Appendix to "A Restatement of the Protein Transition"

This Appendix presents the evidence base surrounding a protein transition in a list of numbered statements structured into three main sections. Each statement is organised as follows: the numbered sections provide a synthesis of the relevant scientific evidence, and the lettered subsections offer detailed information and supporting references for each piece of evidence. It starts with a background section covering what proteins are and why they are needed, as well as a short historical perspective on the focus on protein. The second section focuses on the social, political, occupational health and economic contexts currently shaping the protein transition landscape in the EU. Finally, the last section focuses on the impacts of a protein transition on various sustainability dimensions including human health, environment, animal health and welfare, and the economy. The terms that are used in this Restatement are defined in Box1 in the main paper. Throughout this Restatement, footnotes are used to explain or clarify technical terms that are highlighted in red. Finally, cross referencing is used between the statements to emphasise related dimensions of the protein transition.

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1. Background

1.1. What is protein and why is it needed?

(1) Protein is a vital macronutrient crucial for human health, playing a key role in growth, development, maintenance, and repair of bodily tissues and systems (Lumsden et al., 2024). Protein is made up of amino acids: twenty different amino acids make up the proteins found in the human body and nine of those are classified as indispensable because the human body cannot synthesize them (Lumsden et al., 2024). These **indispensable amino acids**[1] must be obtained through dietary sources. The nutritional quality of a protein food is assessed by its ability to provide all the indispensable amino acid requirements. The quality, amount, and composition of protein can vary significantly between different animal and plant-based foods. This variability will be discussed further in Statements (29) and (32)

(2) For centuries, Europeans have primarily relied on cereals and pulses as their main dietary protein sources (Popkin, 1993, 2006). However, the post-war era witnessed a significant and rapid increase in animal protein consumption, with, for example, a doubling in per capita consumption of aquatic animal-based protein today compared to the 1960s (FAO, 2022). These products quickly transitioned from being occasional luxuries to convenient, everyday staples, reshaping dietary habits and food cultures (Moberg et al., 2020; Vijver, 2005). Over the past two decades, growing concerns about their environmental impacts, animal welfare, and the equitable distribution of food in the context of a rising global population have placed increasing focus on the sources of protein in our diet (Duluins & Baret, 2024a). This has contributed to the emergence of a novel protein sector (Box 1 in the main paper). However, it remains debatable whether this development has been primarily driven by shifts in consumer demand or by the introduction of new offerings in the market.

(3) Protein-rich foods constitute a wide range of different types of foods from different sources, and subject to different levels of processing (Figure 1). These foods are also highly variable in their protein content, and thereby the amount needed to be consumed to reach the daily protein recommendation of 58 grams per day for a 70 kg weighing adult (EFSA, 2012; Figure 1). It should be noted that protein quality (Statement (29)b)) is not

[1] An indispensable amino acid, also known as an essential amino acid, is an amino acid that the human body cannot synthesize on its own in sufficient quantities and must, therefore, be obtained through the diet.

taken into consideration in the amount needed to be consumed for reaching the daily recommendation.

