

Red and processed meat in the context of health and the environment:

many shades of **red** and **green**

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Contents

Acknowledgements	v
Abbreviations	vi
Glossary	vii
Executive summary	viii

1. Background _____ 1

1.1 Red and processed meat consumption – trends and patterns around the world	2
-----------------------------------------------------------------------------------------	---

2. Red and processed meat and human health _____ 4

2.1 Contribution of red meat to nutrient adequacy of the diet	5
2.2 Noncommunicable diseases (NCDs)	6
2.3 Food safety	8

3. Antimicrobial resistance (AMR) and other zoonotic disease risk _____ 9

3.1 Antimicrobial resistance (AMR)	10
3.2 Zoonotic disease risk	11

4. Red and processed meat and the environment _____ 12

4.1 Greenhouse gas (GHG) emissions	13
4.2 Land use and biodiversity loss	13
4.3 Water use and pollution	14
4.4 Livestock and improved environmental outcomes	14
4.5 Impact of climate change on future meat production and consumption	14

5. Current recommendations for red and processed meat intake	15
5.1 Global dietary recommendations	16
5.2 National dietary recommendations	16
5.3 Recommendations from expert and academic groups	17
6. Alternatives to the consumption of red and processed meat	18
6.1 Shifting to higher intake of other animal-source foods (including eggs, poultry and less commonly consumed meats)	19
6.2 Shifting to higher intake of minimally-processed plant-based foods	20
6.3 Shifting to higher novel food intake	20
6.4 Cultural acceptability of dietary transitions	21
7. Substituting red and processed meat and its impact on health and environment	23
7.1 Modelling red and processed meat reduction in different geographical regions and outcomes	24
8. Political economy and power dynamics	26
9. Potential measures to shift dietary patterns	28
10. Summary of evidence and recommendations	32
References	34

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Abbreviations

AMR	antimicrobial resistance
COP28	28th Conference of the Parties of the United Nations Framework Convention on Climate Change
CVD	cardiovascular disease
DALY	disability-adjusted life-year
DASH	Dietary Approaches to Stop Hypertension
EAT-LDI	EAT-Lancet Diet Index
EAA	essential amino acid
FAO	Food and Agriculture Organization of the United Nations
GHG	greenhouse gas
HIC	high-income countries
HR	hazard ratio
IARC	International Agency for Research on Cancer
LMIC	low- and middle-income countries
NCD	noncommunicable disease
NDC	nationally determined contributions
QALY	quality-adjusted life-year
SFA	saturated fatty acid
STEC	Shiga toxin-producing <i>Escherichia coli</i>
UN	United Nations
WCRF	World Cancer Research Fund
WCRF-AICR	World Cancer Research Fund and American Institute for Cancer Research
WHO	World Health Organization
WOAH	World Organisation for Animal Health
YLL	years of life lost

Glossary

Definitions for red and processed meat vary considerably. For the purposes of this information brief, the definitions below apply:

Red meat: All mammalian muscle meat from adult and juvenile animals, including cow meat, pig meat, sheep meat, horse meat, goat meat and camel meat (1).

Processed meat: Processed meat refers to meat from all animals (including pig, cow and other red meats, as well as poultry) that has been transformed through salting, curing, fermentation, smoking or other processes to enhance flavour or improve preservation. Most processed meats contain pork or beef, but processed meats may also contain other red meats, poultry, offal or meat by-products such as blood (1).

The NOVA food processing classification separates the category of “ultra-processed” meat, referring to formulations of ingredients, mostly of exclusive industrial use, obtained through processing meat from all animals (including pig, cow and other red meats and poultry). Examples of “ultra-processed” meat include industrially formulated sausages, burgers, hot dogs or other reconstituted meat products (2).

In addition, the following definitions are used for products intended to replace red meats (although it is acknowledged that different terms are applied to these products with varying definitions):

Plant-based meat analogues: Also referred to as imitation meat or faux meat, plant-based meat analogues are novel food products that are derived from usually pea or soy protein isolates and approximate the aesthetic and taste characteristics of animal-based meat (3).

Cell-based meat: Also referred to as cultured or lab-based meat, cell-based meat is produced using animal cell culture technology that reproduces animal meat via in vitro processes (4).

Executive summary

Key messages

- Red meat can be an important element of a healthy diet, particularly at specific life stages.
- Excess consumption of red meat and processed meat is associated with increased risk of noncommunicable diseases (NCDs).
- Current health recommendations suggest that red meat consumption should be between 98 g and 500 g per week for adults.
- A reduction of 14% in the consumption of red and processed meat in upper-middle income countries, associated with an increase in plant-based food sources, might result in 65 000 fewer attributable deaths.
- Intensive animal farming is associated with increased risk of antimicrobial resistance (AMR), and many forms of livestock farming are associated with unsustainable environmental impacts, such as greenhouse gas (GHG) emissions, use of freshwater and land mass, and biodiversity loss.
- More precise and consistent use of definitions is needed to inform generation of high-quality evidence and implement monitoring and surveillance programmes.
- Integrating systems-wide incentives to shift away from centralized industrial production methods could generate win-wins in multiple areas, including reduced AMR risk, greater worker and animal welfare, protection of biodiversity and reduced water pollution.

There is growing international consensus that food systems transformation is important to address the challenges of malnutrition in all its forms, the burden of NCDs, environmental sustainability, increasing inequality and ensuring the welfare of workers and animals (5).

In light of the urgency of these challenges, there are questions about the role of red and processed meat in healthy and sustainable food systems. Globally, production and consumption of all types of meat has increased substantially in the last 50 years, and – although red meat consumption is now plateauing in high-income countries (HICs) – is predicted to increase by a further 50% by 2050 (6). Meat consumption remains highly unequal both between and within countries (7), and animal-source food intakes, including red meat, are lowest among those at most risk of undernutrition (8).

This information brief synthesizes the evidence on the role of red and processed meat production and consumption in health and environmental outcomes, and in different social and political contexts. It does not give consumption recommendations, but, rather, represents the first stage in a scoping process that could lead to World Health Organization (WHO) guidance on the role of red and processed meat in healthy diets from sustainable food systems.

In relation to human health, red meat can be an important element of a healthy diet, particularly at key life stages. It is rich in highly bioavailable vitamins and minerals – particularly iron and vitamin B¹² – and other essential compounds for growth, development and good health (9,10). Excess consumption of red meat and processed meat, however, is associated with increased risk of NCDs, including cancer, cardiovascular disease (CVD) and type 2 diabetes (11). High temperature cooking – such as grilling, frying, deep frying and barbecuing – produces high amounts of harmful compounds (12, 13). “Ultra-processed” meats appear to contribute to NCD risk over and above the risks related to processed meats (14). In addition, over a third of foodborne diseases are linked to animal-source foods, including meat (15), and some of the compounds present or additives used in processed meats may add to food safety risks (16, 17). Other health concerns relating to intensive and industrialized animal farming include the increased risk of AMR, due to misuse and abuse of antibiotics (18,103), and of transmission of zoonotic disease between animals and humans (19, 20, 112).

Ruminant farming is also associated with unsustainable environmental impacts, such as GHG emissions, use of freshwater and land mass, and biodiversity loss (21). Red meat production, together with dairy milk, contributes to 55% of total global agriculture GHG emissions (22). Globally, 30% of flora and fauna biodiversity has been impacted by livestock-associated deforestation (23). These impacts vary according to different production systems, the type of animal and the scale of production. Certain livestock production systems, for example, can lead to positive environmental outcomes. Shifting away from centralized and intensive production systems towards more diverse and integrated ones, using higher quality feed, rotating grazing pastures and improving livestock management can all lead to positive outcomes, such as improved soil health, carbon sequestration, better quality of life for livestock and protection against biodiversity loss (24).

To date, inclusion of quantitative recommendations on red meat intakes in national dietary guidelines is very rare (25), but current health recommendations suggest that red meat consumption should be between 98 g and 500 g per week for adults.

Although there is a need for further evidence using more precise and consistent definitions, the existing evidence is clear that high consumption of red meat, and processed meat even more so, can have detrimental impacts on the health of populations and the planet. Fairer distribution of red meat across populations – especially those at risk of food insecurity and micronutrient deficiencies – is needed for both improved health and equity outcomes. In populations with high, and in some cases, excessive, intakes of red and processed meat, an overall reduction in consumption may be an appropriate recommendation, whereas an increase in consumption may be necessary and more appropriate for other populations.

Alternatives to consumption of red and processed meat include shifts to higher intakes of other animal-source foods, minimally-processed plant foods or novel meat alternatives (including meat analogues, cell-based meat and insects). A reduction of 14% in the consumption of red and processed meat in upper-middle income countries, associated with an increase in plant-based food sources, might result in 65 000 fewer attributable deaths (26).

Reconsidering the centralized nature of red and processed meat production globally may be a key component of efforts to shift toward more healthy and sustainable dietary patterns. Policies that incentivize more environmentally friendly agricultural practices, reduce intensive livestock operations and promote and incentivize the availability of minimally-processed plant-based foods, can bring multiple health and environmental benefits to humans, animals and the planet.

Making progress towards consumption of a healthy diet from sustainable food systems for all will require a holistic and systems-based lens. WHO is using a One Health approach to design and implement policies, programmes and research that incorporates the visions of multiple sectors in order to achieve improved public health outcomes (27). This approach is particularly pertinent in relation to red and processed meat, given the cross-cutting nature of its associated impacts, including food safety, AMR, zoonotic disease risk and environmental health.



