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Discussion Paper

Livestock-derived foods and sustainable healthy diets

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Acknowledgements

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Abstract

The health and nutrition implications of livestock-derived foods in sustainable healthy diets are complex. They vary significantly depending on context, time of life and livestock commodity and production methods. Blanket messages about livestock-derived foods in sustainable diets mask these crucial differences and hinder the development of tailored approaches.

This paper delves into that diversity, exploring the importance of livestock-derived foods to nutrition (past and present) and their important and often controversial interface with two key areas: human health and the environment. It provides an overview of the current discussion on the potential role of livestock-derived foods in sustainable healthy diets and the major health benefits and risks of livestock-derived food consumption.

It presents the opportunities and potential trade-offs of sustainable consumption and production to help build a consensus on the role of livestock-derived foods in sustainable, healthy and equitable diets. By integrating farm-to-table solutions across food systems, progress can be made on achieving multiple Sustainable Development Goals (SDGs).

The analysis recognizes that because of their high nutritional value, livestock-derived foods are essential to the diets of infants and young children, especially in low-resource settings. For other groups, such as those that eat high amounts of livestock-derived foods, consumption should be reduced to improve health and lessen environmental impacts.

The paper concludes with suggestions on next steps for positive change through programmes and policies, research and institutional commitments. To achieve sustainable healthy diets for all, any consideration of livestock-derived foods must take into account evidence-based, integrated solutions that incorporate diversity and equity.

1 Introduction

Sustainable healthy diets are "dietary patterns that promote all dimensions of individuals' health and wellbeing; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable" (FAO and WHO, 2019). However, the role of livestock-derived foods in sustainable healthy diets has not been clearly defined (Tirado-von der Pahlen, 2017). While such foods are essential at certain times of life (for small children and pregnant and lactating women, for instance), some populations over-consume livestock-derived foods, with negative health consequences. There is also controversy surrounding the environmental impact of livestock production. This paper, therefore, aims to clarify the role of livestock-derived foods in sustainable healthy diets.

Box 1.
What are livestock-derived foods?

Livestock-derived foods include all products from domesticated land-based animals; these vary in type and level of consumption globally (FAO, 2020). In nutrition, they are traditionally classified into the food groups of meat, eggs, milk or dairy and their derivative products. In agriculture, they tend to be grouped by animal type: large ruminants (cattle, buffalo, camelids), small ruminants (sheep, goats), and monogastric animals (pigs, equines, poultry (including chicken, ducks, turkey), guinea pigs and rabbits.

Humans consume other animals not considered livestock-derived foods, which are not covered in this paper. Wild animals (such as bush meat) are eaten in many parts of the world, including reptiles, pangolins, rodents, primates, carnivores and ungulates (FAO, 1997). Insects are another animal food source for many populations, including beetles, caterpillars, bees, wasps, ants and grasshoppers. Fish are considered animal-source foods, but are covered in the accompanying UN Nutrition discussion paper, The Role of Aquatic Foods in Sustainable Healthy Diets.

Artificial or plant-based alternatives to livestock-derived foods may play a role in addressing future food needs, but will also be subject to the same environmental and human health evaluations and trade-offs. These foods are not addressed in this paper.

Livestock-derived foods can be part of a sustainable healthy dietary pattern that is tailored to meet individual needs (based on age, gender or lifestyle, for instance), is appropriate to the cultural context, aligns with local availability and, importantly, ensures the environmental sustainability of livestock food systems. However, the basic principles of what constitutes a healthy diet remain the same (WHO 2020).

This discussion paper aims to synthesize evidence on the role of livestock-derived foods in sustainable healthy diets. It is part of a broader effort to contribute to build a robust narrative for use in policy discussions, communications, information and capacity-development activities.

Together with the accompanying discussion paper on *The role of aquatic foods in sustainable healthy diets*, it will be disseminated to nutrition, environment and livestock stakeholders globally, with the aim of:

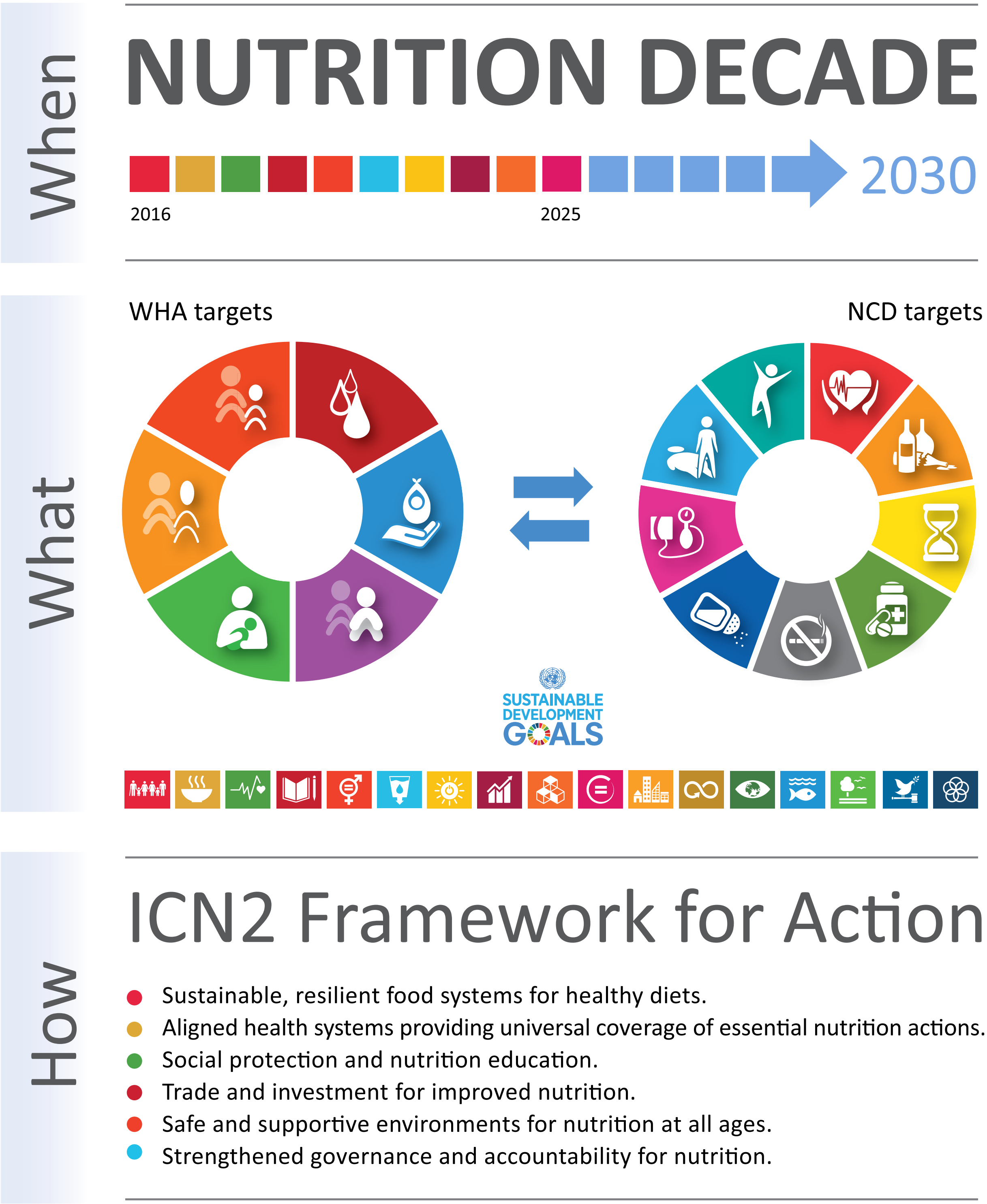
- providing an overview of the major health benefits and risks, opportunities and potential trade-offs associated with sustainable production and consumption;
- helping to build consensus on the role of livestock-derived foods in sustainable healthy diets by taking into account the vulnerability of different target groups from a health, social, economic and contextual perspective to better understand local opportunities and trade-offs; and
- considering various production methods and their impact on health and the environment.

The world is currently experiencing a global health pandemic that has exacerbated issues of nutrition insecurity across the board. COVID-19 is zoonotic in origin and may have emerged from wild meat being introduced to a food system. Globally, there are more than 690 million people who are hungry or undernourished and 144 million young children with stunted growth – a number that also flags hidden hunger (FAO et al., 2020). COVID-19 has probably increased the number of undernourished people by between 83 million and 132 million and further compromised the nutritional status of the most vulnerable groups, including poor rural women and children (FAO et al., 2020). Although evidence is still limited, we could also see increases in the number of overweight and obese people globally as a result of the pandemic. SOFI 2020 estimates that healthy diets will be further out of reach for more than 3 billion people as a result of COVID-19 (FAO et al., 2020).

Around the world, the prevalence of food insecurity is higher among women than men, with the largest differences evident in Latin America. Globally, one in three women (32.8 percent) of reproductive age is affected by anaemia, a nutritional problem that can be addressed with livestock-derived foods (FAO et al., 2019). Overweight and obesity, currently at unprecedented levels globally (13 percent), are issues also associated with livestock-derived foods in certain populations (Swinburn et al., 2019). The World Health Organization (WHO) *Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2013–2020* presents a roadmap for Member States and other stakeholders to reduce cardiovascular disease, cancer, chronic respiratory diseases and diabetes, setting nine global targets pertaining to key risk factors, including aspects of unhealthy dietary behaviour (Francis, 2011; WHO, 2014).

The United Nations Decade of Action on Nutrition 2016–2025 aims to address the prevailing forms of malnutrition globally (UNSCN, 2017). The World Health Assembly (WHA) has set targets to reduce stunting and wasting, anaemia and low birthweight, to stall the rise in childhood overweight and to increase rates of exclusive breastfeeding in the first six months of life (WHO, 2014). In addition, the WHA has set targets to reduce non-communicable diseases, these sets of targets are mutually supportive and have been integrated in the SDGs. The Nutrition Decade aims to achieve the WHA targets as well as accelerate the achievement of the SDGs (Figure 1).

Figure 1.
The targets of the United Nations Decade of Action on Nutrition



Source: *UNSCN, 2017.*

The consumption of livestock-derived foods can ease progress towards these targets by providing critical nutrients and protecting the health and wellbeing of vulnerable populations (Iannotti, 2018). Stunted growth and anaemia are two conditions that remain especially challenging, with only minimal evidence that interventions are effective. At the same time, over-consumption of livestock-derived foods may contribute to the onset of some of the diet-related NCDs.

Livestock systems (Box 2) are seen as playing a major role in environmental degradation. Since *Livestock's Long Shadow* (Steinfeld et al., 2006), various publications have highlighted the negative impacts of livestock production on the environment and climate.

Box 2.
Livestock systems

There are various ways to categorize livestock systems. Based on the initial categorization of Seré and Steinfeld (1996), Thornton et al. (2002) and Robinson et al. (2011), there are four main livestock production systems. Pastoral systems use permanent grasslands based on the seasonal movement of livestock; agro-pastoral systems use land areas for cropping in addition to seasonal animal movements for grazing. Systems with integrated crop production and livestock raising are called mixed systems. According to Robinson (2011), "mixed farming systems are those in which either more than 10 percent of the dry matter fed to animals comes from crop by-products or stubble, or more than 10 percent of the total value of production comes from non-livestock farming activities." Landless systems are those where livestock are reared based on external inputs, including feed. These production systems may be further categorised according to agroecology and the extent of irrigation.

Livestock-only systems are largely grass based (as in pastoral systems, with considerable seasonal movement of animals), landless (mainly industrial production, using considerable external inputs, especially common for monogastrics), or mixed, where animals and crops are raised in an integrated manner – systems that are ubiquitous throughout LMICs.

The studies introduce and build on key concepts, such as the planetary-boundary framework and a safe operating space for a stable biosphere, and describe distinct areas of environmental impact (Springmann et al., 2018). Animal production is most closely linked to greenhouse gas (GHG) emissions, though it can also have impacts in other areas, such as freshwater use and biodiversity loss.

Most of the documented evidence comes from large-scale, single-commodity production, however, with less information available on small and medium-scale production or mixed systems. On the consumption side, more attention tends to be paid to high-income dietary intake patterns among adults and less to the dietary and livelihood needs of the millions of people in low-resource settings, particularly children and women of reproductive age. Blanket messaging about livestock-derived foods in sustainable diets masks these important differences and hinders the development and implementation of tailored approaches.

In Section 2, we provide an overview of the health, dietary and nutritional aspects of livestock-derived foods, putting consumption in the context of human evolution and where we are today as a society. We discuss both the biological and epidemiological evidence surrounding livestock-derived foods in terms of health outcomes over a person's lifetime. The section concludes with an outline of the One Health approach, which is particularly pertinent in the face of the prolonged COVID-19 pandemic.

Section 3 deals specifically with livestock-derived food production as it relates to the environment. We first discuss key challenges, acknowledging the important gaps in the evidence base on the environmental impacts of small and medium-scale production. We then present opportunities and potential solutions, including the diversification of livestock-derived food production systems and efficiency improvements.

In Section 4, we connect consumption and production issues in an overview of how food systems might better function to ensure sustainable approaches and equitable access to livestock-derived foods in different populations. We discuss the enabling environment needed for effective programmes and policies, including food-based dietary guidelines for achieving sustainable healthy dietary patterns. We conclude with remarks on building the evidence base on livestock-derived foods for both human and planetary health.

2 Health and nutrition implications of livestock-derived foods

The health and nutrition implications of livestock-derived foods are complex. They vary depending on context, time of life and livestock commodity. Healthy diets should include a diverse range of high-quality foods, including vegetables, fruits, wholegrains, legumes and nuts (WHO, 2020). Under- and over-consumption of certain foods may result in nutrient deficiencies (for example, zinc, iron, vitamin A or B12) and associated health risks (for example from excessive intake of calories, saturated fat, trans-fat, sodium and free sugars). Healthy dietary patterns vary according to context and, in many countries, food-based dietary guidelines offer advice for individuals on dietary choices, including livestock-derived foods.

In this section, we first discuss the evolutionary history of livestock-derived foods and their importance to humans over time. We then present the nutrient composition of livestock-derived foods and their biological importance over a person's lifetime, followed by an overview of the epidemiological evidence of the consequences to health of livestock-derived foods. We conclude with arguments for adopting the One Health framework, which takes into consideration human–animal–environment interactions globally.

The significance of livestock-derived foods to human evolution

For more than 99.5 percent of our evolutionary past, dietary patterns were markedly different to those of today, with far more animal-source foods being consumed. Our ancestors ate a much wider variety of foods and there is compelling archaeological evidence of an omnivore diet that included both plants and animals (Kuipers et al., 2012). The entry of more animal-source foods into the hominin diet was accompanied by changes in anatomy and physiology. Our early ancestors, notably *Homo erectus*, saw an increase in stature, body mass and brain size compared with other primates and it is thought that the nutrient- and energy-dense quality of animal-source foods spurred these changes (Kuipers et al., 2012).

There is evidence that hominins secured animal-source foods from both aquatic and terrestrial ecosystems, depending on where they lived. A shore-based paradigm and evidence from shell middens going back 18 000 to 100 000 years show hominins living near water in East and Southern Africa depending on foods such as eggs, turtles, shore birds, molluscs and fish (Broadhurst et al., 2002). Cut-marks in bones offer evidence of scavenging and intentional hunting (Domínguez-Rodrigo et al., 2009). European populations of Neanderthals and early humans, *Homo sapien sapiens*, had a high proportion of meat and later fish and marine foods in their diets. Access to these products often depended on successful hunts, so supply was not always stable.

