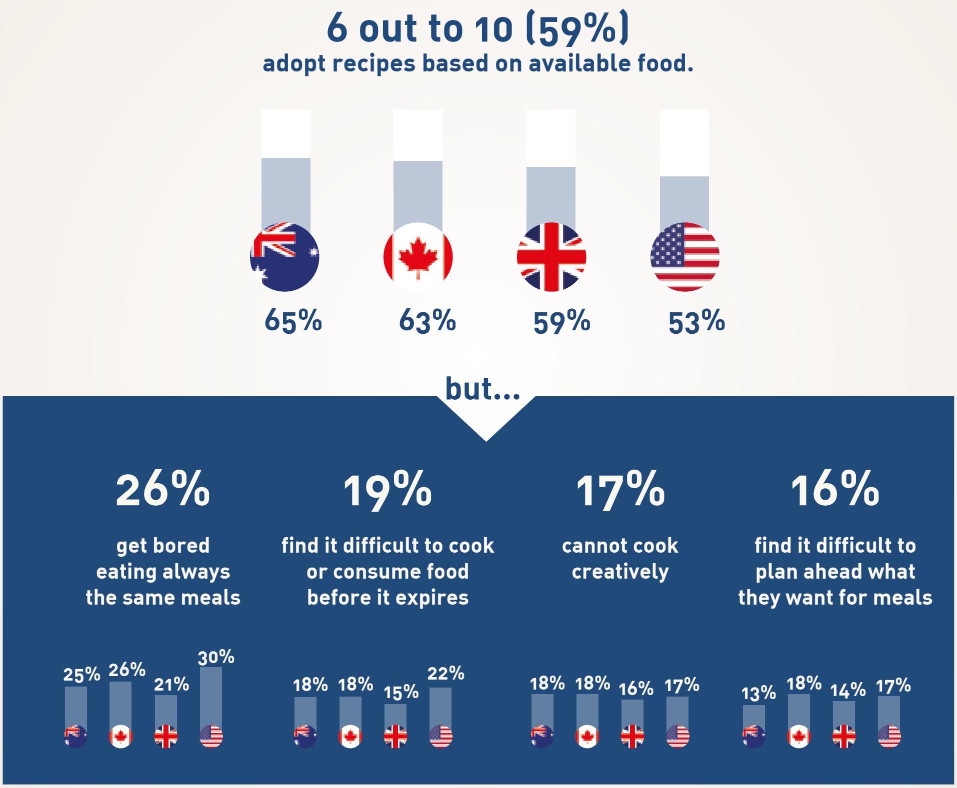
Production: 31,000
Surplus: 2,500
Waste: 2,500



2.3. Consumer behaviour

According to research conducted on a European scale[14], the phenomenon of domestic waste is essentially determined by three causes: **motivations, skills and opportunities**. Consumer motivations (e.g., awareness of negative consequences of food waste, social approval) appear as the main cause. However, skills in preventing food waste are also of great importance: without adequate skills and knowledge about food handling (e.g., knowing how to cook creatively, knowing how to evaluate food safety, knowing how to correctly plan food purchases) a consumer, even if driven by strong motivations, encounters difficulties in preventing food waste. Finally, opportunities are essential, such as the availability of equipment and space in the home for storing food, accessibility to shops/supermarkets in terms of distance and time, availability of products in terms of format and quality at the habitual point of purchase. The same barriers have been found in other developed countries (as shown in the infographic below).