1. Background

Key messages

- Increasingly, questions are asked about the role for red and processed meat in healthy diets from sustainable food systems.
- Health, food security and environmental outcomes associated with red and processed meat production and consumption vary in different social and political contexts.
- Globally, production and consumption of all types of meat has increased substantially in the last 50 years, and is predicted to increase by a further 50% by 2050.
- Red meat consumption is plateauing in high-income countries (HIC), but continues to increase in middle-income countries.
- Average intakes of processed meat vary hugely – with a 10-fold difference, for example, between HIC (30 g per person per day) and South Asia (3 g per day).
- Meat consumption is highly unequal between and within countries, and populations at the highest risk of undernutrition are among the lowest consumers of animal-source foods generally, including red meat.
- Context-specific and nuanced approaches will be needed to define appropriate levels of red and processed meat production and consumption.

There is growing international consensus that food systems transformation is important for the realization of environmental sustainability goals (28). These goals intersect with other crises of concern, including malnutrition in all its forms; the global burden of noncommunicable diseases (NCDs); increasing economic and wealth inequality; and the welfare of workers and animals (5). Over the past half century, there have been unprecedented transitions in dietary patterns, with shifts away from traditional diets towards ones comprising high amounts of highly-processed and animal-source foods (29). These transitions occurred initially in HIC, but are now rapidly occurring in middle- and low-income settings (30).

In light of the urgency of global environmental sustainability challenges, coupled with the recent and ongoing global dietary transitions, there are questions about the role of red and processed meat in healthy diets from sustainable food systems. Existing analyses highlight a variety of factors to consider in relation to appropriate levels of red and processed meat production and consumption and their associated impacts. These include the highly context-specific nature of both health and environmental outcomes, and the importance of power dynamics within food systems. There is no consensus yet on how best to address the challenges associated with animal agriculture and consumption levels of red and processed meat.

Context-specific and nuanced approaches will be needed to determine how to mitigate the health and environmental effects associated with some forms of production and some levels of consumption of red and processed meat. A critical lens will also need to be applied to the power dynamics at play in food systems, both historically and today.

This information brief synthesizes the evidence on the role of red and processed meat production and consumption in health and environmental outcomes, and in different social and political contexts. It is not a systematic and complete analysis of the evidence and **does not** provide consumption recommendations.¹ The brief represents the first stage in a scoping process that could lead to World Health Organization (WHO) guidance on the role of red and processed meat in healthy diets from sustainable food systems.

This information brief may also be used to inform the development of commitments and policy action on climate change and food systems at the 28th Conference of the Parties of the United Nations Framework Convention on Climate Change (COP28) in late 2023 and beyond.

1.1 Red and processed meat consumption – trends and patterns around the world

At the global level, the consumption of meat generally (including red meat, poultry and other meats) is vastly different today than it has been for 99.5% of humans' evolutionary past (31). Historically, dietary patterns have varied by time and place, but the vast majority of our predecessors consumed a much greater diversity of foods in their diets, including a wide range of plant-based foods and a greater balance of plant foods relative to animal-source foods (32).

Though diets today still vary by geographical context, average global consumption of all types of meat per capita has increased substantially in the past half-century, and global meat production is anticipated to further increase by 50% by 2050 (6).

Although within-country data are limited, the Food and Agriculture Organization of the United Nations (FAO) regularly provides data on regional and country trends in consumption (33). There is inequitable distribution of meat consumption (including poultry) between regions and countries, particularly affecting specific regions, populations, age groups and income levels (34). FAO food balance sheets depict average meat consumption (including poultry and other meats) ranging from 4 kg per capita per year in some sub-Saharan countries to 100 kg per capita per year in the United States of America (33).

¹ WHO recognizes that there are people who for religious, ethical or cultural reasons may not eat meat, or only eat certain types of meat, or other animal-source foods. The discussion in this information brief about dietary shifts and recommendations concerning meat consumption does not relate to these populations.

Per capita consumption of unprocessed red meat has, until recently, been greatest in HIC (Table 1) (35). In 2019, high red meat consuming populations included those in the United States of America, Australia and some European countries. Although still above most national dietary recommendations for daily intakes of red meat (see chapter 5), rates of red meat consumption in HIC are now plateauing. In comparison, intakes of red meat are increasing – and even surpassing these levels – in many middle-income countries, indicative of food systems transitions (36). Rapidly emerging economies are now also becoming high consumers, particularly of beef and pork. For example, in 2019, Mongolia consumed more than 50 kg of sheep and goat meat per person, Argentina consumed 48 kg of beef and 14 kg of pork per person, Brazil consumed 37 kg of beef and 14 kg of pork per person and China – where consumption of pig meat is growing most rapidly – consumed 39 kg of pork per person (7).

Table 1. Yearly per capita consumption of red meat

Per capita red meat consumption in 2019	
Countries	Meat (kg/capita)
High income countries	
The Kingdom of Spain	Pork (55); beef (14)
United States of America	Beef (38); pork (31)
Australia	Pork (29); beef (26); sheep and goat (11)
United Kingdom of Great Britain and Northern Ireland	Pork (24); beef (17)
Middle-income countries	
Mongolia	Sheep and goat (51); beef (27)
The Argentine Republic	Beef (48); pork (14)
The Federative Republic of Brazil	Beef (37); pork (14)
The People's Republic of China	Pork (39)

Source: Data sourced from Ritchie et al, 2019 (7).

Although there are fewer data available on global processed meat consumption, recent evidence suggests approximate average global intakes of 17 g/day. However, there are significant regional variations. Average intakes vary from 30 g/day in high-income regions (such as Central Europe) to 3 g/day in South Asia and 12 g/day in sub-Saharan Africa (8).

There are limited published data regarding how meat intakes vary within countries. For example, little is known about the influence of income differentials for high and low meat dietary intakes, and there are minimal data available on how intakes vary by sex or age. What is known is that many populations globally lack adequate access to sufficient and diverse nutrient and energy intake and are at risk of deficiencies and conditions related to undernutrition. Low-income populations in South Asia and sub-Saharan Africa, for example, particularly children and women of child-bearing age, are among the most at-risk populations for undernutrition and micronutrient deficiencies, particularly iron deficiency (30). These populations are also among the lowest consumers of animal-source foods generally, including red meat (8).

2. Red and processed meat and human health

Key messages

- Red meat is rich in highly bioavailable vitamins and minerals – particularly iron and vitamin B₁₂ – and other essential compounds for growth, development and good health.
- Red meat can facilitate the delivery of essential nutrients at key stages of life, including before and during pregnancy and in the first 1 000 days between conception and a child's second birthday.
- Whilst the consumption of red meat is not the only source of these compounds, there are some regions and specific populations where red meat may be the main bioavailable source, although other foods in the diet can affect bioavailability.
- Excess consumption of red meat and processed meat is associated with increased risk of NCDs, including cancer, cardiovascular disease (CVD) and type 2 diabetes.
- Specifically in relation to cancer, the International Agency for Research on Cancer (IARC) has classified processed meat as “carcinogenic to humans” and red meat as “probably carcinogenic to humans”.
- The way in which meat is prepared and processed appears to be linked with disease risk, as high temperature cooking – such as grilling, frying, deep frying and barbecuing – produces high amounts of harmful compounds.
- Over a third of foodborne diseases are linked to animal-source foods – red meat in particular has been associated with increased risk of *Salmonella* and *Escherichia coli* infections and outbreaks – and some of the additives used in processed meats may add to food safety risks.

2.1 Contribution of red meat to nutrient adequacy of the diet

2.1.1 Nutrient composition of red meat

Red meat is rich in vitamins and minerals which are highly bioavailable, meaning that they are easily absorbed and used by the body. These include high iron and vitamin B₁₂ availability (9, 10) and several other essential compounds including vitamin D₃, vitamin A, zinc, choline and all essential amino acids (EAAs), namely lysine, threonine, methionine, phenylalanine, tryptophan, leucine, isoleucine and valine (37). Iron plays a key role in transport of oxygen and electrons around the body, as well as in DNA synthesis (38). Vitamin B₁₂ is a vital micronutrient that is used to help form red blood cells and DNA, which also has a major role in the development and functioning of brain and nerve cells (39). While EAAs are not exclusive to red meat, they play key roles in human health, including regulating anti-inflammatory and immune pathways (40), liver function (41, 42), brain function (43) and cardiovascular health (44).

The nutrient composition of red meat is influenced by the animal breed, type of feed (grain, pasture or grass) and genetics (45). Meat from pasture-raised cattle is higher in omega-3 polyunsaturated fatty acids compared to meat from cattle raised on grain (46, 47). However, there is a lack of evidence to show whether these small variations in fat composition modify the associations between red meat intake and health. Almost half the fat in red meat is saturated fat, predominantly palmitic acid. Because of this saturated fatty acid (SFA) content, red meat is a key dietary source of saturated fat. Given the association between SFA intake and all-cause mortality and coronary heart disease incidence (48), this provides a nutrient-level explanation for why a reduction in the consumption of red meat is often promoted for human health.

2.1.2 Red meat consumption for delivery of key nutrients across the life course

There are several key stages of life where red meat consumption can facilitate the delivery of essential nutrients that aid growth, development, health maintenance and repair. For example, amino acids such as taurine, carnosine, anserine, creatine and 4-hydroxyproline – found abundantly in red meat – are important for optimal growth in children (49, 50). A lack of these – and other compounds – during certain life stages (for example, pregnancy or during the first 1 000 days from conception to a child's second birthday) can lead to cognitive impairment, birth defects or increased risk of infection or disease (51).