The domestication of animals occurred over a period spanning thousands of years, but is thought to have commenced in tandem with the expansion of cultivation and agricultural practices, around 10 000 to 11 000 years ago. Goats, sheep and dogs were domesticated first, followed by pigs and cattle (Smil, 2013). Animals were initially kept as productive assets for their drafting power and fertilizing manure, though their milk and meat were sometimes consumed. Smaller animals remained part of the human diet, such as rabbits in European cultures and guinea pigs in South America. Feed limitations drove choices as to the types of animals raised and consumed. Humans continued to consume animal-source foods during this period, but there was a notable shift towards plant-based foods and more monotonous diets as agriculture began to be practised in different parts of the world. With these changes in diet came major health consequences, including shorter lifespans, reduced stature and increased rates of infection, traded off against more stable food supplies and increased fertility.

The importance of animal-source foods over our long evolutionary history – from 2 million to about 10 000 years ago – is evident and linked to key dietary diversity practices (Cordain et al., 2000). The domestication of animals allowed some aspects of hunter-gatherer-fisher diets to continue, but the ensuing losses of dietary diversity and quality remain today, affecting health across the nutritional spectrum (Eaton and Iannotti, 2017).

Nutrient composition of livestock-derived foods

As a group, livestock-derived foods contain several important bioavailable nutrients essential to growth and brain development, as well as numerous bioactive factors that play a role in metabolism (Box 3). Here, we discuss the commonalities and differences across livestock-derived foods and emphasize the importance of considering each within the context of the entire food matrix and dietary pattern.

Box 3.
Essential nutrients, bioavailability of nutrients and bioactive factors

Essential nutrients. Nutrients are elements or compounds needed by an organism to survive, grow and reproduce. Essential nutrients are those that are not, or insufficiently, produced endogenously by the organism and must, therefore, be provided by food or come from the environment in other ways.

Bioavailability of nutrients. Bioavailability refers to how efficiently nutrients are absorbed and metabolized in the human body. Several factors influence bioavailability. The matrix of compounds delivering and transporting the nutrient in the food is very important. For example, iron packaged in the haem protein contained in animal-source foods can be absorbed more readily than plant-based non-haem iron delivery. Some foods act to enhance (such as citrus foods, that contain high levels of vitamin C with iron) or inhibit (such as phytates with iron) the bioavailability of nutrients. Other factors influencing bioavailability can include the ecology of the microbiome or the background health status of the individual.

Bioactive factors. It is estimated that there are more than 26 000 distinguishable compounds to be found in food beyond the 150 tracked nutritional components (Barabási et al., 2020). Some of these “bioactive factors” have been linked to health outcomes; others, we are still learning about. One example from livestock-derived foods is trimethylamine N-oxide (TMAO), which has been linked to increased mortality in individuals with coronary heart disease (Senthong et al., 2016). TMAO occurs in fish and milk, but can also be derived from L-carnitine and choline, found in red meat. Advances in analytical instruments and bioformatics have enabled progress in understanding the food metabolome, or the “part of the human metabolome directly derived from the digestion and biotransformation of foods and their constituents”. Metabolite databases are also growing in size (Scalbert et al., 2014).

Eggs and milk as "first foods" for animals, supporting early life, are holistic in nutrient composition. The digestible indispensable amino acid score (the percentage of digestible indispensable amino acids compared with a reference protein) evaluates the quality of proteins in foods (FAO, 2011). The digestible indispensable amino acid score for milk and eggs both exceed 100 percent, compared with rice, at 37 percent, and wheat, at 45 percent, for example. Several essential fatty acids are also present in those two food types. Egg yolks, for example, are rich in linoleic acid and α-linolenic acid, with some variability in docosahexaenoic acid (DHA) content depending on the avian species and their diet (Golzar et al., 2013).

The DHA content of milk also depends on animal type and diet, but it can be rich in these essential fatty acids. Buffalo milk contains twice as much fat, on average, as cow's milk, so is more energy dense (Muehlhoff et al., 2013). Goat's milk is another key source of essential fatty acids and can supplement the diet of young children, particularly when their nutrient requirements are high. Compared with some fish types, however, livestock-derived foods are not as concentrated in polyunsaturated fatty acids, particularly DHA. For example, herring contains 0.86mg/100g of DHA, while an egg contains 0.06mg/100g.

While there is an established link between blood cholesterol and heart disease, eggs, which contain high levels of cholesterol, have not been shown to increase the risk of cardiovascular disease unequivocally (Blesso and Fernandez, 2018). More broadly, dietary cholesterol explains a smaller proportion of blood cholesterol than previously thought. Eggs may even have beneficial effects by increasing high-density lipoprotein-cholesterol relative to low-density lipoprotein, but more evidence is needed. Similarly, systematic reviews of randomized controlled trials and prospective studies show that milk or other dairy products have no association with or any positive benefits on reducing cardiovascular risk and mortality (Bhupathi et al., 2020).

Eggs and milk are also rich in many micronutrients. For example, eggs have a high concentration of choline, a micronutrient vital to cell division, growth and membrane signalling. In the form of acetylcholine, it plays a role in neurotransmission, neurogenesis and myelination and synapse formation (Zeisel and da Costa, 2009). Eggs are also an important source of vitamins A, B12, D, E and folate, as well as bioavailable minerals, especially selenium, but also iron and zinc (Iannotti et al., 2014). Milk is recognized as an important source of calcium (Muehlhoff et al., 2013), though not necessarily the best one. Excess intake of milk may also have harmful effects, such as obesity, or the over-consumption of saturated fat and hormones, though studies are still in progress (Vanderhout et al., 2020). Similar to human milk, animal milks are lower in iron and zinc content, but may be more readily absorbed than plant-based foods. Animal milks are rich in vitamin A, B12 and other B vitamins.

Meat includes muscle tissue and other organs (such as the liver, brain, skin and hooves). Similar to eggs and milk, meats contain high-quality proteins and several micronutrients. Some B vitamins are abundant in meat, notably niacin and vitamins B6 and B12, while pork is rich in thiamine (Lofgren, 2013). Vitamin B12 is largely provided by animal-source foods, though also found in fortified foods, seaweeds and fermented foods. Vitamin B12 deficiencies may be prevalent in low-resource populations with limited access to these foods in sufficient supply to meet intake requirements (Green et al., 2017). Other vitamins, such as A, D and E, can also be found in meats. Legumes, nuts and seeds can provide high-quality fats, proteins and other nutrients and may be more affordable than livestock-derived foods. However, as we will discuss, these foods may not be a suitable replacement for animal-source foods at certain times of life.

The mineral content and bioavailability of meat is especially important in human nutrition. Meat delivers iron in the highly bioavailable haem compound of blood tissue and may be absorbed at twice the rate of non-haem plant-based foods. Iron is highly concentrated in organ meats, in particular, with 10mg/100g in lamb liver, for example. Zinc, necessary for multiple biological functions, such as growth, immunity and neurocognition, is also concentrated in beef, chicken and pork. Zinc deficiency, resulting from high zinc-to-phytate ratios in high maize-consuming populations, infectious diseases and other aetiologies, affects an estimated 17 percent of the world's population (Wessells and Brown, 2012).

Meats, especially processed meats, may contain fats that are harmful to human health if consumed to excess. Fats are grouped into saturated fatty acids, unsaturated fatty acids (monounsaturated fatty acids, polyunsaturated fatty acids) and trans-fatty acids (natural and industrially produced ones). It is recommended that total daily fat intake not exceed 30 percent of total energy intake, while saturated fats should be less than 10 percent and trans-fats less than 1 percent of total energy intake. People should also shift from saturated fats and trans-fats to unsaturated fats (WHO, 2020). Evidence supports the need to eliminate industrially produced trans-fats from the global food supply, as set out in the WHO action plan REPLACE Trans Fat by 2023 (WHO, 2019). Processed meats have been shown to increase the risk of overall and cause-specific mortality (Rohrmann and Linseisen, 2016). Excess consumption of saturated or trans-fatty acids play a role in these effects, though studies do not describe it consistently.

Dietary patterns influence the metabolism by way of interactions between nutrients and other bioactive factors. Examples might include peptides, dietary fibres, lipids and choline metabolites, such as trimethylamine-N-oxide and trimethylamine (TMAO), which play a role in gut microbiome health and chronic disease (Barabási et al., 2019). The Lulun Project in Ecuador showed increased concentrations of DHA, choline, trimethylamine-N-oxide and dimethylglycine associated with egg consumption in young children, with the potential for health benefits (Iannotti et al., 2017). Evidence of bioactive factors in milk is particularly strong, with a multitude of bioactive molecules that protect against infection, inflammation, organ maturation and microbiome development (Ballard and Morrow, 2013).

Livestock-derived foods over the lifetime

Dietary requirements change over the course of a person's lifetime, in line with their physiological needs (WHO, 2020). Pregnancy and lactation, for example, require greater energy and nutrient intake to support a baby's growth and development. Infants and young children are growing rapidly, too, so need foods with both a high nutrient density and greater bioavailability. Young children have smaller stomachs and gastrointestinal tracts, so need foods that can be efficiently absorbed and metabolized. School-age children and young people, while not growing as rapidly as before, may have a high physiological need for nutrients to support neurological, hormonal and other developmental processes.

Livestock-derived foods can thus be important during these critical periods. Young children's small bodies and storage pools mean they require a steady supply of the bioavailable nutrients found in livestock-derived foods. Similarly, during pregnancy and lactation, high nutrient demands can be met by consuming livestock-derived foods. Iron and zinc deficiencies are common during the complementary feeding period (6–24 months) and during pregnancy and lactation and can be addressed by greater access to livestock-derived foods, particularly in low-resource settings.

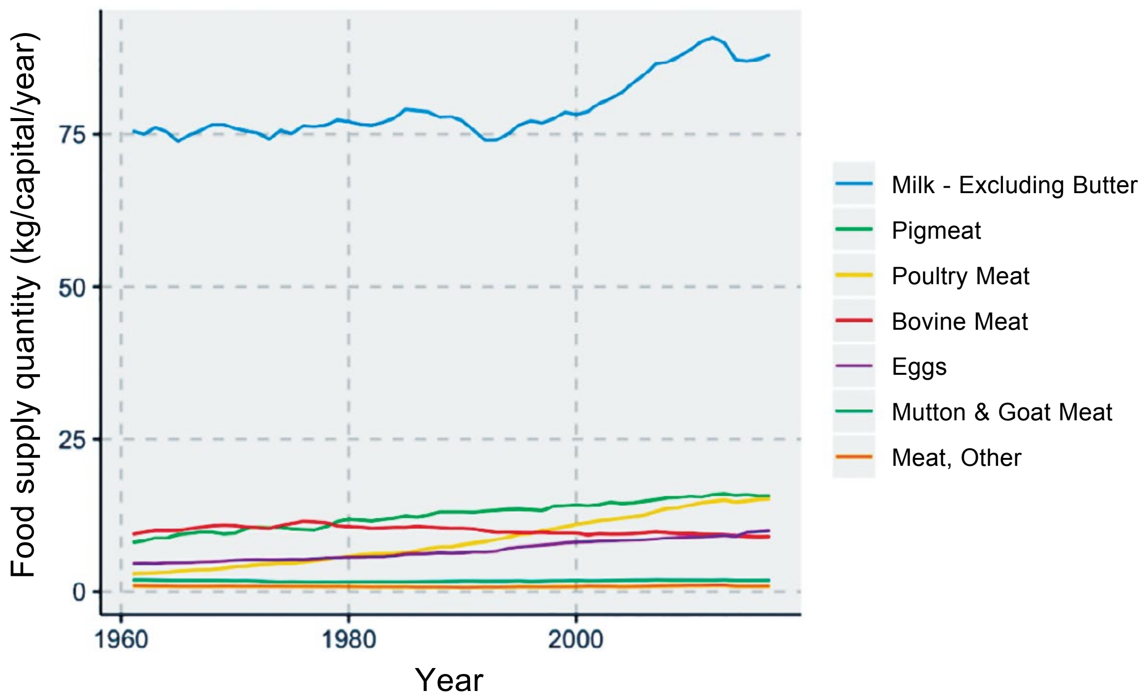
Brain growth and development begins in the womb and continues through adolescence. Nutrition affects both morphological and biochemical processes in the brain, particularly nutrients that are bioavailable in livestock-derived foods – choline, vitamin B12, iron and zinc (Goyal et al., 2018). Livestock-derived foods can also provide the essential fatty acids needed for brain development, function and maintenance. Eggs were recently shown to increase both DHA and choline during the complementary feeding period (Iannotti et al., 2017). There is also evidence that ageing adults need certain livestock-derived foods to preserve memory, bone health and muscle mass (Lonnie et al., 2018).

Livestock-derived food consumption and health outcomes

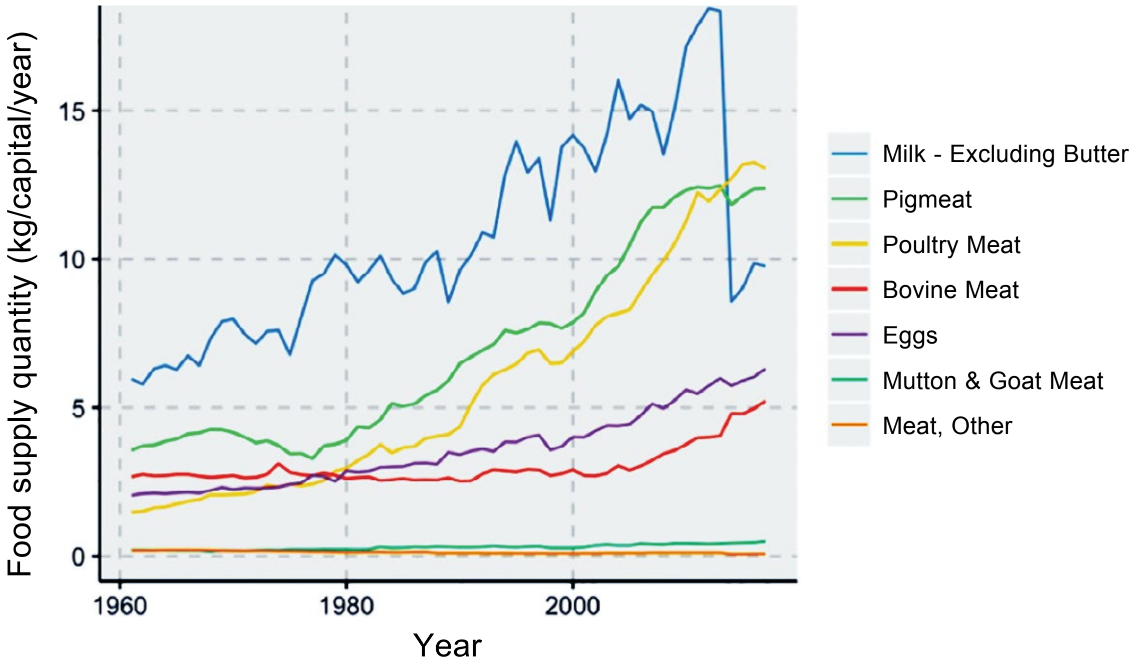
Globally, there are stark differences in consumption patterns when it comes to livestock-derived foods. Since 1960, when data first became available, we have seen upward trends in the supply of livestock-derived foods consumption, with greater increases evident in the last 30 years (FAOSTAT, n.d.) (see Figure 2).