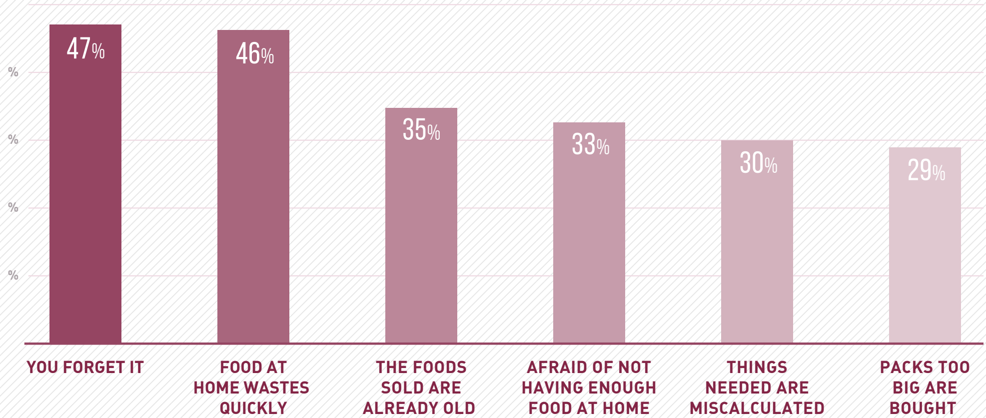
BARRIERS TO OVERCOME TO MAKE FOOD CONSUMPTION MORE EFFICIENT



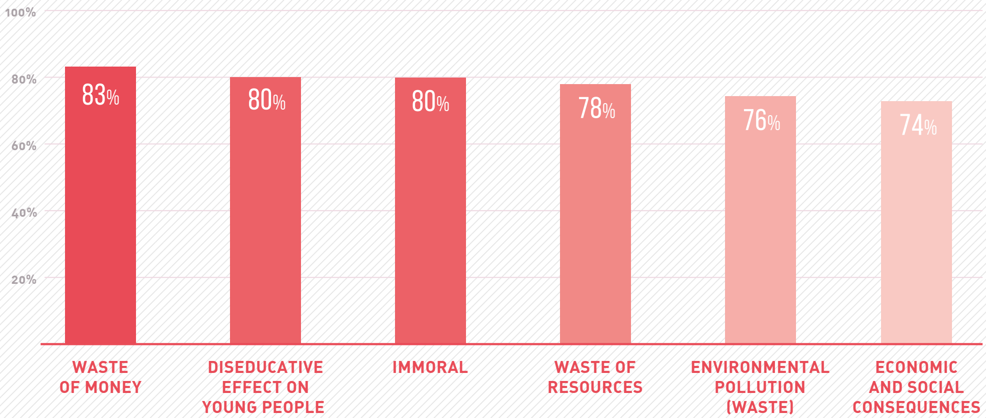
Source: WRAP summary report, 2022[15].

SOME INVESTIGATIONS ON WASTE

WHY IS FOOD WASTED?



WHAT ARE THE PERCEIVED CONSEQUENCES OF FOOD WASTE?



Since 2013, the Waste Watcher has been studying the behaviour of Italian consumers to investigate the main causes of domestic waste: among the main ones are those relating to the conservation and management of food supplies. Source: Waste Watcher Report, 2022[16].

WASTE WATCHER

2.4. Social waste in the world

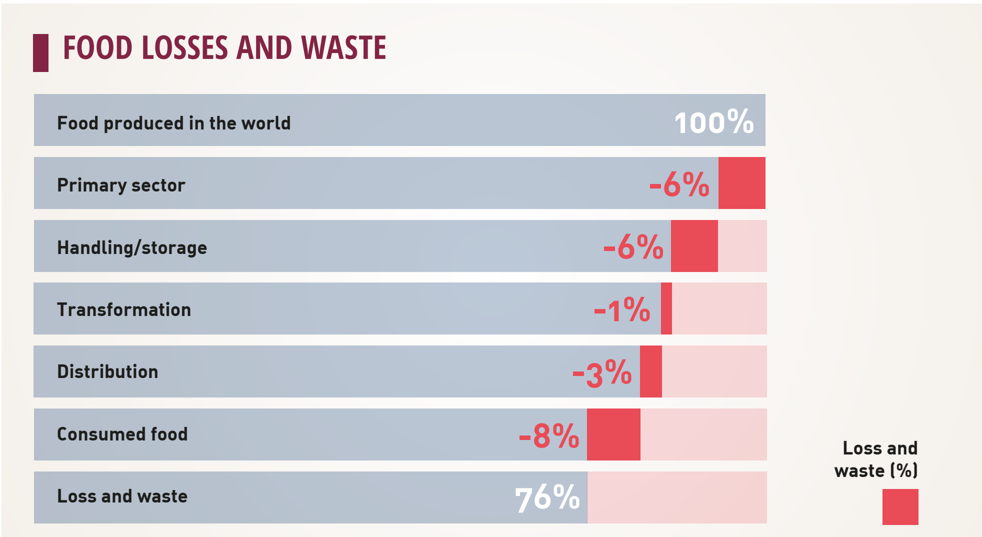
At European level, waste has reached 87.6 million tons of food, for an average of **173 kilos** per person (data referring to the EU-28)[1].

Further extending the observation scale, it is estimated[17] that on average about **one third of the food produced each year in the world is lost before consumption.** And, by converting this amount into **calories**, this loss of food reaches 24% of the total produced.