Another example is delivery of iron to women of reproductive age – over 30% of women in this age group are affected by anaemia globally, particularly iron-deficiency anaemia (34, 52). Iron deficiency is most prevalent in countries such as Azerbaijan (43% in 2013), India (37% in 2016–2018) and Pakistan (42% in 2011), but is also noted in HIC such as the United States (22% in 2015–2016) and the United Kingdom (31% in 2008–2019) (53).

More broadly, the intergenerational nature of malnutrition – whereby the poor nutritional status of a woman affects the growth, development and health of her child – has implications beyond immediate health outcomes, including loss of productivity, decreased earning potential and poorer quality of life (54). Whilst the consumption of red meat is not the only source of these compounds, there are some regions and specific populations where red meat may be the main bioavailable source (55). Many children in low- and middle-income countries (LMIC), for example, lack access to adequate amounts of nutrient-dense foods, including animal-source foods, to aid growth and development (56). It is estimated that over half (56%) of preschool-aged children globally are deficient in at least three core micronutrients (53). In these settings, iron and zinc deficiencies are common during this development period, given that young children require a consistent supply of bioavailable compounds, many of which can be found in high amounts in red meat (and other animal-source foods) (31).

Red meat is an important source of B vitamins, such as vitamin B₁₂, which is almost exclusively available from animal-source foods. Low consumption of vitamin B₁₂ can lead to increased homocysteine, which is a risk factor for CVD (57), and 100 g of lean beef would provide 79% of the daily recommendation of this vitamin (11).

Protein is an essential macronutrient facilitating the growth and repair of cells and development of hormones and enzymes (58). The role of protein in a healthy and sustainable diet is determined by quality of protein (that is, containing adequate amounts of amino acids to meet daily requirements per portion size) as well as quantity. Red meat (as well as meat generally) is a high-quality source of protein, containing all of the EAAs.

Research has increasingly emphasized the important contribution of the synergies within and between whole foods to a healthy diet (59, 60). The matrix of a food – that is, the relationship between various components within foods and their influence on molecular relationships and processes – has a significant and holistic role in determining health outcomes (61). This also extends to constellations of foods eaten together, and the nutritional and health effects of those nutrient synergies (59). For example, iron in red meat (in the form of heme iron) is easily absorbed: it is generally 1.5–2 times more bioavailable than the iron in plant foods (which is in the form of non-heme iron) (62). The context in which non-heme iron is consumed can also enhance or inhibit its bioavailability: foods high in vitamin C, for example, can enhance iron absorption, while foods high in phytates may inhibit absorption (31). Vitamin C is typically found in plant-based foods, such as citrus fruits, peppers and cruciferous vegetables (63). In contrast, foods that are high in phytates, such as lentils or some nuts, or are high in tannins, such as coffee or tea, can prohibit effective absorption of iron (64, 65). Other contributing factors to iron absorption include the gut microbiome – that is, the collective genetic material of gut microorganisms – and the general health status of the individual (31).

2.2 Noncommunicable diseases (NCDs)

The most common NCDs – including heart disease, stroke, cancer, diabetes and chronic lung disease – are collectively responsible for 74% of all deaths worldwide (66). Unhealthy diet is one of the four major risk factors for NCDs.

2.2.1 Red meat

In 2015, IARC reviewed the evidence on red meat and cancer, and classified it as a Group 2A carcinogen, which means that it is “probably carcinogenic to humans” (71). IARC estimated that the risk increases by 17% (95% CI: 5-31) per 100 g of red meat consumed per day.

Unprocessed red meat is also associated with other NCD risks, particularly when consumed in high amounts (the specific amounts vary by study) and when not part of a balanced diet alongside minimally processed plant-based foods (67, 68). The mechanisms behind this association are not fully understood, but some evidence points to high intake of heme iron (the type of iron found in animal-source foods) as associated with CVD, type 2 diabetes and metabolic disease (12, 69-71), despite some level of intake being beneficial for health as described above.

Other compounds in red meat have also been implicated in risk of type 2 diabetes, including lipid and amino acid metabolites and the production of compounds known as advanced glycation end products during roasting or grilling at high temperatures (12, 13).

While suggested cut-off values for consumption still vary across the literature, some evidence provides information on the relative risks of “high” versus “low” intake of red and processed meat. It should be noted, however, that these intake levels are inconsistently defined, and, sometimes, are not defined at all. For example, the relative risk of incidence of breast cancer and lung cancer from high red meat intakes compared to low intakes was increased by 39% and 35% respectively, while the relative risk of some mortalities was actually lower among those with high intakes compared to low intakes of red meat or poultry from studies in low meat consuming populations (72).

The associations between red meat consumption and harmful outcomes are generally tempered in short-term intervention studies, especially in dietary patterns consisting of moderate intake of unprocessed red meat and comparable unprocessed plant-source food intake (73, 74). However, the short-term nature of such studies means that only biomarkers can be assessed, not long-term health outcomes like NCD incidence. Several recent analyses have challenged some of the evidence on red meat and NCD risk as weak and insufficient for conclusive recommendations (75-77). Most notably, the Global Burden of Disease Study findings that diets high in unprocessed red meat were responsible for 896 000 deaths in 2019 (78) have been contested by re-analysis of this study and other recent meta-analyses (76, 79). A final consensus is yet to be established, although authors of the Global Burden of Disease study note that the next iteration of the study is likely to have lower estimates of deaths attributable to red meat (80).

Overall, evidence from LMIC demonstrating a link between red meat and chronic disease outcomes is lacking. However, one pooled analysis of studies in Asian countries – which comprises many LMIC – showed no relationship with morbidity outcomes (81).

The way in which red meat – as well as other types of meat – is prepared and processed appears to be linked with disease risk. High temperature cooking – such as grilling, frying, deep frying and barbecuing – produces higher amounts of harmful compounds, such as N-nitroso compounds, polycyclic aromatic compounds and heterocyclic aromatic amines, which have been suspected of being carcinogenic (82, 83). Low temperature cooking, such as boiling and stewing, produces lower amounts of these compounds. One Danish study found that consumption of barbecued and fried red meat is most harmful, and that 298 and 156 disability-adjusted life-years (DALYs) per 100 000 could be prevented, respectively, if replaced with roasted red meat (84).

2.2.2 Processed meat

Risks associated with processed meat intake include high sodium content, which is, in turn, associated with increased risk of hypertension, stroke, CVD and total mortality (85, 86). The risk for stroke from high sodium intake is higher when consumed in conjunction with low potassium intake (86), further supporting the evidence that the context in which foods are consumed has an influential effect on health outcomes (87, 88).

Reviewing evidence on the risks of processed meats, it is clear that variable definitions of “processed” are being used, if the term is defined at all. Accordingly, extrapolating the level of risk associated with processing is difficult. Nevertheless, based on the available evidence, IARC classified processed meat as a Group 1 carcinogen (meaning it is “carcinogenic to humans”), with the strongest evidence being for risk of colorectal and stomach cancers (11). Conclusions from the World Cancer Research Fund (WCRF) are comparable, with “convincing” associations between processed meat and increased risk of colorectal cancer, and “limited” or “suggestive” associations between processed meat and increased risk of nasopharyngeal, oesophageal, lung, stomach (excluding cardia) and pancreatic cancer (89).

The associations with cancer are thought to be due to the presence of compounds such as sodium, nitrites, nitrates and/or saturated fat (16, 17), as well as those generated from high temperature cooking, such as heterocyclic amines, polycyclic aromatic hydrocarbons and advanced glycation end products (90, 91). The IARC working group found that each 50 g portion of processed meat eaten daily increases the risk of colorectal cancer by 18% (95% CI: 10–28%) (11). The carcinogenic mechanisms – including the role of cooking and processing – that lead to colorectal and other cancers are not fully understood.

Very few studies specifically focus on “ultra-processed” meat intake and health risks. However, some studies have found that greater intake of “ultra-processed” meats is associated with faster cognitive decline in those with type 2 diabetes (92) and an increase of around 5% in risk of CVD (Hazard ratio (HR): 1.05; 95% CI: 1.02–1.08) (93). Although some types of meat such as sausages and burgers can be either processed (group 3 according to the

NOVA classification) or “ultra-processed” (NOVA group 4),² and many studies do not distinguish between levels of processing, there is some evidence to suggest increased risks associated with “ultra-processed” meat. This evidence is in line with an emerging body of research indicating health harms associated with foods defined as “ultra-processed” by the NOVA classification in general (not only specific to “ultra-processed” meats) (95).

“Ultra-processed” meat has been shown to contribute to higher energy intake than processed (group 3) meats in most countries with nationally representative data. For example, in the United States (2.3% of total energy intake from “ultra-processed” meat vs 1.2% from processed meat) (96), the United Kingdom (3.8% vs 0.5%) (97), Australia (2.4% vs 1.2%) (98), France (4.4% vs 3.3%) (99) and Chile (2.7% vs 0.5%) (100). “Ultra-processed” meats appear to contribute to NCD risk, over and above the risks related to processed meats. This is possibly because “ultra-processed” meats not only contain nitrites, nitrates and heterocyclic amines, which are also present in processed meats, but they have also undergone physical and chemical modifications. Such modifications can result in food matrix deconstruction, a poorer nutrient profile and presence of substances such as oils, fats and sugars extracted from whole foods alongside additives such as thickeners, flavours and colours that may disrupt the microorganisms in the gut or be endocrine disruptors and/or obesogenic (14). More systematic evidence specifically on the topic of “ultra-processed” meats is needed.