Figure 2.
Livestock-derived food supply trends, 1961–2017

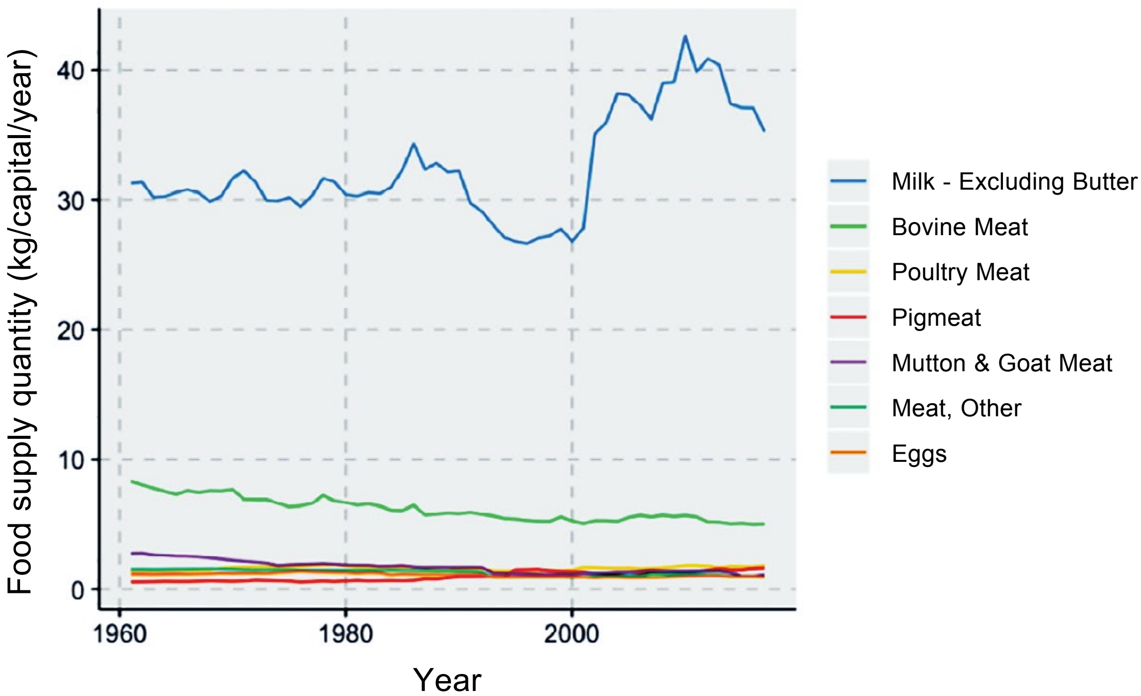
2a: Global livestock-derived food supply, 1961–2017



2b: Southeast Asia livestock-derived food supply, 1961–2017



2c: East Africa livestock-derived food supply, 1961–2017



Source: *FAOSTAT database.*

Pork and chicken supply has increased globally in recent years, while in high-income countries, red meat has seen a decline. Regionally, Southeast Asia has seen the greatest increase in the supply of livestock-derived food, while sub-Saharan Africa has seen a slight decline.

While our assessment provides a high-level view of global averages, this masks the huge disparity between regions and even within countries. Higher consumption of livestock-derived food tends to be associated with higher national gross domestic product and higher household income levels. Thus, according to Organisation for Economic Co-operation and Development (OECD) data for 2018, the average meat consumption of European Union countries is around 69kg per capita per year, compared with less than 10kg in sub-Saharan Africa (OECD and FAO, 2018).

Globally, the amount of meat available for individual consumption on a daily basis is estimated at 122g, with one-third of that pork and poultry, one-fifth beef and the remainder goat, sheep and other animals (Godfray et al., 2018). Red meat consumption is highest in Australasia, southern Latin America and tropical Latin America, while high-income North America, high-income Asia-Pacific and western Europe show the highest consumption of processed red meat (GBD 2017 Diet Collaborators, 2019). Milk consumption by adults globally is 71g per day (95 percent, confidence interval 70–72g), with just 16 percent optimal intake (GBD 2017 Diet Collaborators, 2019). Egg consumption among young children varies across regions. Among children less than two years of age, eggs are most frequently consumed in Latin America and the Caribbean (37 percent), followed by Asia (28 percent) and lowest in Africa (12 percent) (Iannotti et al., 2014).

The *Global Burden of Disease Study 2019* sets thresholds for dietary intake levels for various foods based on strong epidemiological evidence for links to health outcomes (GBD 2017 Diet Collaborators, 2019). "Red meat" is defined as beef, pork, lamb and goat (excluding poultry, fish, eggs and all processed meats) and a "diet high in red meat" as 23g (18g–27g) a day.

"Processed meats" are defined as including meat preserved by smoking, curing, salting or the addition of chemical preservatives and a "diet high in processed meats" as 2g (0g–4g) per day (GBD 2017 Diet Collaborators, 2019). The study finds the consumption of processed meats globally to be 4g per day, 90 percent higher than the optimal amount. However, compared with other dietary risk factors (such as high sodium, low fruits and low grains), the consumption of red meat and processed meats ranks towards the bottom in terms of life-years lost to death or disability, in part because the evidence is still emerging. Some prospective studies in high-income countries have shown all-cause mortality rates to be higher in populations consuming more red and processed meat than in those consuming lower quantities, with no association or inverse for poultry (Godfray et al., 2018).

Processed meats were classified as carcinogenic by the International Agency for Research on Cancer in 2015 (Box 4) and have been clearly linked to colorectal and other cancers, cardiovascular disease and diabetes (Rohrmann et al., 2013; Wang et al., 2016; Wolk, 2017).

Box 4.

International Agency for Research on Cancer evaluation of the carcinogenicity of red and processed meats

The International Agency for Research on Cancer (IARC) conducted an evaluation of the carcinogenicity of red and processed meat. The agency convened experts from 10 countries, the IARC Working Group, to review the scientific literature. Consumption of red and processed meats was found to vary considerably, both within and between countries. After considering more than 800 studies and more than 12 different types of cancer, it concluded that: (1) the consumption of red meat should be classified as probably carcinogenic to humans (Group 2A) and (2) the consumption of processed meat should be classified as being carcinogenic to humans (Group 1) (IARC, 2015).

The carcinogenic mechanisms by which processed meats lead to colorectal cancer and other cancers have yet to be fully understood, as well as the influence of cooking. Few studies have been conducted in low- and middle-income countries (LMICs) to examine meat in association with chronic disease outcomes, though one pooled analysis from Asia showed no relationship (Lee et al., 2013). Some "processing" of livestock-derived foods, in particular, may be necessary for food safety reasons. For example, processing milk through pasteurization eliminates pathogens and extends shelf life. This is also the case for other dairy and meat products, to ensure both food safety and access for longer periods of time.

Evidence of the benefits of livestock-derived foods for young children is growing, though data from low-resource settings remain somewhat limited. One review of animal-source food interventions among young children aged 6–24 months in five countries found that livestock-derived foods increased the height-for-age z-score, a key growth indicator (Eaton et al., 2019). The Lulun Project in Ecuador showed that introducing eggs early in the complementary feeding period improved growth, reducing stunting by 47 percent, and a child's nutrition biomarker status (Iannotti et al., 2017). The study used social marketing strategies to encourage egg nutrition, as well as to involve and engage all mothers and the wider community in the study. Another study, the Mazira trial, designed to replicate the Lulun Project in Malawi, did not find an effect on linear growth, possibly because the baseline level of stunting in children was low, as they were already consuming animal-source foods in the form of fish (Stewart et al., 2019).

Intervention studies have also examined the effects of meat in the diets of children from low-resource settings. One multi-country-cluster, randomized study compared meat with nutrient-fortified cereal (Krebs et al., 2012). The groups' growth velocity and anaemia rates did not differ, though iron deficiency was lower in the cereal group, perhaps attributable to the added nutrients in the cereal. Another well-known study was conducted in Kenya, among school children, and tested the outcomes of four different food groups: meat with *githeri* stew (maize, beans and greens), milk with *githeri* stew, *githeri* stew alone and a control group (Neumann et al., 2007). It showed that children in the meat group performed better in terms of cognitive function than the milk or control groups, though children in both the milk and the meat groups had better growth outcomes than the control group (Neumann et al., 2007).

Strategies that aim to reduce livestock-derived foods in the diet have been assessed for their effects on overweight and obesity. One review of such studies showed that replacing land-based meats with lean seafoods reduced energy intake, leading to weight loss, as well as improved markers of insulin sensitivity (Liaset et al., 2019). Some experts have called for food-system transformations that include a reduction in livestock-derived foods, but also in sugar-sweetened beverages and highly processed foods (Popkin and Reardon, 2018). As we will discuss, the way to address livestock derived foods within national FBDGs should vary depending on context when it comes to meat consumption:

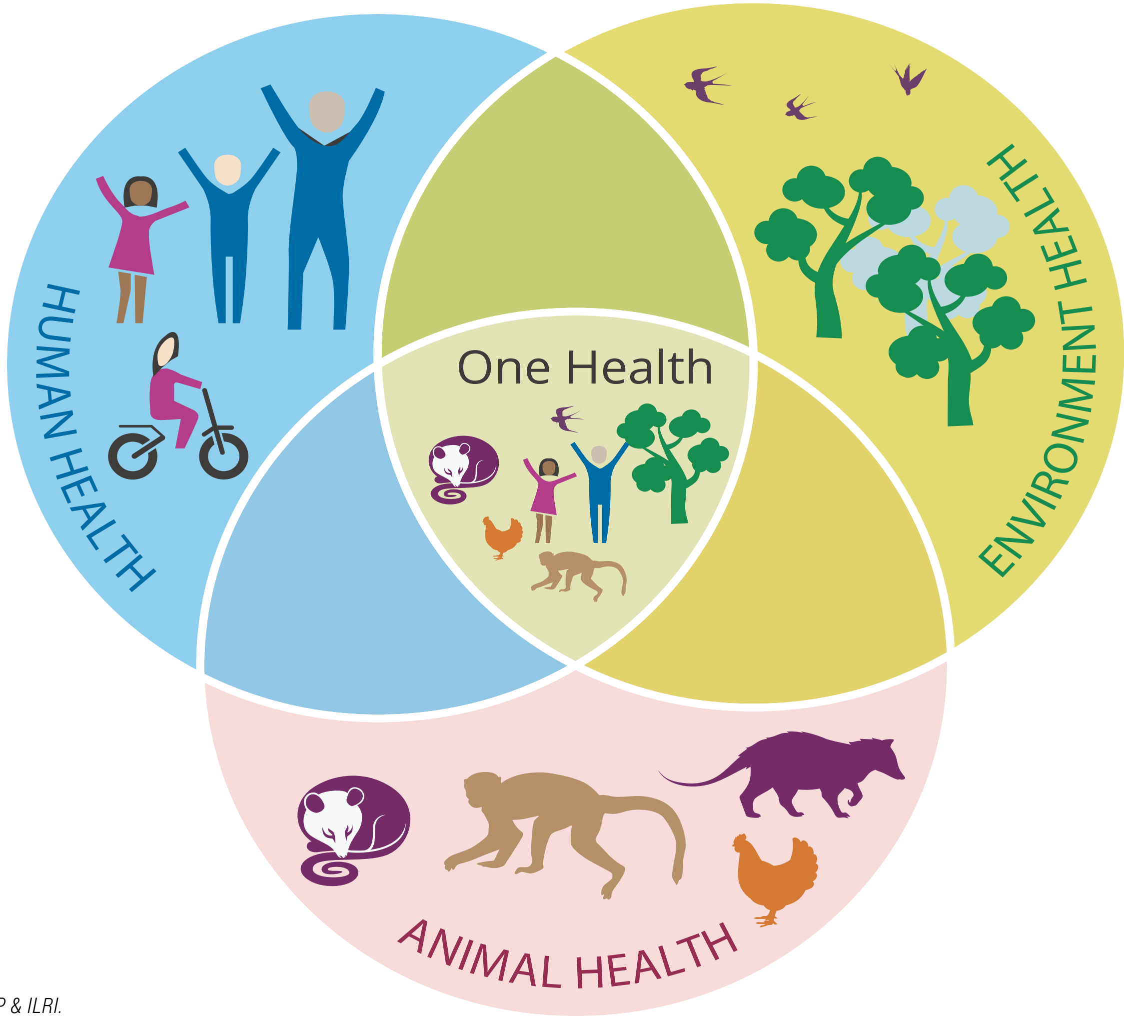
- In high-consumption (generally high-income) countries, there should be advice on reducing consumption.
- In countries where per capita intake is increasing, there should be guidance on moderating consumption, to avoid the problems associated with high consumption levels.
- In low-income populations, where animal-source food intakes are generally very low, the focus should be on increasing the diversity of diets, including greater consumption of vegetables, fruits, legumes, nuts and some meat and dairy products (FAO, 2016a).

To conclude, there is evidence of both positive and negative health effects arising from livestock-derived foods, depending on level of consumption and stage of life. More evidence is needed from LMICs, particularly, where the consumption of livestock-derived foods is lower, but rising rapidly. A fuller understanding of the minimum quantities needed throughout the lifecycle would also be instructive for setting guidelines and establishing policies to ensure adequacy in some populations and reduced excess in others (Willett et al., 2019).

One Health

There are many definitions of One Health and the related field of ecohealth. Core to them all is that human health depends on the health of the environment and animals, both wild and domesticated (see Figure 3). A further principle is that diseases that originate in animals are often best managed in the animal host than in humans, with the corollary that if diseases can be detected before or as they start to emerge, they will cause far less damage and be easier to control than when they have become widespread in the human population.

Figure 3.
One Health Framework



Source: *UNEP & ILRI.*

There are many overlapping and intertwined elements to One Health. Some of the issues that are most relevant to the sustainable production of livestock-derived foods, for example, are emerging infectious diseases, neglected zoonotic diseases, food-borne disease and agriculture-associated antimicrobial resistance. The COVID-19 pandemic is an emerging infectious disease (with bats the probable original host) and its devastating global impact has underscored the threat of zoonotic diseases to humans. But COVID-19 is just one in a long list of diseases that have emerged from wildlife and domestic animals, including Ebola virus disease, avian flu, severe acute respiratory syndrome (SARS), the Zika virus and variant Creutzfeldt-Jakob Disease (mad cow disease).

The pandemics that have occurred in the recent past – such as the highly pathogenic avian flu (HPAI H5N1), swine flu (H1N1) and the Middle East respiratory syndrome coronavirus (MERS-COV) – have been associated with intensive poultry, pig and camel breeding in various parts of the world. Improving the health of animals and the environment, early detection of new diseases and cross-sectoral responses are some of the more promising avenues of control (UNEP & ILRI, 2020).

Unlike emerging zoonotic diseases, neglected zoonoses, by definition, do not get as much public attention or funding. However, their direct health and economic burden on poor livestock-keeping communities is probably greater (Grace et al., 2012). Livestock-derived food production can increase the risk of zoonotic diseases if sanitation and biosecurity measures are inadequate. Humans may also become exposed to many other zoonotic diseases, such as brucellosis, bovine tuberculosis and anthrax if they live in livestock-keeping environments or process their own products in a farm-to-fork chain.