Continuing the comparison in terms of calories, the figure in the following page shows how the amount lost or wasted varies from 15% to 25% in most regions of the world. The only regions with abnormal values are North America and Oceania, where food waste accounts for about 42% of all available food.

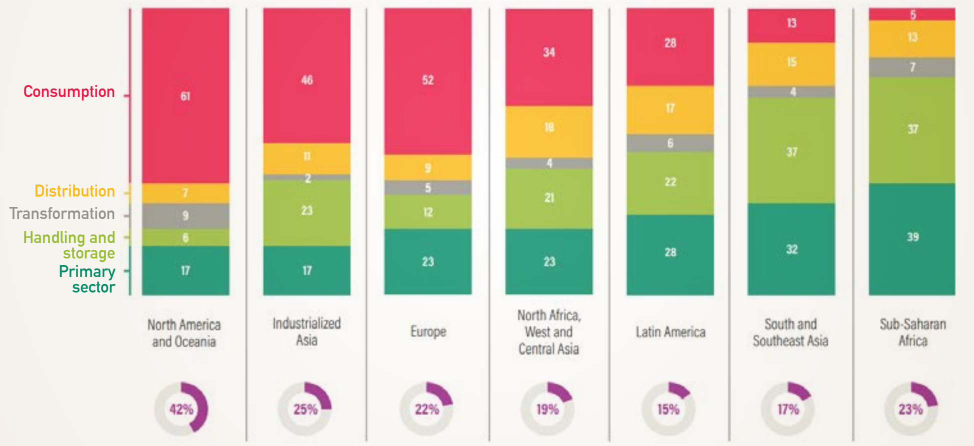
It is also extremely interesting to note how the distribution of food waste along the stages of the supply chain varies considerably between developed and developing regions. Indeed, in the former, the production processes boast a good level of efficiency and the greatest waste occurs on the consumer's table (in North America, Oceania and Europe, over 50% of food is wasted during consumption). In less organised countries, on the other hand, the consumer tries to make the most of the little food he has available, as a large part of this good has already been wasted along the supply chain due to technological and infrastructural shortcomings (in South Asia and southeast and sub-Saharan Africa over two-thirds of total waste occurs in the two phases closest to the farm, production and storage). However, it is expected that in several developing countries the distribution of waste along the supply chain will take on an aspect increasingly similar to that of developed countries due to progressive technological improvement.

Even relating these values to the number of inhabitants in each geographical area, the result does not change. In fact, in terms of **kcal per capita that are lost or wasted every day along the supply**



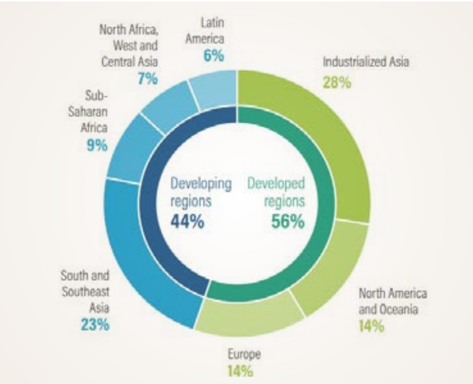
On average, around 24% of all food produced is lost or wasted between field and table. The values are expressed in terms of caloric content. Source: Searchinger et al., 2019[17].

QUOTA OF AVAILABLE FOOD LOST OR WASTED IN VARIOUS GEOGRAPHICAL REGIONS



The values are expressed in terms of caloric content. Source: Searchinger et al., 2019[17].

chain, North America and Oceania stand out with around 1,500 kcal per capita followed by Europe and industrialised Asia (around 750 kcal per capita) and the other regions (less than 600 calories per person). The result is that approximately 56% of global food waste occurs in developed countries: North America, Oceania, Europe and industrialised Asian nations (such as China, Japan and South Korea).



About 56% of global food waste occurs in most developed countries. Source: Searchinger et al., 2019[17].

2.5. Economic and environmental impacts of food waste

Food waste has an impact not only socially but also in economic and environmental terms. According to a study[18] by the Waste and Resources Action Program (WRAP), in fact, it is estimated that by 2030, food waste will reach 2.1 billion tons, for a value of 1,500 billion US Dollars.

In environmental terms however, a study by the World Resources Institute[17] highlights how, if food waste were a country, it would be the third largest emitter of greenhouse gases in the world, after China and the United States of America.