2.3 Food safety

2.3.1 Foodborne pathogens

Thirty-five percent of all foodborne diseases are attributable to animal-source foods, including meat (15). Red meat in particular has been associated with increased risk for *Salmonella* and Shiga toxin-producing *Escherichia coli* (STEC) infections and outbreaks (101). The United States is the source of 50% of all *E. coli* outbreaks reported globally, of which 88% can be traced to ground beef, which is most commonly consumed in fast food restaurants (101). In France, a study evaluated the number of cases and DALYs from biological hazards. Red meat was associated with eight foodborne pathogens (bacteria, parasites and viruses). There were an estimated 670 (95% CI: 380–1 100) illnesses per 100 000 population and diseases caused 0.12 (95% CI: 0.07–0.19) deaths and loss of 39 (95% CI: 8–71) DALYs per 100 000 population (102).

2.3.2 Food additives

The use of additives in meat also contributes to food safety risks. For example, phosphate additives that are used as stabilisers and emulsifiers in processed meats are present in 65% of all processed meat products (103). Excess intake of phosphate has a toxic effect on a number of pathologies, including vascular calcification, tumour formation and accelerated ageing (104). Nitrites are often used in processed meat to prevent foodborne diseases, especially from *Clostridium botulinum*, *Salmonella* and *Listeria monocytogenes*. However, an association between nitrites consumption and colorectal cancer has been suggested from some epidemiological studies (105). Some mechanistic studies support this theory, suggesting that a process known as heme nitrosylation, due to the nitrate or nitrite from the curing salt, is responsible (106).

² Food processing, specifically “ultra-processing”, is an increasingly recognized metric when assessing the healthfulness (as well as environmental impacts) of foods (94). The NOVA framework is one classification system that differentiates levels of processing between foods.

3. Antimicrobial resistance (AMR) and other zoonotic disease risk

Key messages

- AMR occurs when bacteria, viruses, fungi and parasites no longer respond to antimicrobial agents.
- Antibiotics are used to prevent, control or treat infections in animals, but are also still used in 40 countries to promote animal growth.
- Intensive animal farming is associated with increased risk of AMR due to misuse and abuse of antibiotics in livestock production.
- Global efforts have significantly reduced antimicrobial use in animals, but further action is needed to achieve the objectives agreed in the *Global action plan on antimicrobial resistance*, and many countries lack appropriate regulation and monitoring of antibiotic use in livestock production.
- It is imperative that measures aimed at reducing red and processed meat consumption are accompanied by measures promoting responsible and prudent use of antimicrobials in food animal production, including intensively farmed white meat and fish.
- There are other cross-species issues relevant to intensive and industrialized production practices, resulting in transmission of zoonotic pathogens between animals and humans, and there is an urgent need for substantial changes in the way animal-source foods are produced.

3.1 Antimicrobial resistance (AMR)

Antimicrobials are agents used to prevent, control and treat infectious diseases in humans, animals and plants. They include antibiotics, fungicides, antiviral agents and parasiticides. Disinfectants, antiseptics, other pharmaceuticals and natural products may also have antimicrobial properties.

AMR occurs when bacteria, viruses, fungi and parasites no longer respond to antimicrobial agents. As a result of drug resistance, antibiotics and other antimicrobial agents become ineffective and infections become difficult or impossible to treat, thus increasing the risk of disease spread, severe illness and death. An estimated 1.27 million deaths in 2019 were attributable to, and 4.95 million deaths associated with, bacterial AMR (107).

Antibiotics are used by veterinarians to prevent, control or treat infectious diseases in animals (108). However, antibiotics are also still used in animal feed for growth promotion, which is considered a non-veterinary medical use (109). This remains a practice in 40 countries, 12% still using those considered as high priority critically important antimicrobials (110). The risks associated with misuse and abuse of antibiotics include not only the cross-species transmission of bacteria resistant to antibiotics, but also through food and shared environmental sources, such as contaminated water or other food crops grown with contaminated manure (18).

Global efforts have shown a significant reduction in the use of antimicrobials in animals (110). Further action will be needed, however, to achieve objective 4 of the *Global action plan on antimicrobial resistance* (111) – namely, optimization of antimicrobial use at national and local levels in accordance with international standards in order to ensure the correct choice of medicine at the right dose on the basis of evidence (31). Many countries currently lack appropriate regulation and monitoring of antibiotic use in livestock production. Efforts by four partners – FAO, the UN Environment Programme, WHO and the World Organisation for Animal Health (WOAH) – known collectively as the Quadripartite, aim to increase capacity and sustainability in the implementation of international standards provided by WOAH as well as *Codex Alimentarius* guidelines. WHO also provides guidance in this area, categorizing antimicrobials considering their importance in human medicine and providing guidance on risk management measures when antimicrobials are used in animals and plants/crops (112).

It is imperative that measures aimed at reducing red and processed meat consumption are accompanied by measures promoting responsible and prudent use of antimicrobials in food animal production, including intensively farmed white meat and fish.

It is important to note that AMR risk is not confined to the production of red meat, but can be associated with intensive and industrialized livestock production, including aquaculture (113). It is imperative that measures aimed at reducing red and processed meat consumption are accompanied by measures promoting responsible and prudent use of antimicrobials in food animal production, including intensively farmed white meat and fish (114).

3.2 Zoonotic disease risk

In addition to AMR, there are other cross-species issues relevant to intensive and industrialized production practices. The COVID-19 pandemic, while likely derived from the transmission of a zoonotic pathogen – in other words pathogens that are transmitted between animals and humans – in a wildlife context, highlights the urgent need for substantial changes in the way animal-source foods are produced. Since the 1940s, the proportion of infectious disease burden related to zoonotic pathogens has increased to around 60% (115). Pigs, for example, are common vectors for disease, as evidence reveals their enhanced capacity to spread viruses (such as influenza) between pig, bird and human strains (116). Zoonotic disease risks are further exacerbated when factoring in the reduced genetic diversity in livestock breeds used in intensive meat production, making them more vulnerable to infections that would have lesser impact on genetically diverse livestock (19).

The persistent conversion of land for use in farming disrupts the previously intact ecosystems on that land and thus also poses further risk for zoonotic disease spill over (117). This may occur as a result of changes that enable the spread of zoonotic hosts, such as small rodents, in human-modified landscapes or through human-induced disruption to the natural balance of predators and competitors of zoonotic species (20).

4. Red and processed meat and the environment

Key messages

- Ruminant farming is associated with unsustainable environmental impacts, such as greenhouse gas (GHG) emissions, use of freshwater and land mass, and biodiversity loss.
- Red meat production, together with dairy milk, contributes to 55% of total global agriculture GHG emissions.
- Cattle systems, as well as sheep and pig meat production, tend to be the highest emitters, and are set to increase as projections of livestock production continue to grow.
- High GHG contributions associated with animal agriculture are also a result of animal feed production, estimated to account for 55% of agricultural emissions globally.
- Red-meat-related emissions can vary according to different production systems, the type of animal and the scale of production, and there is a need for more evidence from mixed systems and small or medium-size production operations.
- Meat production has had significant impacts on the biodiversity of several mega-diverse tropical regions, and, globally, 30% of flora and fauna biodiversity have been impacted by livestock-associated deforestation.
- Cattle systems are particularly water intensive and animal feed production represents a significant strain on water resources.
- Wastewater from industrial and intensive livestock production accounts for over half (57%) of the pollution of waterways and other natural resources.
- Certain livestock production systems can also lead to positive environmental outcomes, by shifting away from centralized and intensive production systems, using higher quality feed, rotating grazing pastures and improving livestock management.
- Should the climate crisis escalate as is projected, many livestock producers will face significant challenges in continuing production, due to high temperatures and extreme weather patterns, with significant implications for livelihoods and food security.

4.1 Greenhouse gas (GHG) emissions

One third of all global GHG emissions are estimated to be derived from food systems (118). Red meat production has been identified as a key contributor to agricultural GHG emissions, relative to other types of food production. Together with dairy milk, red meat production contributes to 55% of total global agriculture emissions (22). Livestock-derived food more broadly accounts for 72–78% of total agriculture emissions (119), and, within this, cattle production contributes 80% of ruminant emissions (120). Predominantly, these emissions are in the form of methane and nitrous oxide. Methane emissions remain in the atmosphere for a shorter time than carbon dioxide, but are significantly more potent and continue to contribute a significant amount of warming – around 23–40% of the total (121). Red-meat-related emissions can vary according to different production systems, the type of animal and the scale of production (121). Red-meat-related emissions can vary according to different production systems, the type of animal and the scale of production (122). A large majority of the documented evidence is derived from large-scale, single-commodity production systems, leaving a gap for more evidence from mixed systems and small or medium-size production operations (31). Despite this, modelling analysis finds that business-as-usual global agricultural practices and dietary patterns will contribute to between 0.9 ± 0.2 °C and 7 ± 0.2 °C above current warming levels, of which meat and dairy contribute more than half (123).

Together with dairy milk, red meat production contributes to 55% of total global agriculture emissions.