As demand for animal-source foods increases, more productive livestock breeds are being raised. The transition from subsistence to commercial livestock farming (the establishment of semi-commercial enterprises) has seen the greatest zoonotic spill-overs, as these farms lack the infrastructure required to maintain the expected standards of hygiene. Animals raised in this way tend to be kept in congested enclosures, often within the confines of human settlements. Moreover, animals kept intensively are more stressed, more crowded and more genetically similar – all risk factors for disease transmission. In addition, as livestock population densities increase, more natural habitats are converted into grassland. This land-use conversion reduces biodiversity and, thus, the ability of ecosystems to provide crucial functions, such as disease regulation or dilution (Keesing et al., 2010).

Food-borne disease is another externality of food systems. The health burden of food-borne disease is comparable to that of the “big three” – malaria, HIV/AIDS and tuberculosis. Pathogens in animal-source foods are estimated to account for 35 percent of all food-borne diseases, most notably: non-typhoidal *Salmonella enterica, Taenia solium* and *Campylobacter* spp. (Li et al., 2019). The overall burden is higher because animal-source foods can also contain non-zoonotic pathogens, such as norovirus, as they act as an excellent growth and survival medium.

Nearly all of the food-borne disease burden falls on the poor in LMICs, who mostly obtain their animal-source foods from informal, traditional markets. However, industrial animal production and retail are not necessarily safe either, as demonstrated by the recent outbreak of listeriosis in South Africa – the world’s largest to date. Ensuring that food is not only sustainable, but safe has been an under-invested area that has relied too much on regulation. More promising approaches focus on upgrading the informal sector, improving governance, the use of simple information and communications technologies and capitalizing on consumer demand for food safety (GFSP, 2019).

In 2016, a landmark report found that if antimicrobial resistance was not brought under control, it would kill more people than cancer by 2050 (O’Neill, 2016). Animal agriculture, including aquaculture, is by far the greatest user of antimicrobials and growing fastest in LMICs, especially in large-scale pig and poultry systems in the BRICS countries (Brazil, Russia, India, China and South Africa). The extent of the problem is not known and is being actively researched. High input-high output systems are growing rapidly in response to increasing demand for animal-source foods and proteins, but especially where biosecurity and governance are poor and production often relies on veterinary drugs to keep the closely confined and sometimes stressed animals healthy. Alternatives to reliance on antimicrobials have been quite successful in some European countries where their use has been banned for decades and have included measures that also increase sustainability, such as lower stocking rates, better management and improved biosecurity, as well as new technologies. However, extending this success to LMICs will require much adaptation and incentivization.

3 Sustainable production of livestock-derived foods

Globally, food systems have been estimated to account for around 30 percent of global GHG emissions, 70 percent of freshwater withdrawals, 40 percent of land use and major disruptions in nutrient cycles across ecosystems (Clark et al., 2019). As a food group, animal products exert more environmental pressure than other foods through GHG emissions, but they can also impact biodiversity, nutrient flows (such as nitrogen) and freshwater use, largely through cropland use for feed (Springmann et al., 2018). However, animal products and animal production can have multiple interactions with the climate and wider environment, depending on husbandry, scale and production system. Sustainable livestock production and mixed systems may similarly be integral to climate change solutions and achieving not only Sustainable Development Goal 2 (SDG 2) on zero hunger, but also SDGs 12 (on responsible consumption) and 13 (on climate action). Here, we discuss some of the opportunities to mitigate environmental impacts.

Farming and, more specifically, livestock production are critically important to the livelihood and food security of millions of people around the globe. In many regions, particularly those with land unfit for crop production, livestock is an important economic asset to be used as a buffer against acute crises or as an investment in longer-term wealth accumulation. Small and medium-scale farms produce an estimated 51–77 percent of nutrients globally (calories, protein, vitamin A, vitamin B_{12}, folate, iron, zinc and calcium), yet little is known about how these enterprises impact the environment (Herrero et al., 2017). In addition, many women manage small-scale livestock production (such as poultry, sheep and goats), playing a particularly prominent role in dairy value chains, with control over income from milk sales. Yet, they are often bypassed for rural extension services and other agricultural inputs that could improve efficiencies and sustainable practices. Improved practices across all sizes and types of livestock system could protect livelihoods and reduce environmental impacts (Gerber et al., 2013).

In this section, we discuss some of the critical challenges for livestock-derived food production and its impacts on environmental and planetary health. We outline some of the opportunities to overcome these challenges by integrating solutions within the framework of sustainable, healthy food systems.

Challenges: Livestock-derived food production affects the environment and climate

Ecosystems around the world have been affected by food production, while anthropogenic contributions to climate change are mounting. Livestock-derived food production accounts for 14.5 percent of human-induced GHG emissions and other environmental impacts on biodiversity, freshwater use and disruptions to nutrient flows. However, this is largely dependent on production systems, farming practices and supply-chain management, where there may also be opportunities to mitigate these effects (Gerber et al., 2013).

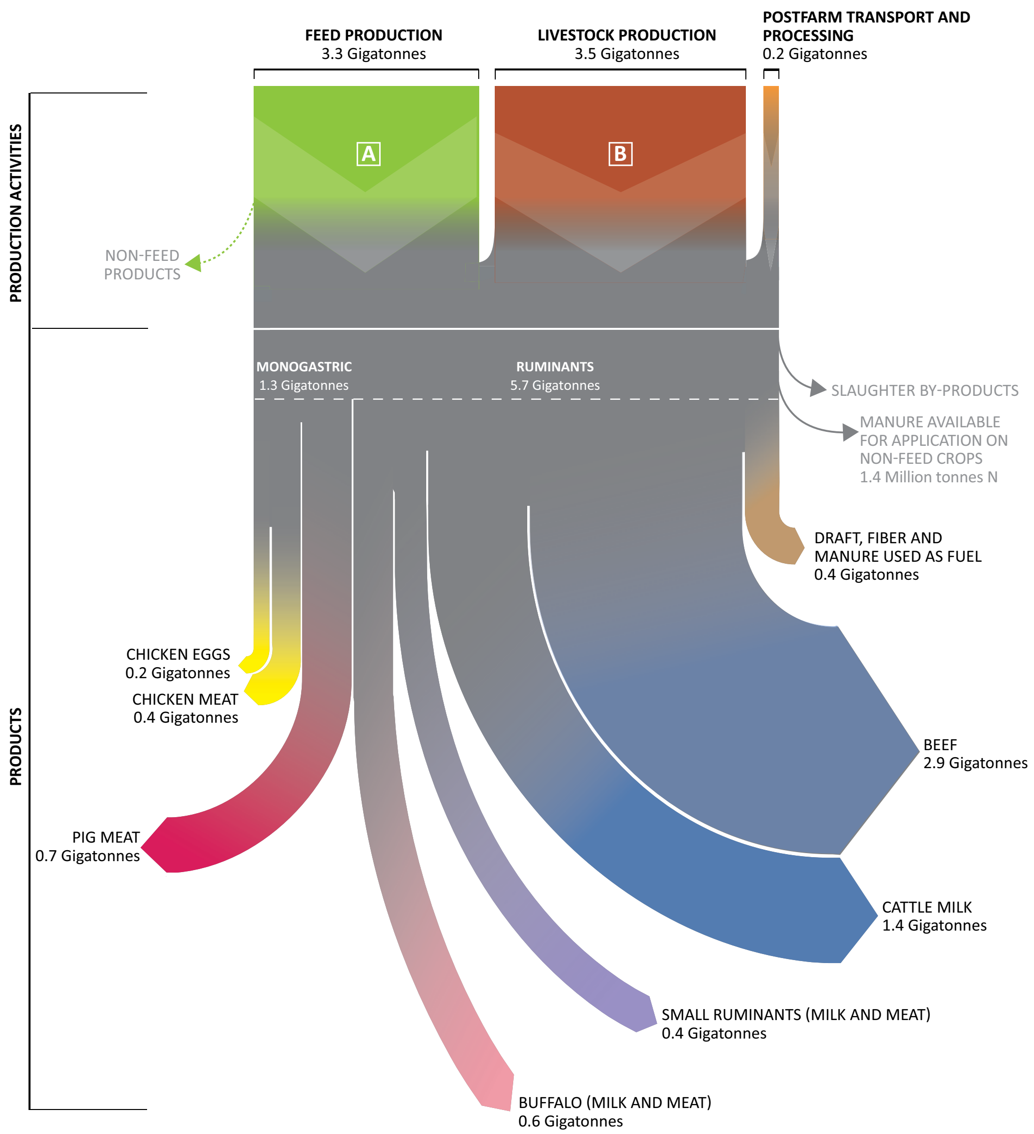
Livestock-derived food production is directly tied to GHG emissions, accounting for between 72 percent and 78 percent of total agriculture emissions (Gerber et al., 2013). This is mainly attributable to the enteric fermentation processes of ruminants, low feed-conversion efficiencies and manure-related emissions (Godfray et al., 2018). However, it is important to distinguish between different production systems, animal types and activities (Herrero et al., 2013; 2016). We also note that the oft-cited global estimates are developed from models and data based on OECD production systems. Countries on the tropics need their own data and models to correctly estimate baseline GHG emissions from their own livestock production systems and to track their progress on mitigation commitments to the UN Framework Convention on Climate Change. Research to date indicates significant variation in emissions (Ndung'u et al., 2018).

Putting definitive numbers on the impact of livestock production on the environment remains controversial for several reasons. The first is the diversity of production, processing and supply-chain environments. Second, setting the boundaries for appropriate lifecycle analysis is complex, especially in mixed crop-livestock systems, where the different elements are complementary. Third, with many countries including livestock-related GHG emissions for the first time in their climate mitigation strategies under the Paris Agreement, non-OECD countries face the new challenge of using Intergovernmental Panel on Climate Change Tier 1 factors – based on emissions from OECD countries – for very different production environments. New information on Tier 2 emission factors based on real-time data in Kenya is now being used to provide better, more realistic metrics for such systems (Marquardt et al., 2020).

Across animal species, beef production produces the most emissions (quantified as tonnes of carbon dioxide equivalent, or CO_{2e}), followed by dairy cattle, pigs, buffalo, chickens, small ruminants and other poultry. Feed production is the main source of GHGs, contributing 45 percent of sector emissions, with enteric fermentation by ruminants in close second, at 39 percent (Gerber et al., 2013). The three main gases linked to inefficiencies within livestock systems include nitrous oxide (N_2O), methane (CH_4) and CO_2. Methane, which has a low half-life compared with CO_2, has high global-warming potential. Poultry production – both chicken meat and eggs – is far less emissions intense than keeping ruminants (Gerber et al., 2013; Godfray et al., 2018).

The GHG emissions associated with livestock-derived food production emanate from the entire supply chain (Figure 4).

Figure 4.
GHG emissions from global livestock supply chains



GHG EMISSIONS FROM GLOBAL LIVESTOCK SUPPLY CHAINS, BY PRODUCTION ACTIVITIES AND PRODUCTS

Source: *Gerber et al. (2013).*

Feed production and processing, including the expansion of pastureland and feed crops into forests, are the largest contributors, followed by enteric fermentation by ruminants. Manure storage and processing and the supply-chain management practices of animal product processing and transport also weigh heavily in terms of GHG contribution.

Fresh water use is another challenge faced in livestock-derived food production. Overall, the food production sector uses more fresh water than other sectors – drawing 84 percent from rainwater and 16 percent from aquifers, rivers, and lakes (HLPE, 2015). More than three-quarters of consumptive water not returned to watersheds as surface or groundwater comes from agriculture. There are an estimated 2 billion people worldwide experiencing water insecurity, with insufficient water for hygiene and sanitation purposes, as well as drinking water needs (UNSCN, 2020). This critical gap can lead to enteric infection and malnutrition.

Fresh water use by the livestock sector is again largely due to feed production. It is estimated that global animal production requires about 2 422 cubic gigametres (Gm^3) of water per year, 87.2 percent green, 6.2 percent blue and 6.6 percent grey. Most of the green water is returned to the water cycle, largely through evaporation (so is not lost or consumed). Estimates of the water footprint vary widely, from less than 50l per kilogram of beef to thousands of litres, again reflecting the diversity not only of production systems, but of assessment approaches. Reducing freshwater losses in parts of the livestock-derived food sector could synergistically reduce environmental impacts and increase nutrition security.

Biodiversity is the "variety of life at genetic, species, and ecosystem levels" (FAO, 2019). While food and agriculture production are among the leading contributors to diminishing biodiversity, they are also highly dependent on ecosystem services, such as plant pollination, healthy soils and controlling pests. Biodiversity makes food production systems more resilient in the face of climate change and other shocks. Livestock-derived food production has a complex relationship with biodiversity; depending on the context, it can lead to losses of biodiversity, be negatively impacted by the processes or help to improve biodiversity.

There have been particularly profound impacts on biodiversity in mega-diverse tropical regions, where demand for meat is increasing in tandem with economic conditions. Brazil and China are two examples of countries where land use for livestock production has resulted in critical reductions in tropical forests and natural habitats for numerous species (Machovina et al., 2015). In many countries, feed-crop production has damaged soil microbiomes and ecosystems. Other, lesser impacts on biodiversity include the loss of top predators and terrestrial carnivores to protect herds, with negative cascading effects, or heavy grazing in riparian systems, leading to soil erosion and vegetation losses (Beschta et al., 2013; Batchelor et al., 2015).

In parallel with trends towards monocropping in crop cultivation, there has been a narrowing of the species and breeds of animals raised in the livestock sector. This may contribute to simultaneous losses of biodiversity and dietary diversity, though more research is needed. In plant-based foods, over half of calories (60 percent) come from only three plants – rice, maize and wheat (USDA & DHHS, 2015). Of the 6 000 plant species cultivated for food, just nine account for 66 percent of all crop production. Similarly, for livestock, there are 7 745 local breeds in existence, 26 percent of which are at risk of extinction and 67 percent are at unknown risk (FAO, 2019). There has been considerable genetic erosion as a result of the failure to value local indigenous breeds. Many countries, especially in the Global North, have opted for modern over locally adapted breeds. Other threats to diminishing genetic diversity include urbanization, conflicts, pests and disease and the intensification of agriculture (FAO, 2004). Diversifying and integrating production systems and using multiple local breeds in livestock-derived food production can help offset these losses.

Opportunities: Mitigating the environmental effects of livestock-derived food production

Sustainable livestock-derived food production and consumption can help us achieve multiple SDGs, mitigate climate change and secure a healthy planet. Solutions have been both tested and proposed for best practices in terms of feed, appropriate breeds, animal health and balance (Eisler et al., 2014).

Livestock production systems that are both mixed and efficient can have tremendous positive implications. Mixed systems produce half of the world's food (Herrero et al., 2010). Within the farm system, crop cultivation is integrated with livestock rearing on intermingled cropland, rangeland and forested land. Livestock contribute draft power and manure to enrich soil biomass, while plants can be cultivated for both human and animal consumption. Many of the inedible crop parts, such as straws and stovers, can be used as animal feed. Dual-purpose and dryland crops, such as sorghum or millet, in dairy systems can enhance efficiencies, as has been seen in India (Herrero et al., 2009).

Great strides have also been made to improve efficiencies, particularly in terms of feed-conversion rates for chickens and pigs. Moving away from single-product intensive systems to coupled systems that support structured ecosystems can have positive effects (Machovina et al., 2015). Ruminant production systems in South Asia, Africa and Latin America and the Caribbean, in particular, could see a rise in productivity from improvements to animal health, quality feed and herd management, with great potential for mitigation (Gerber et al. 2013).