Indeed, this 'country' would consume about a quarter of all the water used by agriculture each year, require an agricultural area larger than the size of China and **generate about 8% of global greenhouse gas emissions annually.**

GLOBAL FOOD LOSSES AND WASTE

1.6 billion tons

of food losses and waste every year, representing...

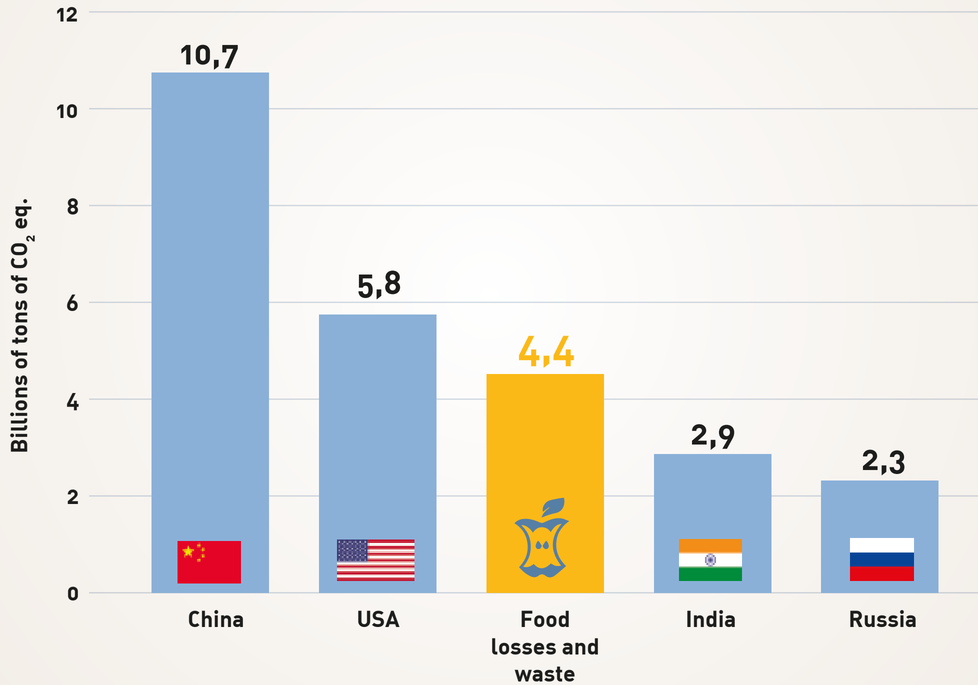
...over **1,000 billion** of dollars

...about **1/3** of all food produced for human consumption.

It is estimated that by **2030** food waste will reach **2.1 billion tons**, worth **$1.5 trillion**.

Source: WRAP report, 2022[18].

FOOD LOSS AND WASTE: THE THIRD LARGEST GREENHOUSE GAS EMITTER



If food loss and waste were a country, it would be the third largest emitter of greenhouse gases in the world. Source: Searchinger et al., 2019[17].