Cattle systems, as well as sheep and pig meat production, tend to be the highest emitters (31). These gases arise from enteric (gut) fermentation from the animals, anaerobic fermentation in manure management and non-carbon emissions from manure deposits on pasturelands (124). Associated emissions are set to increase as projections of livestock production continue to grow. In the past century, the global population of farm animals has tripled while simultaneously wild populations of animals have declined by two-thirds (32). Global demand for meat is anticipated to rise by 73% by 2050, relative to 2010 (32). However, emissions data modelling and collection can be complicated by the fact that many of the global estimates are derived from HIC data, where intensive production systems are most prevalent (31).

High GHG contributions associated with animal agriculture are also a result of animal feed production, estimated to account for 55% of agricultural emissions globally (119). Together with livestock production, the centralized and intensive nature of these two production systems results in energy-intensive operations.

In comparison, extensive livestock systems are shown to be less energy efficient when measured by the output of the final product alone. When grain production used for animal feed in intensive systems is taken into account, however, the total GHG emissions of those extensive systems are greatly reduced (by around 26–47%) (124).

4.2 Land use and biodiversity loss

Ruminant livestock, such as cattle, have had significant impacts on the biodiversity of several mega-diverse tropical regions, especially as meat production has increased as an economic resource. In some cases, including in China and Brazil, large swathes of important forest regions have undergone significant deforestation to accommodate livestock and animal feed production (31). This has been accompanied by extensive reductions in the natural habitats and subsequent populations of native animals (125). It is estimated that, globally, 30% of flora and fauna biodiversity have been impacted by livestock-associated deforestation (23). Furthermore, negative cascading effects flow on from the loss of biodiversity, including soil erosion and the loss of vegetation (126). Loss of diversity is also seen within the agricultural sector, with only five animal species supplying the majority of animal-derived foods, four of which (cows, sheep, goats and pigs) contribute to the red meat supply. The diversity of genetic breeds within these species has also been significantly reduced (127), which may result in reduced bio- and dietary diversity and reduced climate resilience.

4.3 Water use and pollution

Agriculture accounts for approximately 70% of all water withdrawals (128). Cattle systems are particularly water intensive, with the average water footprint of cow meat being 10 times higher than that of cereal production per kg produced (129). However, this is predominantly green water (that is, rainfall that is not removed from its natural cycle), and thus caution is recommended when estimating problematic water usage associated with livestock. Animal-feed production – which makes up 40% of total global cereal production – does represent a significant strain on water resources, and is inextricably linked to certain forms of livestock production, particularly intensive or concentrated feeding operations (130). In addition, pollution of waterways and other natural resources is strongly attributed to industrial and intensive livestock production methods, accounting for 57% of this type of pollution (131). In the context of meat processing facilities, wastewater can contain other organic materials including blood, faeces and hair (131). It may also contain large amounts of nitrogen, which can result in soil damage and water acidification (132).

4.4 Livestock and improved environmental outcomes

In contrast, certain livestock production systems can also work in symmetry with environmental sustainability goals. Shifting away from centralized and intensive production systems towards more diverse and integrated ones, using higher quality feed, rotating grazing pastures and improving livestock management can all lead to positive outcomes, such as improved soil health, carbon sequestration, better quality of life for livestock and protection against biodiversity loss (24). In many LMIC, mixed farming systems generate over 70% of their feed from crop residues or crop by-products, reducing their impact on land use, water and use of intensive chemical and technological inputs (133).

Certain livestock production systems can also work in symmetry with environmental sustainability goals.

4.5 Impact of climate change on future meat production and consumption

High temperatures and extreme weather patterns in some countries may impact the capacity to farm outdoors.

While much discussion considers the impact of livestock production on climate and environmental harms, should the climate crisis escalate as is projected, many livestock producers will face significant challenges in continuing production. This is because high temperatures and extreme weather patterns in some countries may impact the capacity to farm outdoors (134). In LMIC, where pastoral style livestock production is predominant, this will have significant implications for livelihoods and food security (135).

Further impacts of climate change on livestock production include water scarcity, shifting pest control and disease distribution, increased risk of pathogens, price volatility and reduced labour capacity (135).

Some have suggested that “sustainable intensification” of red meat production – that is, intensively managed animals in confined feeding operations – may be a possible solution to both offset carbon emissions and protect food security concerns in light of increased demand for meat products (136, 137). However, this path may have unintended negative consequences given that intensive feeding operations have detrimental effects on animal and worker welfare, can exacerbate power imbalances in the food system, promote the emergence of AMR and are conducive to transmission of more zoonotic pathogens from animals in confined spaces (138).

5. Current recommendations for red and processed meat intake

Key messages

- Global guiding principles on sustainable healthy diets acknowledge that a healthy diet can include “small amounts of red meat”, but no safe level of processed meat consumption has been established.
- National food-based dietary guideline recommendations for red and processed meat consumption vary according to country, and are dependent on current levels of animal-source food intakes.
- One in 10 (11%) of national dietary guidelines include a recommendation to limit or moderate consumption of red or processed meat, according to a recent study.
- Only six national guidelines setting out quantitative limits for red meat or processed meat consumption have been identified, but quantitative limits have been proposed by a number of expert/academic groups.
- Current health recommendations suggest that red meat consumption should be between 98 g and 500 g per week for adults.

5.1 Global dietary recommendations

In the early 1990s, global organizations began providing guidance on the need for more balanced diets (139), and, in more recent decades, started to recommend upper limits for red and processed meat. In 2003, *Diet, nutrition and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation* concluded that diets high in red meat are associated with the development of certain cancers, and recommended moderate consumption (88). No United Nations (UN) agency has set production or consumption targets, however the FAO/WHO *Guiding principles on sustainable healthy diets* acknowledge that a healthy diet can include “moderate amounts of eggs, dairy, poultry and fish; and small amounts of red meat” (15). Processed meat is not included in these guidelines, given that a safe limit of consumption has not been established.

National food-based dietary guidelines are increasingly addressing issues related to sustainability, and, as proposed in recent work by FAO and the University of Oxford, guidance would need to depend on current consumption levels:³

- in high consuming countries (generally HIC) there should be advice on reducing meat consumption;
- in countries where per capita intakes are increasing, there should be guidance on “moderating” consumption, to avoid the problems associated with consumption levels in high meat consuming countries;⁴
- in low-income countries – where animal-source food intakes are generally very low – the focus should be on advice to increase the diversity of diets, including more consumption of vegetables, fruits, legumes, nuts and some meat and dairy products (140).

5.2 National dietary recommendations

National food-based dietary guideline recommendations for red and processed meat consumption vary by country. A recent study examining 90 food-based dietary guidelines found that 53% had key messages related to meat generally, with 11% of food-based dietary guidelines including a recommendation to limit or moderate consumption of red or processed meat (141). Of these, only four countries include a specific upper limit amount: less than 500 g/week (Finland, Sweden and Qatar) and four times per month (Greece) (140, 141). Since the publication of those data, France has also included an upper-limit of 500 g/week for red meat and 150 g/week for processed meat in its dietary guidelines (142). In addition, Belgium has recommended upper limits of 300 g/week for red meat and 30 g/week for processed meat (143).

In recent years, some food-based dietary guidelines are incorporating sustainability dimensions into their red meat recommendations.⁵ Denmark, for example, advises a plant-rich and varied diet, recommending to limit beef, lamb and processed meat (such as smoked and salted meat) “as much as possible” (144). Brazil, Sweden and Qatar all recommend limiting red meat consumption as part of a sustainable diet, with the latter two explicitly mentioning the avoidance of processed meats (140).

³ These recommendations refer to all types of meat.

⁴ Note that this recommendation does not include within-country variations of consumption. For example, in HIC there may still exist low socioeconomic populations that do not consume the same high levels of meat relative to high-income populations.

⁵ During the production of this publication, the sixth edition of the Nordic Nutrition Recommendations was published, which constitute the scientific basis for national dietary guidelines and nutrient recommendations in the Nordic and Baltic countries. This edition gives, for the first time ever, recommendations not only about what food is good for our health, but also what is good for the environment. It recommends: a predominantly plant-based diet high in vegetables, fruits, berries, pulses, potatoes and whole grains, ample intake of fish and nuts, moderate intake of low-fat dairy products, limited intake of red meat and poultry, minimal intake of processed meat, alcohol, and processed foods containing high amounts of fats, salt and sugar. More information here: <https://www.norden.org/en/publication/nordic-nutrition-recommendations-2023>

5.3 Recommendations from expert and academic groups

The EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems is one of few global expert groups that have suggested quantitative targets for red and processed meat consumption. The group stated that red meat consumption, globally, should be reduced by more than 50% by 2050, in order to have a healthier diet. For red meat, they advise no more than 98 g per capita per week. They advise “low intake, if any” of processed meat (145). A revised set of global scientific targets – EAT-Lancet 2.0 – is in development and is due to be published in 2024 (146).

A recent analysis of 48 dietary metrics (many derived from national dietary guidelines) noted that only 14 metrics included recommendations for low intake of red meat, including the EAT-Lancet Diet Index (EAT-LDI), which recommends less than 28 g/day, World Cancer Research Fund-American Institute for Cancer Research (WCRF-AICR) dietary recommendations for less than 71 g/day and a limit of 0.5 servings/day in the Dietary Approaches to Stop Hypertension (DASH) scores (147).

In their 2018 paper published in *Nature*, Springmann and colleagues did not suggest specific recommendations on red and processed meat, but modelled for diets in line with global dietary recommendations for red meat (300 g per week) and compared with more plant-based diets. They found that, compared with baseline environmental projections for 2050, a more plant-based diet could reduce GHG emissions by 56% and other environmental impacts by 6–22% (148).