As mentioned, animal feed production puts pressure on the environment, depleting fresh water, disrupting nutrient flows and diminishing biodiversity. Higher-quality feed and feed balancing can lower enteric and manure emissions (Gerber et al., 2013). Some experts have suggested growing crops that improve efficiency through ruminant protein metabolism, for example, by using red clover (*Trifolium pretense*) (Provenza et al., 2019). Well-managed rangelands can sequester carbon, enhance biodiversity and play a role in water productivity and whole ecosystems (Blackmore et al., 2018). In many of the mixed farming systems in LMICs, more than 70 percent of feed comes from crop residues and other crop by-products, so do not use any additional land, water or other inputs (Blümmel, et al., 2014). They also boast good opportunities for improvement. Pastoral systems that produce livestock products using plant material that is inedible for humans are another opportunity to mitigate impact.

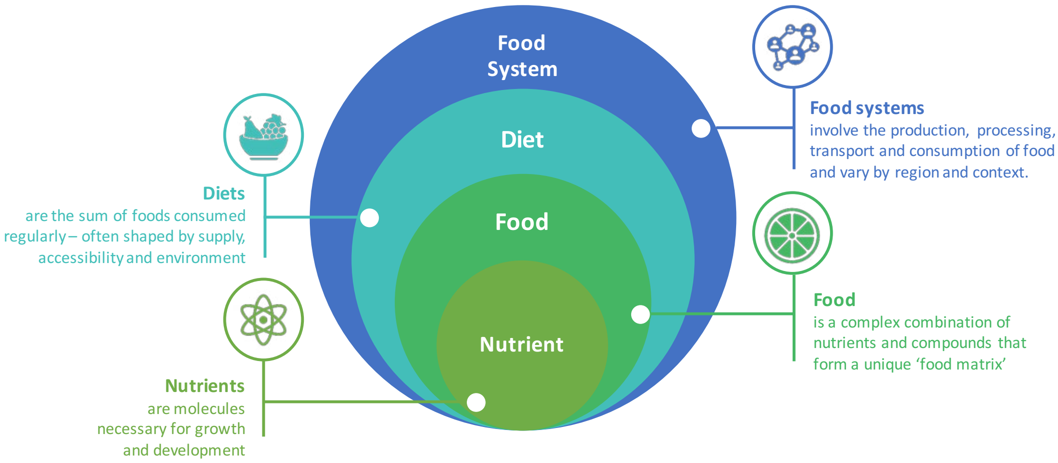
Appropriate animal breeds and types can also contribute to sustainable livestock-derived food production when striking a balance between efficient production and adaptation to local environments. For example, Holstein cows have been bred in North America for maximum milk productivity in temperate climates, but rarely perform well in tropical climates without huge investment in environmentally controlled housing and large-scale feed production. Similarly, Zebu breeds have been unsuccessful in humid environments due to their lack of disease resistance to trypanosomiasis. Local breeds are usually adapted to the local environment (climate, feed resources, diseases) and there may be scope to improve productivity with selective breeding, especially modern genomic selection processes (Mrode et al., 2019). A recent ground-breaking study showed important new genomic information from indigenous African cattle that may be used to identify traits for future smart breeding for heat tolerance, drought and disease (Kim et al., 2020). Another proposed solution related to animal type is to replace ruminants (cattle, goats, sheep) with monogastrics (poultry and pigs) (Machovina et al., 2015).

Protecting animal health is important to human health, but also relates directly to efficiencies in livestock-derived food production. Proper management and preserving the welfare of animals (for example, proper hygiene, low density, vaccinations and reduced use of growth promoters) ultimately reduces cost and environmental footprint. One Health, as described above, should be integrated into sustainable livestock production measures to combat zoonotic diseases and other negative side effects, while enhancing livestock production to end hunger and poverty. It provides a framework for managing immediate human, animal and environmental health threats (emerging or neglected zoonotic diseases and other occupational risks), as well as the enactment of policies that support longer-term interventions (Nabarro and Wannous, 2014).

4 Healthy, sustainable food systems: The role of livestock-derived foods

Diets are embedded in different regional food systems in widely varying contexts. In this section, we look at the outer layers of society (Figure 5), where issues related to livestock-derived food consumption and production converge with considerations of food systems and ecosystems more broadly, and where there is also the opportunity for changes in health and environmental protection.

Figure 5.
From nutrients to food systems



Source: *Cartmill, Iannotti (2020).*

A food system, often represented as a web, encapsulates all the processes involved in feeding a population, from production to processing and distribution, and ultimately, consumption. There are multiple actors in food systems with heterogeneity of purpose and objective. When it comes to livestock-derived foods, these actors may be human (livestock producers, veterinarians, agriculture extension workers, traders, processors, and consumers), institutional or organizational (ministries of health or agriculture, universities or research institutions, non-governmental organizations such as Heifer International, meat manufacturers) or other living organisms (livestock, plants used for feed, microorganisms). System dynamics modelling has been used to model food systems and show the effects of feedback loops and path interdependence over time. As we consider the food supply chain for livestock-derived foods, we will need to consider different spheres: social organizations, science and technology, the biophysical environment, policies and markets (Institute of Medicine and National Research Council, 2015). Processes within each domain could be leveraged to effect change and move food systems closer to the goals of One Health and sustainability.

Equitable food systems. Across these food-system components, efforts can be made to achieve both good nutrition and sustainable environmental practices. In addition to health and sustainability, a third principle considered when planning food systems is equitable access to healthy diets in a population or community, be it physical or economic (easily available and affordable). The *State of Food Security and Nutrition in the World 2020* report showed that the cost of a healthy diet exceeds the international poverty threshold of USD 1.90 a day (in purchasing-power parity terms) and that livestock-derived foods, fruits and vegetables are among the foods driving such costs (FAO et al., 2020).

Livestock-derived foods may be inaccessible to certain population segments due to cost. Economists have shown that the relative caloric price of animal-source foods more broadly, particularly perishables such as milk and eggs, is considerably higher than cereal-based foods (Headey et al., 2018). A major barrier to the affordability of livestock-derived foods is high production costs, which drive up market prices. Recent analyses of proposed healthy, sustainable diets by the EAT-Lancet Commission show a minimum cost of USD 2.84 per day, in part driven by animal-source foods, but also fruits, vegetables, legumes and nuts, well beyond the affordability of most of the world's poor (Hirvonen et al., 2020). In a more equitable food system, these costs could be lowered by increasing supply through increased production and preservation technologies for perishable goods, as well on the demand side, by improving the livelihoods of low-income communities and their ability to access livestock-derived foods in markets.

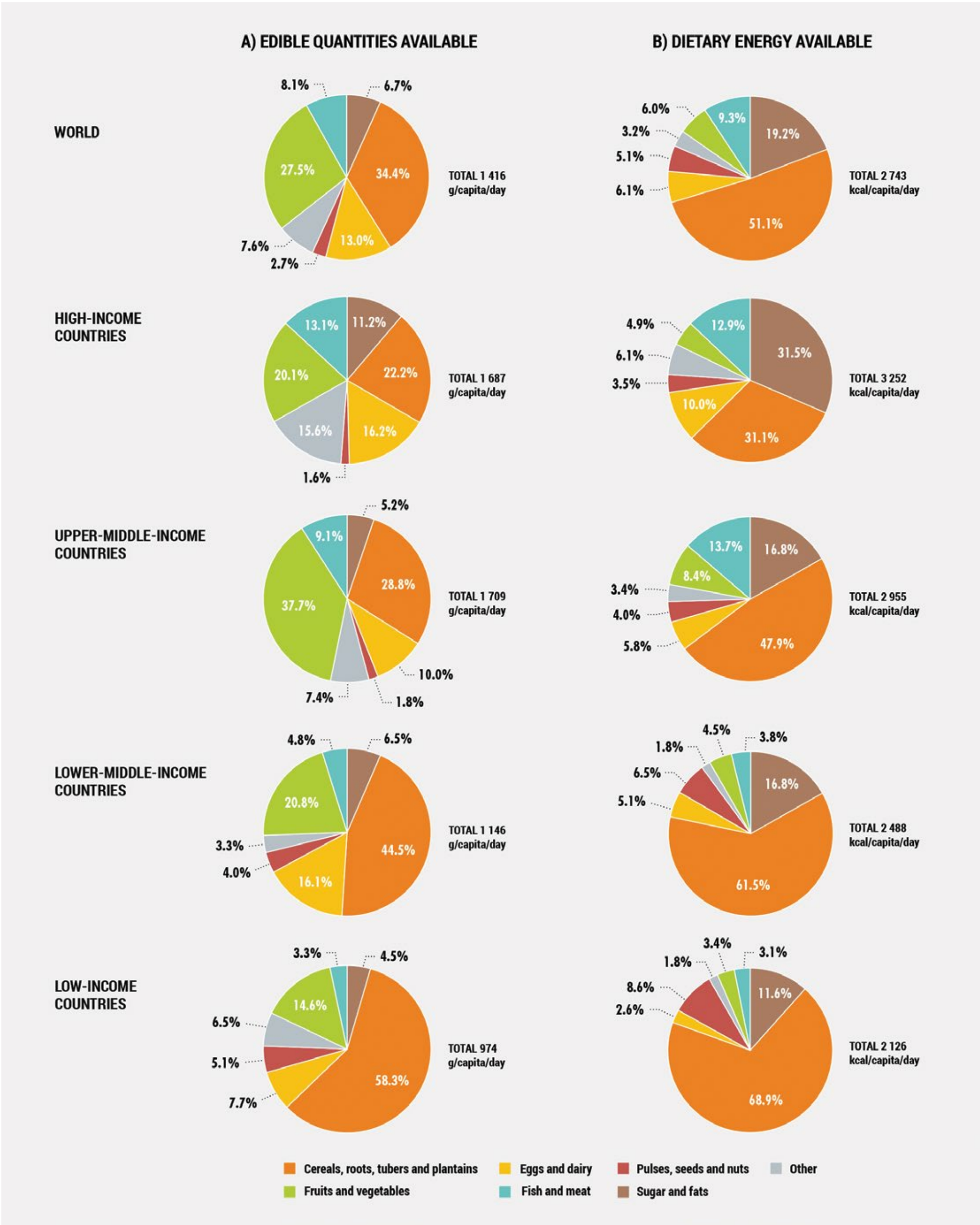
Promoting gender equality is one way of ensuring more equitable food systems (Quisumbing et al., 2014; Galie et al., 2015). Providing women with equal access to and control over income, land, credit and other assets, as well as ensuring that girls and women have access to education and employment, can increase the likelihood of equitable food systems. In some countries, livestock is the only asset that women are allowed to own and can support progress towards women's empowerment.

In addition to the direct costs to the consumer of healthy foods, there are the hidden costs to society that should be considered. These costs include those associated with health, both in terms of expenditure on the healthcare system and lost productivity. Current dietary patterns around the world suggest that health costs are likely to reach USD 1.3 trillion by 2030 as a result of a rise in chronic diseases, with direct healthcare costs accounting for 57 percent of this, informal care 32 percent and labour losses 11 percent (FAO et al., 2020). Hidden costs also include environmental impacts and consequences. Some 21 percent to 37 percent of all GHG emissions are attributable to current food availability patterns and are likely to come at a cost of USD 1.7 trillion by 2030 (FAO et al., 2020). These costs could be dramatically reduced by rebalancing livestock-derived food consumption.

Another important, often overlooked issue related to livestock-derived foods in sustainable healthy food systems and a One Health approach is animal welfare. While we do not cover this in any great detail in this paper, there are numerous practices that uphold ethical principles in the treatment of animals. For example, the extensive production of the Iberian pig in Spain adheres to several principles of animal welfare – an autochthonous breed integrated with the environment, with freedom of movement, natural feeding sources from within an agroforestry system and a longer productive cycle (Aparicio Tovar and Vargas Giraldo, 2006). Across many production systems in lower-income economies, improving productivity (and, thus, access to livestock-derived foods) through better animal health and feeding solutions is synchronous with better animal welfare.

Context and ecosystems. Food systems and food availability patterns vary considerably in different regions and markets around the world and across different biomes. These patterns of livestock-derived food consumption may be down to product availability, cultural practices, macro- and microeconomic dynamics and other market forces, as well as levels of education. The 2020 SOFI report showed that the proportion of energy (kcal per capita per day) coming from animal-source foods varies greatly by income, even more than by region, with the greatest difference observed between high- and upper-middle-income countries and LMICs and low-income countries (Figure 6).

Figure 6.
Proportions of food groups available for human consumption across country income groups, 2017



Source: *FAO (2020).*

In Section 3, we delineated the effects of different dimensions of livestock-derived food production on the environment – be it in terms of climate change, biodiversity, freshwater use or other. As we are considering healthy, sustainable food systems as a whole, we have also explored livestock and livestock-derived foods as they relate to entire ecosystems. Livestock and humans interact with ecosystems in countless ways. Often, we frame this interaction in terms of ecosystem services provided, such as food, water, shelter and raw materials and, conversely, how we manage and value those ecosystems. Livestock can transform feed into highly nutritious foods or alter the environment by grazing, trampling or fertilizing soils. In many contexts, this reduces crop waste or by-product losses. For many rural households, livestock offer a multitude of services beyond food (Table 1).

Table 1.
The services livestock provide to rural households

Cattle	Pigs	Llamas and alpacas	Goats and sheep	Donkeys	Camels	Poultry
Milk, blood and meat for food and income. Hides for shelter. Bedding, clothing and footwear. Savings, dowry and bride price. Manure, animal traction.	Meat for food and income. Savings.	Transport in mountainous terrain. Sales of meat and high-quality fibre. Income from tourisme.	Sales for cash income. Milk, blood and meat for food. Skins for clothing. Savings. Wool and wool products.	Transport of water and goods. Milk for medicinal purposes.	Meat and milk for food and income. Hides for shelter. Bedding and footwear. Savings. Dowry and bride price. Manure, including for use in papermaking, trasport	Eggs and meat for food and income. Feathers for bedding.

Source: *Adapted from FAO (2016b).*

Over time, humans have bred "specialist" livestock that are adapted to particular environments and local feeds or resistant to certain diseases. Worldwide, 17 percent of livestock breeds are at risk of extinction and the phenomenon of "genetic erosion" is threatening our food systems. Decreasing diversity and breed extinction will cause disruption to ecosystem dynamics. In contrast, grazing systems that are well managed will help to keep balance in ecosystems, ensure soil fertility, control weeds and invasive species and ensure a healthy nutrient flow. Pastoralists, whose livelihoods depend on livestock viability, have traditionally managed the world's rangelands well. With climate change, diminishing land tenure and marginalization, however, pastoralists have lost the ability to maintain their livelihoods, environments and even their livestock-derived nutrition.

Sustainable, healthy and equitable food systems are possible with the right enabling environment and investment globally. Respecting ecosystems and protecting the most vulnerable are critical goals to this end. Sadly, there is no one-size-fits-all solution.

The enabling environment: Programmes, policies and research

There are opportunities to maintain and support sustainable healthy and equitable food systems. Policies and programmes that work in tandem can strive to achieve nutritional equity and balance in livestock-derived food consumption, while promoting the sustainable production of livestock-derived foods.