3 WASTE IN THE MEAT SUPPLY CHAIN

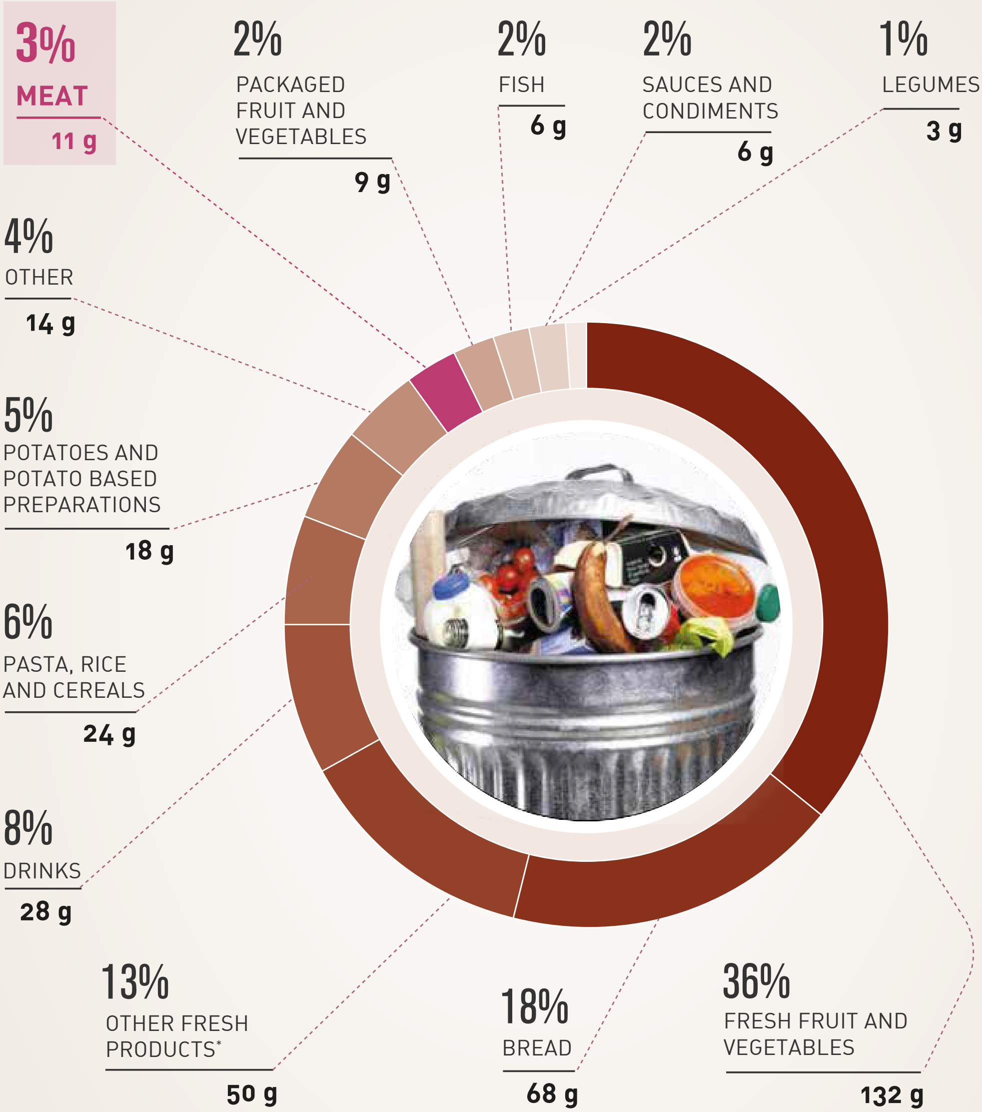
Among the data relating to food waste, there is no information that allows one to go back to precise and clear data regarding meat. However, it has been estimated that the waste of Italian families is equal to 2.5 million tons (about 8% of the total purchased). In this context, **the meat and fish supply chains are among the most virtuous**: adding up the leftovers of food brought to the table and the food thrown away because it has expired or gone bad, the overall waste of meat and fish reaches just 6% by weight of the average family's waste (Garrone et al., 2012)[11]. The results were confirmed by a more recent publication by the CREA[13] food waste observatory, which reports **domestic waste of meat alone estimated at just 11 grams per week per family** (3% of average waste).

Retracing the supply chain, the major cause of waste in the distribution phases is reaching the expiration date, an aspect that can be controlled with careful management of orders with producers. In this phase, the high perishability of the product causes waste because once the expiry date has passed or in the event of interruptions in the cold chain, the suitability and safety characteristics of the products themselves are lacking.

Finally, as regards the livestock farming and initial processing phases, meat waste is extremely reduced, as any overproduction from the slaughtering plants is easily preserved, thanks to the deep-freezing systems.

AVERAGE WASTE OF AN ITALIAN FAMILY

370 g / week



Values expressed in grams / family for a week

** Eggs, cheeses, yoghurts, puddings, fresh snacks, fillings for sandwiches, soups and pureed soup.*

Source: MIPAAF-CREA, 2019[13].

BIBLIOGRAPHY

[1] Stenmarck et al., (2016). Report: estimates of European food waste levels. FUSIONS project. ISBN 978-91-88319-01-2

[2] Official Journal of the European Union. Avoid food waste European Parliament resolution of 19th January 2012, on avoiding food waste: strategies to improve the efficiency of the food chain in the EU (2011/2175(INI)). OJ C 227E, 6.8.2013, p. 25–32.

Available on the web page: https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=CELEX:52012IP0014.

[3] Parfitt J. et al. (2010), Food Waste within Food Supply Chains: Quantification and Potential for change to 2050, Phil. Trans. R. Soc., vol. 365, pp. 3065-3081, doi: 10.1098/rstb.2010.0126.

[4] Smil V. (2004). Improving Efficiency and Reducing Waste in Our Food System. Environmental Sciences 1(1):17-26, doi: 10.1076/evms.1.1.17.23766.