6. Alternatives to the consumption of red and processed meat

Key messages

- In populations with high, and in some cases, excessive, intakes of red and processed meat, an overall reduction in consumption may be an appropriate recommendation, whereas an increase in consumption may be necessary and more appropriate for other populations.
- Alternatives to consumption of red and processed meat include shifts to higher intakes of other animal-source foods, minimally-processed plant foods or novel meat alternatives (including meat analogues, cell-based meat and insects).
- A whole-of-systems approach is critical when considering population dietary shifts, and it is important to take into account potential trade-offs given the multiple health, environmental and social impacts of substituting different foods for red and processed meat.
- Higher consumption of other animal-source foods, such as eggs and less commonly consumed meats – such as game, camel and wild fowl – could diffuse the associated health and environmental impacts.
- There is an abundance of evidence that a transition to a healthy and sustainable diet would ideally involve increased intakes of whole vegetables and fruits, legumes and other minimally-processed plant-based alternatives. It is important that such a shift is underscored by a transition to more agroecological production practices.
- Novel meat alternatives – such as plant-based meat analogues and cell-based meats – are increasingly being positioned as a substitute for red meat consumption, but there is, as yet, little robust, long-term evidence on their health and environmental effects.
- There is potential for health gains from replacement of red meat with insects, which have high nutritional quality and have been consumed in many countries for millennia.
- Creating any shift away from red and processed meat is a cultural and ideological challenge, and a key strategy to help overcome this could be to advocate for dietary diversity – including a combination of nutrient-rich foods such as red meat, fish, poultry and legumes – to reduce health and environmental impacts.

6.1 Shifting to higher intake of other animal-source foods (including eggs, poultry and less commonly consumed meats)

In considering potential reductions in the production and consumption of red and processed meat, it is important to consider the impact such changes would have on the consumption of other foods and overall diet quality. Depending on the dietary shift, a myriad of potential implications exists for human health and the environment – both positive and negative. Such transitions, therefore, require similar food systems evaluations.

From a human health perspective, one observational study found that substituting 150 g/week of red meat with 150 g/week of poultry or fish has been shown to be associated with a lower risk of all-cause mortality and of death due to cancer (149). This is consistent with other systematic reviews that find replacing total red meat with poultry (Relative risk (RR): 0.88; 95%CI: 0.82–0.96) and fish (RR: 0.91; 95%CI: 0.79–1.04) lowers coronary heart disease risk by 12% and 9% respectively (150). Higher intakes of poultry relative to red and processed meat are also associated with a lower risk of metabolic syndrome incidence (151).

Similar to red meat production, chicken and fish can be produced in a multitude of ways, with varying environmental impacts – although all production methods produce substantially lower GHG emissions than intensive and industrially produced red and processed meat (152).

However, taking a whole-of-systems approach is critical when considering dietary shifts of large populations. For example, replacing one meat with another meat that is intensively farmed does not mitigate the risks for AMR or zoonotic pathogen transmission or other food safety concerns (such as *Salmonella*), nor alleviate animal and worker welfare concerns. Poultry is fast becoming the most consumed meat product globally, and almost 81% of all chickens are produced intensively in industrial production operations (153). Scaling up production levels of chicken and fish, despite having lower GHG emission profiles than most ruminant meat, may have flow-on effects to other environmental domains of concern, such as eutrophication (which can cause harmful algal blooms) or acidification (154). Accounting for these potential trade-offs from dietary changes is imperative, particularly given the multiple health, environmental and social impacts relating to various meat products and the implications of substituting different foods for red and processed meat.

Accounting for these potential trade-offs from dietary changes is imperative, particularly given the multiple health, environmental and social impacts relating to various meat products and the implications of substituting different foods for red and processed meat.

Higher consumption of other animal-source foods, such as eggs, as well as other less commonly consumed meats, such as game, camel and wild fowl, could be a means of diversifying animal-based foods in the food supply. This, in turn, could diffuse the associated health and environmental impacts. However, more modelling data is needed to assess the impacts of such a transition. The consumption of wild animal meat, while an important food source in some populations, carries considerable risk for zoonotic disease transmission.

6.2 Shifting to higher intake of minimally-processed plant-based foods

In contrast, there is an abundance of evidence that suggests a transition to a healthy and sustainable diet would ideally involve an increased intake of whole vegetables and fruits, as well as legumes and other minimally-processed plant-based alternatives. In a high red meat consuming country like the United States, substituting beef products with beans, for example, could reduce carbon emissions by an estimated 334 million metric tonnes (155). Moreover, at a population level, there is evidence that reducing red meat by 50% and replacing with legumes in conjunction with a balanced diet would still result in meeting dietary recommendations for protein, fat, zinc, vitamin B₁₂ and total iron intake (156). Albeit, this could require significant changes in attitudes and behaviour relating to the role and amount of meat in diets, and the acceptability to populations may be a challenge (157).

Plant-based foods are not, however, exempt from environmental harms (123). Some plant-based foods are limited to production in specific countries with conducive conditions, and thus require long supply chains to reach other parts of the world. For example, 90% of rice production occurs in Asia (158). Rice production is typically reliant on nitrogen fertilizers, representing a primary source of ammonia, nitrate and nitrogen oxide pollution (159). Thus, it will be important that any shift towards higher intake of plant-based whole foods is underscored by a transition to more agroecological production practices.

6.3 Shifting to higher novel food intake

Novel meat alternatives (such as plant-based meat analogues or cell-based meats) are increasingly being positioned as a substitute for red meat consumption (160). Given their recent entry into the food supply, there is a paucity of robust, long-term evidence on their role in health and environmental effects, especially given the diverse product range and formulations.

6.3.1 Plant-based meat analogues

Plant-based meat analogues (such as imitation meat burgers or sausages) are increasingly more available in the food supply. However, some concerns have been raised around the nutrient composition of plant-based meat analogues specifically, which have been categorized as "ultra-processed" (161, 162) and are typically higher in sodium (163). The comparable quality of plant-based meat analogues as a protein source, compared to animal-based protein is also unclear, as studies suggest that while such products are calorically comparable, they are lower in protein, calcium, potassium, magnesium, zinc and vitamin B₁₂ (164). Furthermore, the environmental protection afforded by plant-based meat analogues is unclear, given the emerging evidence on the significant reliance of processed food manufacturing on finite environmental resources (165). Despite this, these plant-based meat alternatives may still play some role in substituting meat consumption to lower overall red and processed meat intake. It is unclear whether these products are being incorporated into diets that already have low meat content, potentially nullifying any substitution effect (166).

6.3.2 Cell-based meat

Cell-based meat production, which includes tissue engineering and fermentation-based agriculture, is also an emerging market for meat alternatives. Whilst relatively nascent in development, this approach aims to provide a minimally-processed meat substitute that is a nutritional match for traditional animal-based meat products (160). At present, there is a lack of information on the nutritional aspects of cell-based foods (167). Food safety concerns were considered at an FAO and WHO expert meeting in early November 2022, which concluded that the main food safety issues were not new and are comparable to those of traditional food products (168). Compared with plant-based products, however, it is not known how people will perceive cell-based meat and whether it will be acceptable to consumers.

Cell-based meat may serve as an ethical alternative to livestock production, which currently poses significant issues to animal welfare and suffering (169). At present, however, the technology is still in development and, as such, there are insufficient data on the capacity for cell-based meat to act as an environmentally and ethically sound alternative (170). Indeed, cell-based meat may result in lower GHG emissions, reduced water use, eutrophication and land use in comparison to conventional livestock meat production (171-173). However, while currently cell-based meat is lower in energy use than animal-based meat, it is unclear whether producing these products at the same scale as current livestock production would necessarily result in global net reductions in GHG emissions.

6.3.3 Insects

Insects have also been proposed as a potential alternative to larger terrestrial animal-based meats, and have been consumed in many countries for millennia (174). Insects have high nutritional quality, containing fibre, EAAs (such as isoleucine, leucine, lysine, methionine and cystine), and vitamins and minerals (such as calcium, phosphorous, potassium and magnesium) (175). The protein bioavailability in insects has been reported as higher than many plant-based proteins, but lower than that of animal-based proteins (for example, egg and beef) (176). However, the production of insects for food presents several contamination risks, including accumulation of chemical contaminants during production and allergen risks to both workers and consumers (177). A European project (NovRBA Project)⁶ evaluated the potential risks and benefits of replacing beef with edible insects (*Acheta domesticus*) and estimated the expected change in DALYs when shifting from beef to insects among adults. It was estimated that, per 100 000 population, around 8 753 DALYs would be saved in Greece, 6 572 DALYs in Denmark and 21 972 DALYs in France (178). A single risk-benefit consideration based on red and processed meat replacement in France identified that the improvements in years lost to death or disability would outweigh any potential risk of micronutrient deficiency (179).

6.4 Cultural acceptability of dietary transitions

Underpinning any shift away from red and processed meat is a cultural and ideological challenge, even when recommendations are centred around reduction as opposed to elimination. Red meat in particular has long been a symbol of high social and economic status and masculine values, as well as being a central feature of many festive events for some cultures (180). Many processed meats are artisanal or made by specialty butchers, and thus have sociocultural importance in many countries. The purpose of processing therefore is an important distinction to make as, in contrast, many highly-processed meat products (such as chicken nuggets) are manufactured in a way where the foods have undergone extensive processing and may contain very little or reconstitutions of the original meat (94).

⁶ The Novel foods as red meat replacers – an insight using Risk Benefit Assessment methods (the NovRBA project).