Social and behavioural change strategies, including social marketing will be essential to reducing consumption in some groups and increasing it in others (Gallegos-Riofrío et al., 2018). This could be accomplished through individual choice paradigms, whereby people are, ideally, nutritionally informed and consciously opt into healthy eating patterns, or through more automatic processes that bring about changes in the food environment. Such approaches are context-specific, largely conceived in high-income regions where food choice is an option. Food labels could inform consumers of nutritional content, but also production methods and animal stewardship. In some countries, food producers are required to inform consumers of meat origin, and restaurants and food vendors are encouraged to improve consumer awareness and education about nutritional content and production methods.

Healthy dietary patterns can be promoted through different platforms, such as national nutrition programmes targeting vulnerable groups or early childcare or school feeding programmes. Globally, school feeding programmes are one of the largest public investments in nutrition, yet the politics and economics within food systems often prevail over nutritional considerations when determining the composition of meals. Livestock-derived foods could become a systematic part of these programmes, particularly in low-resource settings. Projects linked to local livestock-derived food production could be crucial. One project in Rwanda uses a social and behavioural change communication intervention to promote animal-source foods for children aged 12–36 months and pregnant and lactating women, simultaneously boosting the performance of dairy cooperatives and increasing market access for smallholder milk producers (Kimani, 2019).

Several policy approaches have been proposed to incentivize and improve livestock management with a view to reducing risk, achieving efficiencies and lessening the environmental footprint, such as improved feeding, the use of appropriate breeds and animal health services (Herrero et al., 2009). Others have put forward the idea of rewarding sustainable stewardship with labelling and certification schemes, or remuneration for good management practices (Mehrabi et al., 2020). Government regulation of the industry in relation to multiple practices, such as deforestation and excessive inputs, is used globally.

Programmes and policies that support sustainable transitions for smallholder livestock producers, particularly as part of mixed systems, may be among the most important ways of simultaneously achieving livestock-derived food equity and sustainability. Increasing productivity and reducing the environmental footprint of mixed livestock systems could be achieved through better integration of crops and animals to ensure effective nutrient cycling and a more circular bioeconomy in livestock supply chains. Trade policies, including policies to ensure that smallholder farmers can compete effectively, can provide added protection. Other indirect, but no less important, policies should include protecting the sovereignty of indigenous and nomadic peoples and lands (Mehrabi et al., 2020).

In several countries, food-based dietary guidelines serve as an example of how livestock-derived foods can be incorporated into an overall healthy diet (Box 5).

Box 5.
Food-based dietary guidelines with sustainability considerations

National food-based dietary guidelines are sets of tools and resources, rooted in sound evidence, that:

- provide advice on healthy diets within the specific context of a country's public health situation, priority nutritional issues and current consumption patterns;
- can inform national policies and programmes associated with diets.

Traditionally, national food-based dietary guidelines have considered the relationship between dietary patterns, food groups, foods, ingredients, nutrients, health and nutrition and, on occasion, certain sociocultural aspects, such as culinary practices, traditional meals, food enjoyment and commensality (Gonzalez Fischer and Garnett, 2016). Other dimensions and criteria of sustainability, such as the environmental impacts of consumption and production (such as GHG emissions and resource depletion), the economic effects (such as inequality), and sociocultural impacts (for example, unfair practices) have not been paid due attention.

In response to the challenges of progressing towards the achievement of the SDGs, countries have started to better integrate multidimensional sustainability considerations into their national food-based dietary guidelines. For instance, while the German Nutrition Society's guidelines for wholesome eating and drinking include messages such as "use fresh ingredients whenever possible", which help to reduce unnecessary packaging waste, and "choose fish products from recognized sustainable sources", the Netherlands have set maximum limits for foods with a high environmental impact (Brink et al, 2018).

Integrating sustainability considerations into food-based dietary guidelines requires a rethink of the whole process – from the stakeholders involved, the evidence considered and the data used for dietary optimization to the messages produced. A change of paradigm is needed to create a new generation of food-based dietary guidelines that can address multiple objectives and improve the health of people and the planet. FAO is currently working on a new methodology that enables the integration of sustainability considerations into food-based dietary guidelines, anchored in a food systems-wide approach that goes beyond health and nutrition.

A 2016 FAO report profiled four countries – Brazil, Germany, Sweden and Qatar – that had successfully implemented food-based dietary guidelines in an attempt to meet the needs of vulnerable groups while maintaining planetary health (FAO, 2016a). Recommended servings also vary, from qualitative recommendations (such as "consume moderate amounts") to more quantitative guidelines (such as maximum "one 65g serving of lean red meats per day"). Most food-based dietary guidelines identify the importance of livestock-derived foods in providing protein for a healthy diet, while many highlight the importance of other micronutrients that come from livestock-derived foods, such as iron, calcium, vitamin B12 and zinc (Box 6).

Box 6.
National examples of livestock-derived foods in food-based dietary guidelines

Australia

Livestock-derived foods feature in a "lean meats and alternative" category of Australia's food-based dietary guidelines, which includes "lean meats and poultry, fish, eggs, tofu, nuts and seeds, and legumes/beans", with milk, yoghurt, cheese and alternatives making up their own food group. Using recent dietary survey data for adults, the food-based dietary guidelines suggest that a 40 percent increase in the consumption of poultry, fish, seafood, eggs, tofu, nuts, seeds and legumes/beans is needed to meet recommended intakes, along with a 20 percent reduction in red meat for men with an omnivorous diet. For children aged 2 to 16, a 30–85 percent increase in the former is recommended, as well as a 25–70 percent increase in lean red meats. In addition to protein, it identifies important micronutrients from livestock-derived, such as iron, zinc and other minerals, B12 and essential fatty acids. It establishes a broad connection between the food system and the environment, but does not provide specific guidance on eating sustainably outside of "reducing waste" (National Health and Medical Research Council, 2013).

Kenya

Livestock-derived foods are included within Kenya's animal-source food group, which includes "meat, fish and animal protein products", with a recommended intake of "lean meat, fish and seafood, poultry, insects or eggs at least twice a week" and milk or milk products every day. It identifies a diverse range of livestock-derived foods for consumption, including organ meats, mutton, rabbit, quail, donkey and pigeon, in addition to the more common red meat, poultry, eggs and fish. Portion sizes are presented both in terms of weight (30g for meat, fish, chicken and eggs) as well as in a more practical form, such as "meat, size of three fingers" or "piece of chicken (drumstick/thigh, or breast)". The guidelines further include specific nutrients in relation to livestock-derived foods and their contribution to a healthy diet over a lifetime such as haem-iron for anaemia prevention, oxygen transport and immune-system function, especially during pregnancy, when iron demands increase. There is no distinction made between red meats and other types of livestock-derived foods and no mention of sustainability or environmental impact (Kenyan Ministry of Health, 2017).

India

In India, in contrast, livestock-derived foods are grouped with milk to form a "milk and milk products, egg, meat and fish" category. The guidelines recognize the superiority of animal-sourced proteins in providing essential amino acids, but also suggest that a combination of cereals, millet and pulses can be combined to provide a similar amino-acid profile. Specific consumption recommendations promote some animal-source foods over others, such as "eat fish more frequently (at least 100–200g/week), prefer it to meat, poultry and limit/avoid organ meats such as liver, kidney, brain etc" and "limit the consumption to 3 eggs/week", despite the National Nutrition Monitoring Bureau indicating a lower-than-recommended intake of all foods except cereal and millet. As a high proportion of the Indian population follows a vegetarian diet, milk is listed as an essential food item, especially for infants, children and women. A link between food production and adequate consumption levels is established, but impacts on the environment or sustainable production beyond food availability are not included (Indian National Institute of Nutrition, 2011).

Work is still needed to align food-based dietary guidelines with FAO–WHO Guiding Principles for Sustainable Healthy Diets. Principle No. 4 states that sustainable healthy diets "can include moderate amounts of eggs, dairy, poultry and fish; and small amounts of red meat" (FAO and WHO, 2019). Further clarity on suggested consumption (a moderate versus a small amount) could help to alleviate confusion as to recommended intake. Decoupling livestock-derived foods from other protein-rich food items may also serve to identify the unique nutrient profile of this group and its potential to address deficiencies in certain populations. Including measures of sustainability in relation to livestock-derived food production can also help guide consumers towards choices that improve both personal and planetary health in more localized contexts.

Overall, food-based dietary guidelines serve as an important tool in implementing sustainable healthy diet principles and hold great potential for shifting diets towards more sustainable and healthier livestock-derived food options from production to consumption.

Building the evidence base: Livestock-derived food research

Evidence is needed to better understand the precise dietary requirements in terms of livestock-derived and aquatic foods for infants, children, adolescents and pregnant and lactating women and how context must be taken into account in designing solutions. Pilot interventions can offer clearer insights into the frequency and quantity of animal-source foods required over a lifetime. The contribution of balanced livestock-derived food consumption to addressing anaemia and hidden hunger is a key element in this regard. Studies should also test the livestock-derived food types appropriate to the context in question, taking into account availability and access, cultural norms and overall dietary patterns. Food safety research related to livestock-derived food value chains is important for nutrition and livelihood security, but also for reducing food waste and mitigating environmental impacts. Findings from such research could inform food-based dietary guidelines on locally available and affordable foods.

Research is also needed at the macro level to understand livestock-derived food-consumption patterns and trends across regions and countries and enabling mechanisms that might achieve better parity and health within and across populations. The evidence base could be expanded substantially for "territorial diets", such as the Mediterranean or Nordic diets, which embody sustainability and nutritional quality according to context. Diets that are more closely linked to biomes and accessed locally present an opportunity for communities to integrate into ecosystems. Techniques such as system dynamics, agent-based modelling and network analyses could improve understanding of the dynamics of livestock-derived food consumption and production patterns within food systems, and how processes might be optimized for human health, environmental sustainability and livelihood protection.

The evidence needs to continue to grow for nutrition-sensitive, livestock-derived food production that is also sustainable. Emphasis could be placed on mixed production systems that promote agrobiodiversity and dietary diversity, and for which there are opportunities to transition to higher-yielding, more sustainable systems without switching fully to industrial-scale production. There is a real need for research aimed at small-scale, mixed livestock-derived food producers, to identify innovative approaches and opportunities for sustainable livestock-derived food production, such as the production of animal feed using dryland crops, the propagation of animal breeds adapted to local environments and feed that contributes to greater production efficiency and improved animal metabolism. Lastly, research is needed to identify effective approaches for attaining equality for both producers and consumers.

This section has outlined the larger picture of livestock-derived foods within food systems, including the enabling environment, food-based dietary guidelines and gaps in the evidence base. In future, holistic, creative approaches will be needed that incorporate the principles of One Health, equity and ecosystem vitality.

5 Conclusion

This discussion paper synthesizes evidence on the role of livestock-derived foods in sustainable healthy diets, in the expectation that it will contribute to a robust narrative for policy discussions, communications, information and capacity-development activities. The issues are complex and require informed and integrated approaches.

Livestock-derived foods can have consequences for human health if they are absent from or deficient in the diets of certain vulnerable groups, or if consumed to excess by others. People have high nutrient demands at certain times of life and require bioavailable nutrients to support growth and development, for example, in early childhood, at school-going age and in adolescence, in pregnancy and lactation. Livestock-derived foods can provide valuable sources of protein and minerals to meet these needs, especially in resource-poor contexts. In some populations, however, trends show a rise in consumption beyond what is required to maintain health. This discussion paper highlights the growing evidence base linking an excess of red meat consumption (and the consumption of processed meat, in particular) to increased risk of cancer, cardiovascular disease and all-cause mortality. The evidence is less clear cut for other livestock-derived products, such as eggs and dairy.

Animal type, farming activity and structure of the production system matter in terms of environmental consequences, but also create opportunities in the sector. Mixed livestock production systems that protect animal health and tie in with cultivation activities offer the potential to mitigate environmental impacts. The largest environmental impact from livestock production comes from GHG emissions, though there are other effects, too, related to biodiversity, blue water use and disrupted nutrient flows. Climate change can also negatively affect livestock production, particularly for small-scale producers.

Equitable access to high-quality foods is also an imperative in sustainable, healthy food systems. The affordability of healthy diets is a critical challenge for three billion people (SOFI, 2020). Economic and policy strategies may similarly reduce the over-consumption of livestock-derived foods. Ultimately, context and the public-health backdrop should guide decision-making on recommendations related to livestock-derived foods in the diet. Food-based dietary guidelines can provide the platform for disseminating these messages, in tandem with programmes, such as social and behavioural change strategies.

Taking action: Next steps

- Global, national and local policies and programmes should ensure that people have access to appropriate quantities of livestock-derived foods at critical stages of life for healthy growth and development: from six months of age through early childhood, at school-age and in adolescence, and during pregnancy and lactation. This is particularly important in resource-poor contexts. In other groups consumption can be reduced. Social and behavioural change strategies may be required to increase awareness of appropriate quantities of livestock-derived foods. Such strategies should also take into account social and, in particular, gender norms that may restrict women from accessing information and resources. Food-based dietary guidelines can also play a critical role in setting appropriate quantities of livestock-derived foods for all times of life, drawing on locally available, biome-based foods.

- To ensure intake of livestock-derived foods compliments the principles of sustainable healthy diets, more attention should be given to policies and programmes that work towards *equitable access* to high-quality foods and dietary diversity. This may involve economic and political strategies that safeguard the affordability of livestock-derived foods in some populations and create disincentives to overconsume in others. Food systems globally should espouse the principles of fair trade, sound environmental practices and access to diverse and high-quality diets for all. Small-scale producers, who are vulnerable to both poverty and malnutrition, should be targeted for improved access to high-quality foods and livestock production inputs.

- The environmental impacts of agriculture, including livestock production, could be lessened by policy and programme support for mixed farming systems that embrace circular agriculture and pastoral systems. Production systems for livestock-derived foods should be adapted to local contexts and ecosystems and biome-based strategies should be applied to food systems. Where appropriate, some production systems could transition to more sustainable animal types (such as monogastric animals) and products (such as eggs or dairy). The principles of One Health should be maintained. Small- and medium-scale producers should be integral to solutions and women farmers should be a particular focus for production inputs (such as animal health, credit and extension services). Efficiencies could be gained through improved feed-conversion rates and the use of local breeds that have adapted to the environment.

- Research should continue to build the evidence base on the role of livestock-derived foods within sustainable healthy diets. Deeper insights into the bidirectionality of climate change and livestock-derived food production are needed, together with more evidence on the ability of sustainable food production systems to mitigate and be resilient to climate change. Holistic analysis of the dynamics of food systems will yield crucial evidence to inform optimal policies. Ecologists and public-health nutritionists could collaborate to find solutions that optimize biodiversity and dietary diversity. The CGIAR global research organizations, including the International Livestock Research Institute (ILRI) and the Alliance of CIAT-Bioversity, could work together to tackle issues associated with the role of livestock-derived food in healthy sustainable diets. ILRI has committed to support the United Nations Decade of Action on Nutrition through its research to increase the availability, access and affordability of animal-source foods for poor producers and consumers in LMICs. It will also identify and promote practices that will reduce the environmental footprint of livestock, including their GHG emissions, as well as measures to ensure the safety of animal-source foods, especially in informal markets (UNSCN, n.d.).