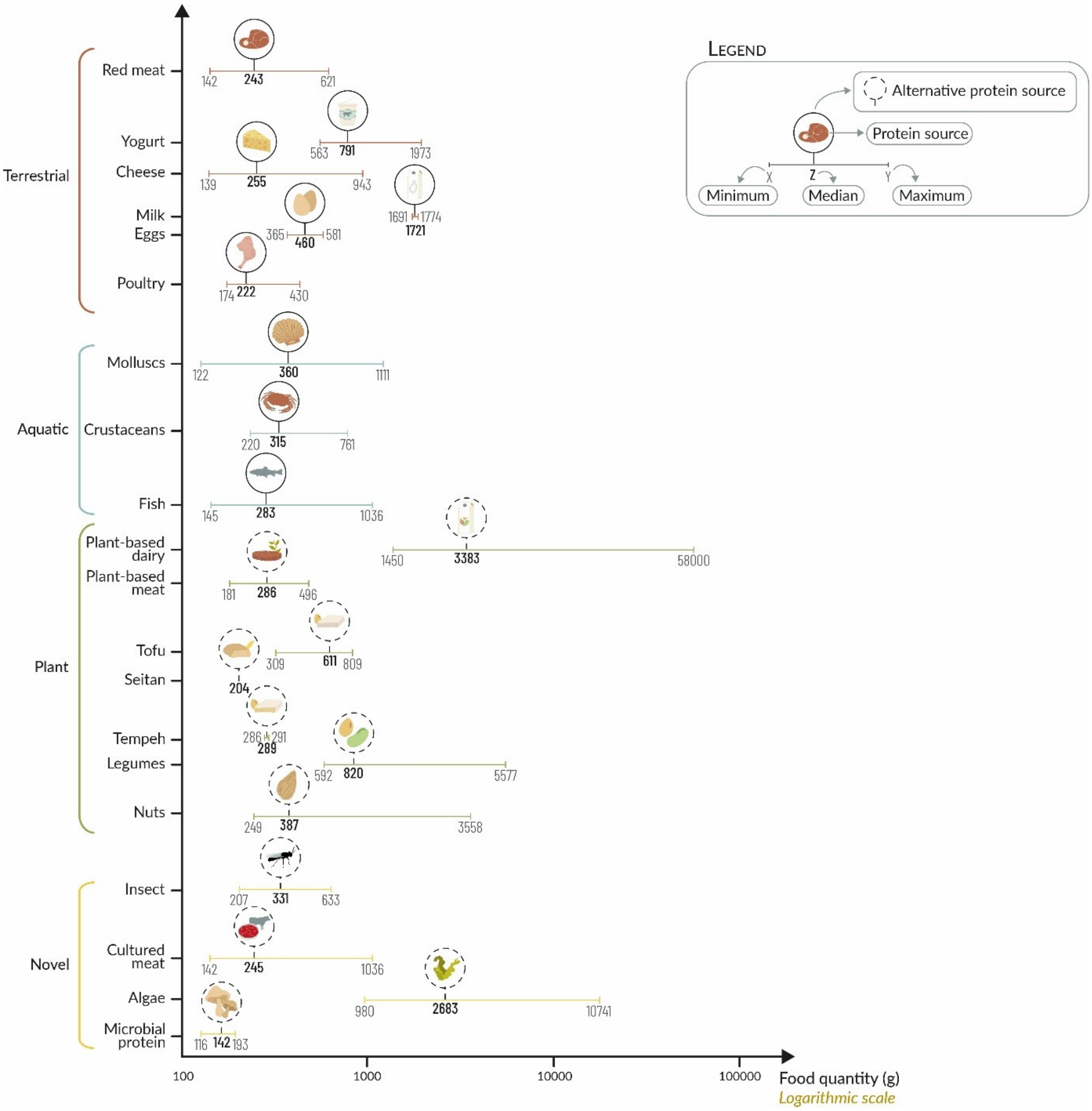

Figure 1: Food quantity (g) required per food type to meet a recommended daily intake of 58 grams for a 70 kg adult (EFSA, 2012). The range reflects the diversity of products within each food type, with the minimum and maximum representing the product with the highest and lowest protein content, respectively, and the middle value representing the mean of all products (protein contents were all based on fresh matter and taken from Anupama & Ravindra, 2000; Parodi et al., 2018; RIVM, 2025; USDA, 2025).

1.2. Historical perspective: The focus on protein is nothing new

(4) In the mid-20th century, international organisations, nation-states, and non-governmental organisations (NGOs) took a particular interest in protein, driven by fears of global protein shortage and a lack of individual protein intake, especially in low-income countries (K. J. Carpenter, 1986). This period, known for its focus on protein deficiencies such as kwashiorkor in children, saw protein emerge as a primary target for nutritional research and intervention programs (Guthman & Biltekoff, 2023). The concept of a “world protein gap” positioned protein as a solution to global hunger and undernutrition. During this period, protein was elevated to the status of a "charismatic nutrient," a term used to describe nutrients that gain a special cultural and political authority (Guthman & Biltekoff, 2023). This charisma was not only based on its nutritional value but also on the socio-political narratives that framed it as essential for feeding a growing population and respecting individual dietary needs (Blaxter & Garnett, 2023; Guthman & Biltekoff, 2023). However, this period also saw the "great protein fiasco", where the focus on protein in development programs led to misguided solutions that failed to address the broader nutritional needs, highlighting the limitations of reducing food to its macronutrient content (K. J. Carpenter, 1986; Mclaren, 1974).

(5) Today, protein remains a dominant focus in debates around health, fitness, and several dimensions of sustainability (Sexton et al., 2019). In high-income countries, the obsession with protein is evident in diet culture, where it is marketed as a vital nutrient for weight management, muscle building, and overall health (Wilson, 2019). While this paper will focus on EU countries, protein remains critically important in low-income settings, where access to sufficient dietary protein is often low (McCullough et al., 2024). The environmental impacts of animal-based protein, in particular, have become a significant concern, leading to debates about sustainable protein sources and the promotion of plant-based and novel proteins (Janin et al., 2023). Aquatic animal-based protein is, however, often omitted or inadequately addressed in these discussions, but when considered, may play a variety of roles due to vast differences in environmental impacts and nutrient content between aquatic species and production methods (Farmery et al., 2017; Koehn et al., 2022). Today, protein still holds a status as a "heroic" nutrient, largely unscathed by the critiques that have befallen other macronutrients like fats and carbohydrates (Guthman & Biltekoff, 2023). Lastly, the narrative of a world protein gap due to increasing demand is still highly used by many actors to justify existing practices and the development of additional protein sources (Duluins & Baret, 2024b).