[5] European Union Council, Food Losses and Food Waste: Council Conclusions (28 June 2016). 10225/16, Brussels.

[6] The agenda is a program of action for people, the planet and prosperity signed in September 2015, by the governments of the 193 member countries of the United Nations. It incorporates the so-called Sustainable Development Goals (SDG), i.e., 17 Objectives for Sustainable Development in a large action program for a total of 169 'targets' https://unric. org/it/agenda-2030/.

[7] The European Food Losses and Waste Platform, visible on the web site: https://ec.europa. eu/food/safety/food_waste/eu-food-loss-wasteprevention-hub/.

[8] Implementing Decision (EU) 2019/2000 of the Commission on 28th November 2019, establishing a format for the reporting of food waste data and for the submission of the quality control report in accordance with Directive 2008/98/EC of the European Parliament and of the Council. https://eur-lex.europa.eu/eli/dec_impl/2019/2000/oj.

[9] European Union Council, Food Losses and Food Waste: Assessment of Progress Made in Implementing the Council Conclusions adopted on 28 June 2016, Information from the Presidency and the Commission (9 November 2020). 11665/20, Brussels.

[10] Segrè L., Falasconi A. (2011), Il libro nero dello spreco in Italia: il cibo. 124 p., Edizioni Ambiente, Milan.

[11] Garrone P. et al. (2012), Dar da mangiare agli affamati. Le eccedenze alimentari come opportunità. 266 p. Guerini e Associati , Milan.

[12] "Observatory on food surpluses, recoveries and waste", established in 2017 by the MiPAAF and located at the CREA-Food and Nutrition Research Centre.
Web page: https://www.crea.gov.it/web/alimenti-e-nutrizione/-/osservatorio-sugli-sprechi-alimentari.

[13] MIPAAF-CREA, 2019. The observatory on surpluses, on food recovery and waste.
Reconnaissance of the measures in Italy and proposals for development. First year report.

[14] Van Geffen et al. (2017), Quantified Consumer Insights on Food Waste: Pan-European Research for Quantified Consumer Food Waste Understanding. REFRESH Deliverable 1.4. Project's website: https://eu-refresh.org/.

[15] WRAP Summary Report (2022), Food Loss and Waste Research on Consumer Behaviour. International Day of Awareness of Food Loss and Waste, 28 settembre 2022, https://wrap.org.uk/resources/report/wrap-food-loss-wasteresearch-summary-report.

[16] Waste Watcher International Observatory on Food and Sustainability, Report, Waste Watcher Italia 2022.

[17] Searchinger T. et al. (2019), Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050. World Resources Institute. www.SustainableFoodFuture.org.

[18] WRAP Report (2022), Food Loss and Waste: from Commitments to Action. A Watching Brief on Nationally Determined Contributions, 6 novembre, 2022. https://wrap.org.uk/resources/report/food-commitments-to-action.

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Animal source foods taken as part of a balanced diet are considered by nutrition experts to be foods of high nutritional value that are important for human health. According to the FAO, the demand for animal proteins worldwide is expected to increase significantly in the coming years, due both to the increase in global population and the growth in demand for higher-quality food in developing countries.

At the same time, starting from the mid-80s, meat consumption in Italy and the Western world has stabilised, and in the face of now consolidated food security, there has been a shift in sensitivity towards ethical issues such as animal welfare and the environmental impacts of livestock farming.

The challenge for livestock production has therefore become to "produce more with fewer resources," aiming for an increased offer but more "sustainable", efficient, environmentally attentive and considerate of animal welfare, ensuring fair compensation for farmers and all those involved in the value of the supply chain. Analysing the sustainability of meat and cured meats means studying in the most objective way possible the various topics that concern both the consumer and livestock production.

This volume sparks from an initial interdisciplinary study published in 2018, to describe the "5 facets" of meat sustainability, represented by five chapters: nutrition, environmental impacts and the application of the circular economy to livestock and industry, food safety and animal welfare, the economic aspects of supply chains and the fight against food waste.

Five years later, a revision by the authors has permitted the publication of this new text, which delves deeper and elucidates the significant recent scientific and technological innovations most recently emerged: from more accurate methods of calculating environmental impacts and preserving biodiversity; from the role of livestock in ecological transition, to new opportunities in bio-economics and the circular economy, as well as recent scientific developments in the fields of nutrition and health.

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