- Institutional commitments are needed to generate the political will and action necessary to anchor livestock-derived foods in sustainable healthy diets. UN Nutrition could play a leading role in orchestrating a concerted effort on the part of Members, through its core functions to achieve policy coherence on and innovation in emerging issues. UN Nutrition, the successor to UNSCN from 2021, is a dedicated platform for open, substantive, forward-looking and constructive dialogue among United Nations agencies on their respective strategies and efforts related to nutrition, as well as for the formulation of aligned and collaborative global approaches, positions and actions to address the complex and many facets of evolving nutrition challenges. It provides thought leadership on nutrition priorities, agendas and goals for the future. In this context, UN Nutrition can bring the conclusions from this paper forward into nutrition dialogue, aligning the strategies of United Nations agencies and translating global-level guidance into country-level guidance and action. UN Nutrition will work with CGIAR, the Global Agenda for Sustainable Livestock, other knowledge centres and academia to enhance the knowledge base to support sustainable healthy diets.

This moment in history calls for global solutions to planetary health issues and to preserve the wellbeing of humans, animals and ecosystems. To achieve healthy sustainable diets for all, evidence-based, integrated solutions are needed that take into account the role of livestock-derived foods.

References

Aparicio Tovar, M.A. & Vargas Giraldo, J.D. 2006. Considerations on ethics and animal welfare in extensive pig production: Breeding and fattening Iberian pigs. *Livestock Science*, 103(3): 237–242.

Ballard, O. & Morrow, A.L. 2013. Human milk composition: nutrients and bioactive factors. *Pediatric Clinics of North America*, 60(1): 49 74. (also available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3586783/).

Barabási, A., Menichetti, G. & Loscalzo, J. 2020. The unmapped chemical complexity of our diet. *Nature Food,* 1: 33–37. (also available at https://www.nature.com/articles/s43016-019-0005-1).

Batchelor, J.L., Ripple, W.J., Wilson, T.M. & Painter, L.E. 2015. Restoration of riparian areas following the removal of cattle in the Northwestern Great Basin. Environmental Management, 55(4): 930–942. (also available at https://www.researchgate.net/publication/272515807_Restoration_of_Riparian_Areas_Following_the_Removal_of_Cattle_in_the_Northwestern_Great_Basin).

Beschta, R.L., Donahue, D.L., DellaSala, D.A., Rhodes, J.J., Karr, J.R., O'Brien, M.H., Fleischner, T.L. & Williams, C.D. 2013. Adapting to climate change on western public lands: addressing the ecological effects of domestic, wild, and feral ungulates. *Environmental Management*, 51: 474–491. (also available at https://pubmed.ncbi.nlm.nih.gov/23151970/).

Bhupathi, V., Mazariegos, M., Cruz Rodriguez, J.B. & Deoker, A. 2020. Dairy Intake and Risk of Cardiovascular Disease. *Current Cardiology Reports*, 22(3): 11.

Blackmore, I., Lesorogol, C., & Iannotti, L. 2018. Small livestock and aquaculture programming impacts on household livelihood security: A systematic narrative review. *Journal of Development Effectiveness*, 10(2): 197–248.

Blesso, C.N. & Fernandez, M.L. 2018. Dietary Cholesterol, Serum Lipids, and Heart Disease: Are Eggs Working for or Against You? *Nutrients*:10(4): 426. (also available at https://pubmed.ncbi.nlm.nih.gov/29596318/).

Blümmel, M., Haileslassie, A., Samireddypalle, A., Vadez, V. & Notenbaert, A. 2014. Livestock water productivity: feed resourcing, feeding and coupled feed-water resource data bases. Animal Production Science, 54(10): 1584–1593. (also available at https://doi.org/10.1071/AN14607).

Brink, E., Rossum, C.V., Postma-Smeets, A.,Stafleu, A., Wolvers, D. & Dooren, C.V. et al. 2018. Development of healthy and sustainable food-bade dietary guidelines for the Netherlands. Public Health Nutrition, 22(13): 2419-2435. (also available at https://pubmed.ncbi.nlm.nih.gov/31262374/)

Broadhurst, C. L., Wang, Y., Crawford, M. A., Cunnane, S.C., Parkington, J.E. & Schmidt, W.F. 2002. Brain-specific lipids from marine, lacustrine, or terrestrial food resources: Potential impact on early African Homo sapiens. In C. Moyes (ed.) *Comparative Biochemistry and Physiology – B Biochemistry and Molecular Biology,* 131: 653–673. (also available at https://pubmed.ncbi.nlm.nih.gov/11923081/).

Clark, M.A., Springmann, M., Hill, J. & Tilman, D. 2019. Multiple health and environmental impacts of foods. *Proceedings of the National Academy of Sciences of the United States of America*, 116(46): 23357–23362. (also available at https://www.pnas.org/content/116/46/23357).

Cordain, L., Miller, J.B. & Eaton, S.B. 2000. Plant-animal subsistence ratios and macronutrient energy estimations in worldwide hunter-gatherer diets. *American Journal of Clinical Nutrition*, 71(3): 682–692.

Domínguez-Rodrigo, M, Mabulla, A, Bunn H.T., Barba, R., Diez-Martín, F., Egeland, C.P., Espílez, E., Egeland, A., Yravedra, J. and Sánchez, P. 2009. Unraveling hominin behavior at another anthropogenic site from Olduvai Gorge (Tanzania): new archaeological and taphonomic research at BK, Upper Bed II. *Journal of Human Evolution*, 57(3): 260–283. (also available at https://pubmed.ncbi.nlm.nih.gov/19632702/).

Eaton, J.C., Rothpletz-Puglia, P., Dreker, M.R., Iannotti, L., Lutter, C., Kaganda, J. & Rayco-Solon, P. 2019. Effectiveness of provision of animal-source foods for supporting optimal growth and development in children 6 to 59 months of age. *Cochrane Database of Systematic Reviews,* 2(2): CD12818. (also available at https://pubmed.ncbi.nlm.nih.gov/30779870/).

Eaton, J.C. & Iannotti, L.L. 2017. Genome-nutrition divergence: evolving understanding of the malnutrition spectrum. *Nutrition Reviews,* 75(11): 934–950. (also available at https://academic.oup.com/nutritionreviews/article/75/11/934/4367836).

Eisler, M.C., Lee, M.R.F., Tarlton, J.F., Martin, G.B., Beddington, J., Dungait, J. A. et al. 2014. Steps to sustainable livestock. *Nature*, *507*(7490), 32–34. (also available at https://www.nature.com/news/agriculture-steps-to-sustainable-livestock-1.14796).

FAO. 1997. *Wildlife and food security in Africa*. Rome. (also available at http://www.fao.org/3/w7540e/w7540e06.htm).

FAO. 2004. Loss of domestic animal breeds alarming. *FAO Newsroom* [online], 31 March 2004. http://www.fao.org/newsroom/en/news/2004/39892/index.html

FAO. 2011. *Dietary protein quality evaluation in human nutrition.* Food and Nutrition Paper 92. Report of an FAO Expert Consultation, 31 March–2 April 2011, Auckland, New Zealand. Rome. (also available at http://www.fao.org/ag/humannutrition/35978-02317b979a686a57aa4593304ffc17f06.pdf).

FAO. 2016a. Plates, Pyramids, Planet – Developments in national healthy and sustainable dietary guidelines: a state of play assessment. Rome. (also available at http://www.fao.org/sustainable-food-value-chains/library/details/en/c/415611/).

FAO. 2016b. *The contributions of livestock species and breeds to ecosystem services*. Rome. (also available at http://www.fao.org/sustainability/news/detail/en/c/453640/).

FAO. 2019. *The State of the World's Biodiversity for Food and Agriculture.* Rome: FAO Commission on Genetic Resources for Food and Agriculture Assessments. (also available at http://www.fao.org/3/CA3129EN/CA3129EN.pdf).

FAO. 2020. *Nutrition and livestock– Technical guidance to harness the potential of livestock for improved nutrition of vulnerable populations in programme planning.* Rome. (also available at http://www.fao.org/3/ca7348en/CA7348EN.pdf).

FAO & WHO. 2019. *Sustainable healthy diets – Guiding principles*. Rome. (also available at www.fao.org/documents/card/en/c/ca6640en/).

FAO, IFAD, UNICEF, WFP & WHO. 2019. *The State of Food Security and Nutrition in the World 2019: Safeguarding against economic slowdowns and downturns*. Rome: FAO. (also available at http://www.fao.org/3/ca5162en/ca5162en.pdf).

FAO, IFAD, UNICEF, WFP & WHO. 2020. *The State of Food Security and Nutrition in the World 2020*: *Transforming food systems for affordable healthy diets*. Rome: FAO. (also available at https://doi.org/10.4060/ca9692en).

FAOSTAT. n.d. *New Food Balances* [online]. Electronic dataset. Rome. [Last accessed 28 October 2020]. http://www.fao.org/faostat/en/#data/FBS

Francis, D.A. 2011. Sexuality Education in South Africa: Wedged Within a Triad of Contradictory Values. *Journal of Psychology in Africa*, 21(2): 317–322.

Galie, A., Mulema, A., Mora Benard, A.M., Onzere, S. & Colverson, K. 2015. Exploring gender perceptions of resource ownership and their implications for food security among rural livestock owners in Tanzania, Ethiopia, and Nicaragua. *Agriculture and Food Security*, 4: 2. (also available at https://cgspace.cgiar.org/handle/10568/56833).

Gallegos-Riofrío, C.A., Waters, W.F., Salvador, J.M., Carrasco, A.M., Lutter, C.K., Stewart, C.P. & Iannotti, L.L. 2018. The Lulun Project's social marketing strategy in a trial to introduce eggs during complementary feeding in Ecuador. *Maternal & Child Nutrition,* 14 Suppl 3(Suppl 3): e12700. (also available at https://pubmed.ncbi.nlm.nih.gov/30332535/).

Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G. 2013. *Tackling climate change through livestock: A global assessment of emissions and mitigation opportunities*. Rome: FAO. (also available at http://www.fao.org/3/a-i3437e.pdf).

Global Food Safety Partnership (GFSP). 2019. *Food safety in Africa: Past endeavors and future directions*. Washington, DC: World Bank. (also available at https://datacatalog.worldbank.org/dataset/food-safety-africa-past-endeavors-and-future-directions).

GBD 2017 Diet Collaborators. 2019. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*, 393(10184): 1958–1972. (also available at https://www.thelancet.com/article/S0140-6736(19)30041-8/fulltext).

Godfray, H.C.J., Aveyard, P., Garnett, T., Hall, J.W., Key, T.J., Lorimer, J., Pierrehumbert, R.T., Scarborough, P., Springmann, M. & Jebb, S.A. 2018. Meat consumption, health, and the environment. *Science*, 361(6399). (also available at https://science.sciencemag.org/content/361/6399/eaam5324).

Golzar Adabi, S.H., Ahbab, M., Fani, A.R., Hajibabaei, A., Ceylan, N. & Cooper, R.G. 2013. Egg yolk fatty acid profile of avian species – influence on human nutrition. Journal of Animal Physiology and Animal Nutrition, 97(1): 27–38.

Gonzalez Fischer, C. & Garnett, T. 2016. *Plates, pyramids and planets: Developments in national healthy and sustainable dietary guidelines: a state of play assessment*. Rome: FAO and Food Climate Research Network, University of Oxford. (also available at http://www.fao.org/3/a-i5640e.pdf).

Goyal, M.S., Iannotti, L.L. & Raichle, M.E. 2018. Brain Nutrition: A Life Span Approach. *Annual Review of Nutrition*, 38: 381–399. (also available at https://pubmed.ncbi.nlm.nih.gov/29856933/).

Grace, D., Mutua, F., Ochungo, P., Kruska, R., Jones, K., Brierley, L., Lapar, M.L.A. et al. 2012. *Mapping of poverty and likely zoonoses hotspots*. Nairobi, Kenya: International Livestock Research Institute. (also available at https://cgspace.cgiar.org/bitstream/handle/10568/21161/ZooMap_July2012_final.pdf).

Green, R., Allen, L.H., Bjørke-Monsen, A.L., Brito, A., Guéant, J.L., Miller, J.W. et al. 2017. Vitamin B_{12} deficiency. *Nature Reviews Disease Primers*, 3: 17040. Erratum in: *Nature Reviews Disease Primers* 3:17054.

Headey, D., Hirvonen, K. & Hoddinott, J. 2018. Animal sourced foods and child stunting. *American Journal of Agricultural Economics*, *100*(5): 1302–1319. (also available at https://doi.org/10.1093/ajae/aay053).

Herrero, M., Thornton, P.K., Gerber, P. & Reid, R.S. 2009. Livestock, livelihoods and the environment: understanding the trade-offs. *Current Opinion in Environmental Sustainability*, *1*, 111–120. https://doi.org/10.1016/j.cosust.2009.10.003

Herrero, M., Thornton, P.K., Notenbaert, A.M., Wood, S., Msangi, S., Bossio, D. et al. 2010. Smart Investments in Sustainable Food Production: Revisiting Mixed Crop-Livestock Systems. *Science*, 327(5967): 822–825. (also available at https://doi.org/10.1126/science.1183725).

Herrero, M., Havlik, P., Valin, H., Notenbaert, A., Rufino, M.C., Thornton, P.K. et al. 2013. Biomass use, production, feed efficiencies, and greenhouse gas emissions from global livestock systems. *Proceedings of the National Academy of Sciences of the United States of America,* 110(52): 20888–20893. (also available at https://www.pnas.org/content/110/52/20888).

Herrero, M., Henderson, B., Havlik, P., Thornton, P.K., Conant, R.T., Smith, P. et al. 2016. Greenhouse gas mitigation potentials in the livestock sector. *Nature Climate Change*, 6: 452–461.

Herrero, M., Thornton, P.K., Power, B., Bogard, J.R., Remans, R., Fritz, S. et al. 2017. Farming and the geography of nutrient production for human use: a transdisciplinary analysis. *The Lancet Planetary Health*, 1(1): e33–e42. (also available at https://doi.org/10.1016/S2542-5196(17)30007-4).

High Level Panel of Experts on Food Security and Nutrition (HLPE). 2015. *Water for food security and nutrition*. Rome: FAO. (also available at http://www.fao.org/3/a-av045e.pdf).

Hirvonen, K., Bai, Y., Headey, D. & Masters, W.A. 2020. Affordability of the EAT-Lancet reference diet: a global analysis. *The Lancet Global Health*, 8(1): e59–e66. (also available at https://www.thelancet.com/journals/langlo/article/PIIS2214-109X(19)30447-4/fulltext).

Iannotti, L.L. 2018. The benefits of animal products for child nutrition in developing countries. *Revue Scientifique et Technique (International Office of Epizootics)*, 31(1): 37–46. (also available at https://doc.oie.int/dyn/portal/index.seam?page=alo&aloId=36884).

Iannotti, L.L., Lutter, C.K., Bunn, D.A. & Stewart, C.P. 2014. Eggs: the uncracked potential for improving maternal and young child nutrition among the world's poor. *Nutrition Reviews*, 72(6): 355–368. (also available at https://pubmed.ncbi.nlm.nih.gov/24807641/).

Iannotti, L.L., Lutter, C.K., Stewart, C.P., Gallegos Riofrío, C.A., Malo, C., Reinhart, G. et al. 2017. Eggs in Early Complementary Feeding and Child Growth: A Randomized Controlled Trial. *Pediatrics*, 140(1): e20163459. (also available at https://doi.org/10.1542/peds.2016-3459).

Institute of Medicine & National Research Council. 2015. *A Framework for Assessing Effects of the Food System*. Washington, DC: The National Academies Press.

International Agency for Research on Cancer (IARC). 2015. *IARC Monographs evaluate consumption of red meat and processed meat*. Press release. Paris. (also available at https://www.iarc.fr/wp-content/uploads/2018/07/pr240_E.pdf).