2. Socio, political and economic contexts shaping the protein transition in the EU

This section describes the European social, political, and economic contexts within which the protein transition unfolds. It also aims to put forward the enabling and disabling factors that facilitate or hinder the protein transition. This section focuses on transitions that operate within the boundaries of current systems, regimes, and paradigms rather than challenging or reimagining these structures. Alternative visions for the future of food, such as agroecology and food sovereignty, might critique this approach, arguing that addressing systemic lock-ins requires more transformative changes.

2.1. Economic context

Economic protein landscape

(6) The European livestock sector remains a critical pillar of the EU agricultural economy, with key contributions from the pig, dairy, cattle, and poultry sectors. However, structural shifts are evident, with declining livestock farms and concentration on larger-scale holdings. In parallel, European **capture fisheries and aquaculture**[2] supply a significant share of seafood products, although dependence on imports is increasing, with production concentrated in specific member states. Meanwhile, dietary shifts and the rise of alternative protein markets are reshaping the food industry, attracting major players from both traditional meat and large food corporations.

a) The livestock sector is a cornerstone of the EU agricultural economy (Pais et al., 2020), contributing approximately €214 billion in production value in 2023, representing 39.8% of the total agricultural economy (Eurostat, 2024b). In 2023, the pig and dairy sectors were the most significant contributors to the production value, accounting for 9.2% and 13.9%, respectively, of the 39.8% total from the animal sector. Other significant contributors included cattle (6.6%), poultry (5.0%), and eggs (3%) (Eurostat, 2024b). Although most of the seafood consumed in Europe is imported (Bell et al., 2018), European fisheries and aquaculture contribute up to 38% to the supply of seafood products in the European Union (EUMOFA, 2024).

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[2] Capture fisheries refer to harvesting aquatic organisms from oceans, seas, rivers and lakes, while aquaculture is the practice of raising aquatic organisms for food in a controlled environment.

b) In 2020, the EU had 4.1 million agricultural holdings with livestock, representing 44.9% of all farms (Eurostat, 2020). Of these, 21.6% are specialised in livestock production, with specialist dairy farms (5.1%) and specialist cattle-rearing (4.2%), and fattening (4.2%) the most numerous (Eurostat, 2023). This figure represents a decline from 2010, where 55.7% of farms had livestock, reflecting broader structural shifts in European farming (European Commission, 2024i). Larger-scale farms accounted for a substantial share of the total livestock population, showing a clear trend towards the concentration of livestock production on fewer but larger holdings (Eurostat, 2022). In 2020, it is estimated that 39% of LSU are found on the biggest farms (over 100ha), while 21% of LSU are found on farms under 10ha (Eurostat, 2022). This concentration can be characterised by livestock density, which measures "the stock of animals converted in **livestock units**[3] per hectare of utilised agricultural area" (Eurostat, 2022). In 2020, the average livestock density in the EU was 0.7 LSUs per hectare of UAA. This figure varied significantly across member states, with the highest value in the Netherlands (3.4 LSU/ha), and the lowest in Bulgaria, Latvia and Lithuania (0.2 LSE/ha) (Eurostat, 2022).

c) In 2022, the total production value of EU fisheries, including both landings and aquaculture, was estimated at around €11.6 billion (Eurostat, 2025a). Specifically, the value of aquaculture production alone was approximately €4.8 billion, with EU aquaculture production mainly focused on finfish species (e.g., trout, seabream, seabass, carp, tuna) and molluscs (e.g., mussels, oysters, and clams) (Eurostat, 2025a). The EU's fisheries sector produced about 4.2 million tonnes of aquatic animals, with landings contributing 3.1 million tonnes and aquaculture 1.1 million tonnes (Eurostat, 2024d). Aquaculture is concentrated in four countries that account for ~70% of total

[3] The livestock unit, abbreviated as LSU (or sometimes as LU), is a reference unit which facilitates the aggregation of livestock from various species and age as per convention, via the use of specific coefficients established initially on the basis of the nutritional or feed requirement of each type of animal.
The reference unit used for the calculation of livestock units (=1 LSU) is the grazing equivalent of one adult dairy cow producing 3 000 kg of milk annually, without additional concentrated foodstuffs (Eurostat, 2025b).