Furthermore, protein as a macronutrient has become highly emphasized in some cultures, particularly in relation to dieting, health and fitness (181). Therefore, consumption is culturally embedded in many high-income nations, and as such, responses to calls for reduction in these countries have typically been emotionally charged and deeply divisive (182).

One key strategy around this could be to advocate for dietary diversity – that is, consumption of a combination of nutrient-rich foods such as red meat, fish, poultry and legumes – to reduce health and environmental impacts while ensuring these foods are affordable for all. This is particularly relevant to populations with high, and in some cases, excessive, intakes of red and processed meat. An overall reduction in consumption of red and processed meat (as well as other meats) may be an appropriate recommendation in these cases, whereas an increase in consumption in other populations may be necessary and more appropriate (183).

Livestock production is also an important source of livelihoods in many parts of the world, particularly for women (31). Efforts towards reduction may need to account for the potential socioeconomic impacts, potentially through government support.

7. Substituting red and processed meat and its impact on health and environment

Key messages

- Modelling studies enable assessment of replacing meat intakes in a defined context (such as in one country) on health metrics, emissions profiles and other outcomes of interest to policy-makers.
- Findings from published modelling studies consistently show appreciable health benefits with red and processed meat replacement, irrespective of setting. They also show reduced health care costs and health inequities.
- A reduction of 14% in the consumption of red and processed meat in upper-middle income countries, associated with an increase in plant-based food sources, might result in 65 000 fewer attributable deaths.
- The environmental benefits of red and processed meat replacement within the published modelling literature appear consistent, with a 20–35% reduction in dietary GHG emissions.

In the absence of sufficient data from randomized trials on red and processed meat intakes over a longer period of time and on outcomes such as premature mortality, modelling studies provide some indication of the potential national-level benefits of red and processed meat replacement in the diet. These studies are theoretical applications only, relying on nationally representative dietary intake sampling and the established diet-disease associations from large data pooling initiatives, such as the Global Burden of Disease Study (78). Modelling studies enable assessment of replacing meat intakes in a defined context (such as in one country) on health metrics, emissions profiles and other outcomes of interest to policy-makers. These studies also permit flexible replacement scenarios, where red and processed meat are replaced at specific amounts (184-186), in line with guidelines (187) or with comparable food such as plant-based protein sources (184, 188, 189).

The most common replacement of red and processed meat modelled to date has been replacement with legumes (184, 188-190). This is likely due to the association of legumes with health benefits (191, 192) and their greatly reduced environmental footprint when compared with red meat production (153). Other replacements modelled include fish (193), combinations of animal- and plant-based protein sources (194), cell-based meat (167, 169, 184) and highly processed plant-based meat alternatives (184, 195, 196).

Some of the modelling work undertaken so far has been to either directly consider a change in red and processed meat intake on outcomes (184). Other modelling has considered the effects of a change in food environment that would be expected to reduce red and processed meat intakes and have subsequent impact on outcomes. Key examples of these changes to the food environment modelled are fiscal policies (taxation) (26, 197-199) or food labelling policies (such as front-of-pack labels) (198).

7.1 Modelling red and processed meat reduction in different geographical regions and outcomes

Relevant outcomes considered in modelling red and processed meat replacement include health metrics, healthcare systems costs, planetary boundaries, nutrient adequacy, grocery costs to the individual and equity.

Health metrics used in modelling studies often incorporate metrics of death, illness and disability, such as DALYs (179), quality-adjusted life-years (QALYs) (184) or years of life lost (YLLs) (194). Some studies include individual disease end-points relevant to red meat intake (187, 197, 198), such as colorectal cancer (187, 200). Findings from these published studies consistently show appreciable health benefits with red and processed meat replacement, irrespective of setting. Although there are fewer publications that have considered healthcare system cost (184, 201) or health inequities (184), their findings are consistent with the health metrics, suggesting reductions in healthcare systems cost and inequities when red and processed meats are replaced in the diet (Table 2). While there has been some concern that red and processed meat replacement in the diet might introduce new risks, such as certain micronutrient deficiencies (such as iron, zinc and vitamins B₆ and B₁₂), it is worth noting that red and processed meat reduction does not reduce intakes of poultry, fish, eggs and dairy, which also provide these nutrients. Modelling data focusing on meat consumption only (and not diets more broadly, as was the focus in the EAT-Lancet study (145)) from LMIC is limited, however, there are some indications of potential health gains.

Table 2. Red and processed meat reduction and replacement on expected health changes from modelling studies in different geographical locations

Location	RPM reduction	Replacement	Health gain
Low-income countries (26)	1.2% of processed meat	Other animal-source foods	880 fewer attributable deaths ^a
Lower-middle income countries (26)	6.5% of processed meat	Other animal-source foods	35 000 fewer attributable deaths ^a
Upper middle-income countries (26)	14.3% of processed meat	Other animal-source foods	65 000 fewer attributable deaths ^a
New Zealand (184)	100%	Legume dishes	297 QALYs per 1 000 people
Sweden (194)	100%	Poultry/fish	1.4 million YLL over 30 years

RPM: Red and processed meats; QALY: Quality-adjusted life-year; YLL: Years of life lost.

^a Estimated reduction in 2020 mortality due to a meat reduction tax.

The environmental benefits of red and processed meat replacement within the published modelling literature appear consistent, with a 20–35% reduction in dietary GHG emissions (184, 187, 196, 202, 203) (Table 3). Less has been published on other planetary boundaries. It has been noted, however, that reduced red and processed meat consumption would reduce land use footprint (204) and mitigate future climate change related deaths (205).

Finally, while few modelling studies have considered a change in cost to the individual when purchasing groceries (184, 206), the studies that did examine this outcome identified that red and processed meat replacement can result in a cost saving when replaced with less processed plant-based foods such as legumes, but that replacement with foods such as “ultra-processed” plant-based alternatives would be more expensive.

Table 3. Expected GHG emission changes from red and processed meat reduction and replacement from modelling studies in different geographical areas

Region/country	RPM reduction	Replacement	Dietary GHG emissions reduction (%)
Canada (203)	50%	Poultry	31
China (186)	50 g/day	Soy	23
4 EU countries (196)	75%	Mainly UPPB	24-39
New Zealand (184)	100%	Legume dishes	34

RPM: Red and processed meats; GHG: greenhouse gas; EU: European Union;

UPPB: “Ultra-processed” plant-based alternatives, such as a vegetarian burger or hotdog

8. Political economy and power dynamics

Key messages

- The scale and dominance of current industrial methods of red and processed meat production have detrimental effects on many groups, including Indigenous Peoples, workers in meatpacking factories, farmers and livestock animals.
- Reducing the production and consumption of red and processed meat can have consequences for a number of actors, including farmers, corporations and governments of high meat producing countries in the short and medium term.
- Agricultural and food policies need to be repurposed – including reorienting financial support – to support healthy and sustainable food systems.
- Reconsidering the centralized nature of red and processed meat production globally may be a key component of efforts to shift toward more healthy and sustainable dietary patterns.

How food systems policies are prioritized depends on dynamic and influential social factors, such as governance structures, vested interests and sociocultural norms. Reducing the production and consumption of red and processed meat will have consequences for a number of actors, including livestock farmers, meatpacking and animal feed corporations, as well as governments of high meat producing countries (207). The perspectives of these stakeholders, in addition to the political contexts of countries and the awareness of the relevant health or environmental issues – as well as the importance of these issues to government – are key determinants of whether agriculture and food policy can be successfully repurposed for healthy and sustainable food systems (113). However, these are complicated by the diverse governance mechanisms and regulatory frameworks that are required to both facilitate and implement these repurposing efforts. *The state of food security and nutrition in the world 2022* report notes that the degree of agricultural protection afforded within a given country is often dependent on the level of political and economic competition (113).

Reconsidering the centralized nature of red and processed meat production globally may, therefore, be a key component of efforts to shift toward more healthy and sustainable dietary patterns.

Efforts to transition toward more healthy and sustainable production practices may need to account for the potential impacts on affected stakeholders. For example, single-commodity livestock farmers may benefit from government support in transitioning to mixed farming systems or production methods that follow agroecological principles (208). Nevertheless, the

scale and dominance of industrial methods of red and processed meat production, as currently practiced in most parts of the world, have detrimental effects on many groups, including Indigenous Peoples, workers in meatpacking factories, farmers and livestock animals. For example, many Indigenous Peoples in the Amazon region in South America have been targeted by illegal land seizures in order to clear the land for soy production, the majority of which is shipped internationally to be used for animal feed (209). Reconsidering the centralized nature of red and processed meat production globally may, therefore, be a key component of efforts to shift toward more healthy and sustainable dietary patterns (210-212).

9. Potential measures to shift dietary patterns

Key messages

- The evidence is clear that high consumption of red meat, and processed meat even more so, can have detrimental impacts on the health of populations and the planet.
- It is also clear, however, that fairer distribution of red meat across populations – especially those at risk of food insecurity and micronutrient deficiencies – is needed for both improved health and equity outcomes.
- Integrating systems-level incentives away from centralized industrial production methods could generate win-wins in multiple areas, including reduced AMR risk, greater worker and animal welfare, biodiversity protection and reduced water pollution.
- Various food system policy measures – targeting both production and consumption – are available to shift dietary patterns toward optimum health and environmental outcomes, which may ultimately include lower intakes of red and processed meat.