Keesing, F., Belden, L.K., Daszak, P., Dobson, A., Harvell, C.D., Holt, R.D. et al. 2010. Impacts of biodiversity on the emergence and transmission of infectious diseases. *Nature*, 468(7324): 647–652. (also available at https://www.nature.com/articles/nature09575).

Kim, K., Kwon, T., Dessie, T., Yu, D., Mwai, O.A., Jang, J. et al. 2020. The mosaic genome of indigenous African cattle as a unique genetic resource for African pastoralism. *Nature Genetics* 52: 1099–1110. (also available at https://doi.org/10.1038/s41588-020-0694-2).

Kimani, J. 2019. *Research helps parents 'give milk' to improve nutrition and livelihoods in Rwanda* [online]. Blog, 15 March 2019. Nairobi: International Livestock Research Institute. https://www.ilri.org/news/research-helps-parents-%E2%80%98give-milk%E2%80%99-improve-nutrition-and-livelihoods-rwanda

Krebs, N.F., Mazariegos, M., Chomba, E., Sami, N., Pasha, O., Tshefu, A. et al. 2012. Randomized controlled trial of meat compared with multimicronutrient-fortified cereal in infants and toddlers with high stunting rates in diverse settings. *American Journal of Clinical Nutrition*, 96(4): 840–847. (also available at https://doi.org/10.3945/ajcn.112.041962).

Kuipers, R.S., Joordens, J.C. & Muskiet, F.A. 2012. A multidisciplinary reconstruction of Palaeolithic nutrition that holds promise for the prevention and treatment of diseases of civilisation. *Nutrition Research Reviews,* 25(1): 96–129. (also available at https://pubmed.ncbi.nlm.nih.gov/22894943/).

Lee, J.E., McLerran, D.F., Rolland, B., Chen, Y., Grant, E.J., Vedanthan, R. et al. 2013. Meat intake and cause-specific mortality: A pooled analysis of Asian prospective cohort studies. *American Journal of Clinical Nutrition*, 98(4): 1032–1041. (also available at https://pubmed.ncbi.nlm.nih.gov/23902788/).

Li, M., Havelaar, A.H., Hoffmann, S., Hald, T., Kirk, M.D., Torgerson, P.R. & Devleesschauwer, B. 2019. Global disease burden of pathogens in animal source foods, 2010. *PLoS One*, 14(6): e0216545. (also available at https://pubmed.ncbi.nlm.nih.gov/31170162/).

Liaset, B., Øyen, J., Jacques, H., Kristiansen, K. & Madsen, L. 2019. Seafood intake and the development of obesity, insulin resistance and type 2 diabetes. *Nutrition Research Reviews,* 32(1): 146-167. (also available at https://pubmed.ncbi.nlm.nih.gov/30728086/).

Lonnie, M., Hooker, E., Brunstrom, J.M., Corfe, B.M., Green, M.A., Watson, A.W., Williams, E.A., Stevenson, E.J., Penson, S. & Johnstone, A.M. 2018. Protein for Life: Review of Optimal Protein Intake, Sustainable Dietary Sources and the Effect on Appetite in Ageing Adults. *Nutrients*, 10(3): 360. (also available at https://pubmed.ncbi.nlm.nih.gov/29547523/).

Machovina, B., Feeley, K.J. & Ripple, W.J. 2015. Biodiversity conservation: The key is reducing meat consumption. *Science of The Total Environment*, 536: 419–431.

Marquardt, S., Ndung'u, P.W., Onyango, A.A. & Merbold, L. 2020. *Protocol for a Tier 2 approach to generate region-specific enteric methane emission factors (EF) for cattle kept in smallholder systems.* ILRI Manual 39. Nairobi: International Livestock Research Institute. (also available at https://cgspace.cgiar.org/handle/10568/109579).

Mehrabi, Z., Gill, M., Wijk, M. Van, Herrero, M. & Ramankutty, N. 2020. Livestock policy for sustainable development. *Nature Food*, 1: 160–165.

Mrode, R., Ojango, J.M.K., Okeyo, A.M. & Mwacharo, J.M. 2019. Genomic selection and use of molecular tools in breeding programs for indigenous and crossbred cattle in developing countries: Current status and future prospects. *Frontiers in Genetics*, 9: 694. (also available at https://www.frontiersin.org/articles/10.3389/fgene.2018.00694/full).

Muehlhoff, E., Bennett, A. & McMahon, D. (eds.) 2013 *Milk and dairy products in human nutrition*. Rome: FAO. (also available at http://www.fao.org/3/i3396e/i3396e.pdf).

Nabarro, D. & Wannous, C. 2014. The potential contribution of livestock to food and nutrition security: The application of the One Health approach in livestock policy and practice. *Revue Scientifique et Technique (International Office of Epizootics)*, 33(2): 475–485. (also available at https://pubmed.ncbi.nlm.nih.gov/25707178/).

National Nutrition Centre Barbados. 2017. *Food based dietary guidelines for Barbados: Revised Edition (2017).* Bridgetown: Barbados Ministry of Health. (also available at http://www.fao.org/3/I9680EN/i9680en.pdf).

Neumann, C.G., Murphy, S.P., Gewa, C., Grillenberger, M. & Bwibo, N.O. 2007. Meat Supplementation Improves Growth, Cognitive, and Behavioral Outcomes in Kenyan Children. *Journal of Nutrition,* 137(4): 1119–1123. (also available at https://academic.oup.com/jn/article/137/4/1119/4664672).

Ndung'u, P.W., Bebe, B.O., Ondiek, J.O., Butterbach-Bahl, K., Merbold, L. & Goopy, J.P. 2018. Improved region-specific emission factors for enteric methane emissions from cattle in smallholder mixed crop-livestock systems of Nandi County, Kenya. *Animal Production Science*, 59(6): 1136–1146. (also available at https://www.publish.csiro.au/AN/AN17809).

O'Neill, J. 2016. *Tackling drug-resistant infections globally: Final report and recommendations*. London: Review on Antimicrobial Resistance. (also available at https://amr-review.org/sites/default/files/160525_Final%20paper_with%20cover.pdf).

OECD & FAO. 2018. *OECD-FAO Agricultural Outlook 2018–2027: Data on meat consumption* [online]. Data spreadsheet. http://dx.doi.org/10.1787/888933741998.

Popkin, B.M. & Reardon, T. 2018. Obesity and the food system transformation in Latin America. *Obesity Review,* 19(8): 1028–1064. (also available at https://pubmed.ncbi.nlm.nih.gov/29691969/).

Provenza, F.D., Kronberg, S.L. & Gregorini, P. 2019. Is Grassfed Meat and Dairy Better for Human and Environmental Health? *Frontiers in Nutrition*. 6: 26. (also available at https://www.frontiersin.org/articles/10.3389/fnut.2019.00026/full).

Quisumbing, A.R., Meinzen Dick, R., Raney, T., Croppenstedt, A., Behrman, J. & Peterman, A. (eds.) 2014. *Gender in agriculture: Closing the knowledge gap*. Dordrecht, the Netherlands: Springer and FAO.

Robinson, T.P., Thornton P.K., Franceschini, G., Kruska, R.L., Chiozza, F., Notenbaert, A. et al. 2011. *Global livestock production systems*. Rome: FAO and ILRI. (also available at http://www.fao.org/3/i2414e/i2414e.pdf).

Rohrmann, S. & Linseisen, J. 2016. Processed meat: the real villain? Proceedings of the Nutrition Society, 75(3): 233–241.

Rohrmann, S., Overvad, K., Bueno-de-Mesquita, H.B., Jakobsen, M.U., Egeberg, R., Tjønneland, A. et al. 2013. Meat consumption and mortality – Results from the European Prospective Investigation into Cancer and Nutrition. *BMC Medicine*, 11: 63 (also available at https://pubmed.ncbi.nlm.nih.gov/23497300/).

Scalbert, A., Brennan, L., Manach, C., Andres-Lacueva, C., Dragsted, L.O., Draper, J., Rappaport, S.M., van der Hooft, J.J. & Wishart, D.S. 2014. The food metabolome: a window over dietary exposure. *American Journal of Clinical Nutrition*, 99(6): 1286–1308. (also available at https://academic.oup.com/ajcn/article/99/6/1286/4577352).

Senthong, V., Wang, Z., Li, X.S., Fan, Y., Wu, Y., Tang, W.H.W. & Hazen, S.L. 2016. Intestinal microbiota-generated metabolite trimethylamine-N-oxide and 5-year mortality risk in stable coronary artery disease: the contributory role of intestinal microbiota in a COURAGE-like patient cohort. *Journal of the American Heart Association,* 5(6): 1–7. (also available at https://pubmed.ncbi.nlm.nih.gov/27287696/).

Seré, C. & Steinfeld, H. 1996. *World Livestock Production Systems, Current Status, Issues and Trends*. FAO Animal Production and Health Paper, No. 127. Rome. (also available at http://www.fao.org/3/a-w0027e.pdf).

Smil, V. 2013. *Should We Eat Meat? Evolution and Consequences of Modern Carnivory*. Hoboken, NJ: John Wiley and Sons.

Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B.L., Lassaletta, L. et al. 2018. Options for keeping the food system within environmental limits. *Nature*, 562(7728): 519–525.

Steinfeld, H., Gerber, P., Wassenaar, T. & Castel, V. 2006. Livestock's long shadow – environmental issues and options. Rome: FAO. (also available at http://www.fao.org/3/a0701e/a0701e.pdf).

Stewart, C.P., Caswell, B., Iannotti, L.L., Lutter, C., Arnold, C.D., Chipatala, R., Prado, E.L. & Maleta, K. 2019. The effect of eggs on early child growth in rural Malawi: the Mazira Project randomized controlled trial. *American Journal of Clinical Nutrition*, 110(4): 1026–1033. (also available at https://academic.oup.com/ajcn/article/110/4/1026/5544362).

Thornton, P.K., Kruska, R.L., Henninger, N., Kristjanson, P.M., Reid, R.S., Atieno, F., Odero, A.N. & Ndegwa, T. 2002. *Mapping poverty and livestock in the developing world*. Nairobi: ILRI. (also available at https://cgspace.cgiar.org/handle/10568/915).

Tirado-von der Pahlen, C. 2017. *Sustainable Diets for Healthy People and a Healthy Planet*. UNSCN Discussion Paper. Rome: United Nations System Standing Committee on Nutrition. (also available at https://www.unscn.org/uploads/web/news/document/Climate-Nutrition-Paper-EN-WEB.pdf).

United Nations Environment Programme (UNEP) & International Livestock Research Institute (ILRI). 2020. *Preventing the next pandemic: Zoonotic diseases and how to break the chain of transmission*. Nairobi: UNEP. (also available at https://www.unenvironment.org/resources/report/preventing-future-zoonotic-disease-outbreaks-protecting-environment-animals-and).

United Nations System Standing Committee on Nutrition (UNSCN). n.d. *The UN Decade of Action on Nutrition 2016–2025: ILRI commits to the Nutrition Decade* [online]. Rome. [Last accessed 28 November 2020]. https://www.unscn.org/en/topics/un-decade-of-action-on-nutrition?idnews=1998

UNSCN. 2017. *By 2030, end all forms of malnutrition and leave no one behind*. UNSCN Discussion Paper. Rome. (also available at https://www.unscn.org/en/unscn-publications?idnews=1674).

UNSCN. 2020. *Water and Nutrition: Harmonizing Actions for the United Nations Decade of Action on Nutrition and the United Nations Water Action Decade.* UNSCN Discussion Paper. Rome. (also available at https://www.ifpri.org/publication/water-and-nutrition-harmonizing-actions-united-nations-decade-action-nutrition-and).

United States Department of Agriculture (USDA) & United States Department of Health and Human Services (DHHS). 2015. Scientific report of the 2015 Dietary Guidelines Advisory Committee. Washington, DC. (also available at https://health.gov/sites/default/files/2019-09/Scientific-Report-of-the-2015-Dietary-Guidelines-Advisory-Committee.pdf).

Vanderhout, S.M., Aglipay, M., Birken, C., Li, P., O'Connor, D.L., Thorpe, K. et al. 2020. Cow's Milk Fat Obesity pRevention Trial (CoMFORT): a primary care embedded randomised controlled trial protocol to determine the effect of cow's milk fat on child adiposity. *BMJ Open*, 10(5): e035241. (also available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7228521/).

Wang, X., Lin, X., Ouyang, Y.Y., Liu, J., Zhao, G., Pan, A. & Hu, F.B. 2016. Red and processed meat consumption and mortality: Dose-response meta-analysis of prospective cohort studies. *Public Health Nutrition*, 19(5): 893–905. (also available at https://pubmed.ncbi.nlm.nih.gov/26143683/).

Wessells, K.R. & Brown, K.H. 2012. Estimating the global prevalence of zinc deficiency: results based on zinc availability in national food supplies and the prevalence of stunting. *PloS One,* 7(11): e50568. (also available at https://pubmed.ncbi.nlm.nih.gov/23209782/).

Willett, W., Rockström J., Loken, B., Springmann, M., Lang, T., Vermeulen, S. et al. 2019. Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. *The Lancet,* 393(10170): 447–492. (also available at https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(18)31788-4/fulltext).

World Health Organization (WHO). 2014. *Global Nutrition Targets 2025: Policy brief series*. Geneva, Switzerland. (also available at http://www.who.int/nutrition/publications/globaltargets2025_policybrief_overview/en/).

WHO. 2019. *REPLACE Trans Fat: An action package to eliminate industrially produced trans-fatty acids.* Geneva, Switzerland. (also available at https://www.who.int/docs/default-source/replace-transfat/1-replace-framework-updated-june-2019-ke.pdf).

WHO. 2020. Healthy diet: Key facts [online]. Geneva, Switzerland. [Last accessed 28 October 2020]. https://www.who.int/news-room/fact-sheets/detail/healthy-diet

Wolk, A. 2017. Potential health hazards of eating red meat. *Journal of Internal Medicine*, 281: 106–122. (also available at https://pubmed.ncbi.nlm.nih.gov/27597529/).

Zeisel, S.H. & da Costa, K. 2009. Choline: an essential nutrient for public health. *Nutrition Reviews*, 67(11): 615–623. (also available at https://pubmed.ncbi.nlm.nih.gov/19906248/).

Acronyms

AFOLU	Agriculture, Forestry and Other Land Use
BRICS	Brazil, Russia, India, China and South Africa
COVID-19	Coronavirus disease 2019
DHA	Docosahexaenoic acid
DHHS	United States Department of Health and Human Services
GBD	Global Burden of Disease (group)
GFSP	Global Food Safety Partnership
GHG	Greenhouse gas
H1N1	Swine flu
HLPE	High Level Panel of Experts on Food Security and Nutrition
HPAI	Highly pathogenic avian influenza
IARC	International Agency for Research on Cancer
IFAD	International Fund for Agricultural Development
ILRI	International Livestock Research Institute
IPCC	International Panel on Climate Change
LMICs	Low- and middle-income countries
MERS-COV	Middle East respiratory syndrome coronavirus
OECD	Organisation for Economic Co-operation and Development
SARS	Severe acute respiratory syndrome
SDG	Sustainable Development Goal
SOFI	State of Food Security and Nutrition in the World
TMA	Trimethylamine
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund
UNSCN	United Nations System Standing Committee on Nutrition
USDA	United States Department of Agriculture
WHA	World Health Assembly
WHO	World Health Organization

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