A variety of factors influence what types of foods are consumed and how. The guiding principles for sustainable healthy diets, defined by FAO and WHO, acknowledge that diets are built on, and respect, the cultural context in which plant- and animal-based foods are consumed. This includes respecting the surrounding culinary practices and traditions, as well as the knowledge and values connected to the way food is sourced, produced and consumed (15). Animal-based foods produced through traditional practices have important social and cultural values, and often, have different nutrient profiles and consumption contexts than animal-based foods obtained from industrial food production. Evidence-informed decision making that is conscious of sociocultural dynamics will help inform context-specific and nuanced efforts to shift dietary patterns toward ones that are both healthy and sustainable.

The evidence as presented in the preceding chapters suggests that high consumption of red meat, and processed meat even more so, can have detrimental impacts on the health of populations and the planet. However, it is also evident that in relation to red meat, fairer distribution across populations – especially those at risk of food insecurity and micronutrient deficiencies – is needed for both improved health and equity outcomes. Achieving appropriate and population-specific reductions in red and processed meat consumption, as well as incentivizing more agroecological aligned production methods, will require multipronged and system-wide policy measures. A number of policy proposals have been put forward as part of the recent global attention on the need for food systems transformation, which was particularly highlighted at the UN Food Systems Summit in 2021. Some of these policy proposals – such as nutrition labelling or fiscal measures – are also relevant for achieving reductions in red and processed meat consumption. There are multiple leverage points across food systems that can be addressed simultaneously in order to avoid unintended consequences or furthering issues of inequity (212). Regulatory instruments that extend past the consumer level – in other words, measures which are not just targeted at influencing consumers' behaviour – are integral. In many high- and upper-middle-income countries currently, agricultural financial support is given primarily to a narrow range of foods, including grain crops like corn and wheat, dairy production and animal-source foods, while vegetable and fruit producers typically receive less support (113). Reorienting this financial support may be a critical component of system-driven consumption shifts.

Evidence-informed decision making that is conscious of sociocultural dynamics will help inform context-specific and nuanced efforts to shift dietary patterns toward ones that are both healthy and sustainable.

Integrating systems-level incentives away from centralized industrial production methods could generate win-wins in multiple areas.

Integrating systems-level incentives away from centralized industrial production methods could generate win-wins in multiple areas, including reduced AMR risk, greater worker and animal welfare, biodiversity protection and reduced water pollution (213). A shift in public procurement incentives toward more healthy and sustainable food purchasing, focused on

quality foods from sustainable sources, would provide compound benefits for population and planetary health outcomes. Aligning policy measures with the Sustainable Development Goals and the Paris Agreement⁷ will be predicated on policy actions that are laterally coherent across government departments and that target both production and consumption domains (212).

⁷ The Paris Agreement is an international treaty on climate change, which was adopted on 12 December 2015, by 196 parties at the UN Climate Change Conference in Paris, France. It covers climate mitigation efforts, adaptation and finance.

Table 4 provides an overview of some of the implemented and possible policy actions to shift dietary patterns toward optimum health and environmental outcomes, which may ultimately include lower intakes of red and processed meat.

Table 4. Food systems interventions to promote dietary patterns for optimal health and environmental outcomes

Type of action	Description
Food supply	
Subsidy	Subsidies toward mixed-farm and agroecology production methods
Tax	Fiscal disincentives for centralized and intensive production methods (214)
Tax	Fiscal disincentives for antibiotic use (215)
Subsidy	Investment in agroecology and regenerative agriculture implementation
Investment	Investment in agricultural technologies – including innovation, technology and knowledge for farmers (207)
Regulatory measure	Regulation of land clearing or conversion of land use
Tax	Tax on intensively produced red meat (to account for health and environmental impacts) (215)
Subsidy	Retailer incentives for purchasing certified sustainably produced meat (216)
Policy	Public food procurement (217) – including context-specific programmes (including school feeding programmes) which are sensitive to different populations' needs
Food demand	
Policy	Food-based dietary guidelines including guidance on red and processed meat intakes (218)
Regulatory measure	Marketing restrictions on processed/"ultra-processed" meats by food manufacturers, food retailers including supermarkets, and quick-service restaurants (219)
Tax	Zoonotic tax on meat produced using high risk production methods (for example, confined animal feeding operations) (220)
Tax	Tax on red and processed meat in high- and middle-income countries (221)
Regulatory measure	Labelling: nutrient declarations for total fats /saturated fats, sodium (222); front-of-pack labelling for level of processing (223); animal welfare (224); fair trade; carbon emissions; biodiversity
Policy	Consumer nudging and education (225) – including social and behavioural change communication for all, with special attention to pregnant people, young children or populations in areas of low food security (31)
Cross-cutting	
Regulatory measure	Competition policy to address high corporate concentration in meat processing sector
Regulatory measure	Transparent lobbying regulation (226)
Policy	Trade policy – carbon tariffs (227) or protections to smallholder farmers for more effective market competition (31)
Policy	Foreign direct investment policy
Policy	Fiscal policies, such as incentivizing whole food and plant-based food production and consumption (228)

Policy platforms to enact these changes include National Adaption Plans and Nationally Determined Contributions for climate action, the national pathways for food system transformation developed for the UN Food Systems Summit and policies for health, agriculture and social protection. These are important arenas of governance to facilitate the holistic implementation of these policy proposals, albeit it is critical to safeguard public health and protect these policy-making fora from undue influence by real, perceived or potential conflicts of interest.

There may be several trade-offs associated with enacting policy measures to shift production and consumption patterns. For example, removing subsidies to intensive livestock production may inevitably increase the cost of red meat to consumers (229). This may result in issues of even more inequitable availability of red meat, favouring high-income consumers. However, there are many hidden environmental and social costs of meat production in large-scale intensive and industrialized operations, which may artificially depress the price of meat to increase its availability in the food supply (230). Policy coherence to address these potential trade-offs might include increasing subsidies toward legume production, providing fiscal incentives toward agroecological transitions for livestock farmers and providing support to public procurement programmes to source foods from certified sustainable producers (229).

10. Summary of evidence and recommendations

Key messages

- Some methods of production and some levels of consumption of red and processed meat have negative implications for humans, animals and the planet.
- There is sufficient evidence that lower (compared to higher) levels of red and processed meat consumption are beneficial to human health.
- There are, however, ways in which red and processed meat production and consumption can be beneficial to human health, environmental outcomes, livelihoods and/or culture.
- There is a need to generate further evidence with more precise and consistent definitions to inform a more coherent picture of the risks and benefits of red and processed meat.
- More dietary monitoring and surveillance of broader dietary patterns is needed, along with further exploration of the synergies within and between foods.
- Healthy diets from sustainable food systems may include a reduction in the production and consumption of red and processed meat.
- Policies that focus on healthy diets from sustainable food systems, including incentivizing more environmentally-friendly agricultural practices, reducing intensive livestock operations and promoting and incentivizing the availability of minimally-processed plant-based foods, can bring multiple health and environmental benefits.

The evidence presented in this information brief paints a complex picture of the relationship between red and processed meat and health and environmental outcomes. Some methods of production and some levels of consumption have negative implications for humans, animals and the planet. There are, however, ways in which red and processed meat can be beneficial to human health, environmental outcomes, livelihoods and culture. There are several reasons why it is difficult to form recommendations for maximum consumption levels. These include the different definitions of red meat and processed meat in the literature, the lack of distinction between levels of processing and the conflicting nature of associations with health and the environment. Furthermore, the inconsistent definitions used for these meats have implications for how dietary assessment tools are developed (for example, items in food frequency questionnaires), which have further impact on estimating the associations between different types of meat and outcomes. There is a need to generate further evidence with more precise and consistent definitions to inform a more coherent picture of the risks and benefits of red and processed meat. Additionally, more dietary monitoring and surveillance of broader dietary patterns is needed, along with further exploration of the synergies within and between foods (e.g., meat and vegetables, meat and highly-processed foods).

More broadly, focusing on healthy diets from sustainable food systems may be a more holistic and effective approach to address the risks and benefits associated with red and processed meat. Such an approach may include a reduction in the production and consumption of red and processed meat. Focusing on incentivizing more environmentally-friendly agricultural practices and reducing intensive livestock operations will have a multitude of beneficial flow-on effects, including lowered risk from AMR and zoonotic pathogens, lower GHG emissions, reduced biodiversity loss and improved worker and animal welfare outcomes. As summarized in the preceding chapters, there is sufficient evidence that lower levels of red and processed meat consumption are beneficial to human health (in contrast to high consumption). Promoting and incentivizing the availability of minimally-processed plant-based foods wherever possible, particularly in high- and middle-income countries, may inevitably influence a reduction in consumption of red and processed meat. Furthermore, acknowledging the role of power dynamics in food systems – and promoting targeted policy actions towards addressing that power imbalance – are critical components in sustainably transforming food systems for health and wellbeing for people and planet. Positioning these policy agendas as win-wins and demonstrating the multiple positive benefits to be gained across several domains may be the most conducive approach to successful policy change.

As summarized in the preceding chapters, there is sufficient evidence that lower levels of red and processed meat consumption are beneficial to human health.

Making progress towards consumption of a healthy diet from sustainable food systems for all will require a holistic and systems-based lens. WHO is using a One Health approach to design and implement policies, programmes and research that incorporates the visions of multiple sectors in order to achieve improved public health outcomes. This approach is particularly pertinent in relation to red and processed meat, given the cross-cutting nature of its associated impacts, including food safety, AMR, zoonotic disease risk and environmental health (27).

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