aquaculture production in the EU: Spain, France, Greece and Italy (Eurostat, 2025a). Wild capture fisheries mainly come from Spain, Denmark, France, the Netherlands and Ireland (EUMOFA, 2024).

d) The shift in dietary preferences and the rise of novel protein substitutes have resulted in a new market structure for alternative proteins. While it initially gained momentum through a surge of innovative startups, it is now witnessing increasing involvement from major players in the meat industry (e.g., Vion Food Group (Netherlands) and large food corporations such as Danone (including Alpro), Unilever (including the Vegetarian Butcher and Nestlé (Good Food Institute, 2024a; Guthman et al., 2022; Lurie-Luke, 2024). For seafood, commercial fisheries are shifting their attention to aquaculture (Cleaver et al., 2024; Uzunca & Li, 2018). There are concerns that cell-based meat will be monopolised by large meat industry players (Howard et al., 2021; Santo et al., 2020; Sholar, 2025).

(7) The Common Agricultural Policy (CAP) shapes the EU livestock sector's profitability through direct subsidies, **coupled income support**[4] for ruminants, and targeted rural development programs. Many farms, especially cattle operations, heavily rely on CAP payments, which account for a substantial share of their income. Fisheries and aquaculture also benefit from subsidies through the European Maritime, Fisheries and Aquaculture Fund. Protectionist measures, such as tariffs and sanitary trade barriers, further bolster EU livestock producers by restricting imports and maintaining high domestic prices, particularly for beef, while dairy faces global price competition due to export dependency.

a) The CAP plays a central role in shaping profitability in the livestock sector. Under Pillar 1, direct income subsidies provide significant support, particularly for larger farms. While most payments are decoupled from production levels, 13–15% of Pillar 1 funds remain coupled to sectors deemed vital for agricultural diversity, notably ruminant production systems such as beef, dairy, and sheep farms (Guyomard et al., 2021). In contrast, pig and poultry production systems do not receive coupled support from CAP. Furthermore, CAP's Pillar 2

[4] Coupled payments are subsidies provided to farmers that are directly linked to the production of specific agricultural products (Guyomard et al., 2021)

directs approximately 60% of its funds toward livestock farms, particularly in less-favoured areas, through programs like the Areas of Natural Constraints and Agri-Environment and Climate Schemes (European Commission, 2021b). The CAP also incentivises protein crop cultivation by offering Coupled Income Support and eco-schemes to promote leguminous crops (European Commission, 2024i).

b) The European Union (EU) provides substantial subsidies for its fisheries and aquaculture sectors through the European Maritime, Fisheries and Aquaculture Fund which allocates approximately €6 billion for the 2021–2027 period (European Parliament, 2024b). The fund, largely managed in collaboration with Member States, supports areas such as fleet modernisation (under strict conditions to prevent overcapacity), cessation of fishing activities, and the development of sustainable aquaculture (European Parliament, 2024b). In addition to the European Maritime, Fisheries and Aquaculture Fund, the EU allocates €1 billion for the external dimension of its Common Fisheries Policy (CFP), funding multilateral agreements and partnerships like the Sustainable Fisheries Partnership Agreements (Skerritt et al., 2020). Lastly, the EU fisheries sector benefits from fuel tax exemptions, with the EU fleet consuming 1.9 billion litres of fuel, accounting for an estimated cost of €700 million (European Parliament, 2022). Over time, EU subsidies have increasingly shifted away from fleet expansion and toward promoting environmental sustainability, conservation, and diversification, reflecting a broader commitment to balancing economic resilience with environmental stewardship (Skerritt et al., 2020).

c) Research indicates that the economic performance of many farms relies heavily on receiving CAP payments (Duluins et al., 2022; Guyomard et al., 2021; Muñoz-Ulecia et al., 2021). Specialist cattle farms are highly dependent on subsidies to remain profitable, with subsidies accounting for 66% of their gross income in 2020 —the highest among livestock farms. In comparison, specialist sheep and goat farms, dairy farms, and pigs and poultry relied on subsidies for 31%, 13% and 4% of their gross income, respectively (*FADN Public Database SO*, 2024)**.** Mixed farms showed moderate dependency, with subsidies constituting 31% of gross income for mixed livestock farms and 39% for mixed crops and livestock farms, most of which are based on ruminant livestock operations (*FADN Public Database SO*, 2024).

d) Despite a general shift toward market-oriented agricultural policies in recent decades, the EU continues to apply protectionist measures, particularly in the beef and dairy cattle sector (Adams et al., 2024). High tariffs restrict imports and protect domestic production, allowing European livestock farmers to maintain higher prices within EU markets (Guyomard et al., 2021; Matthews, 2020). **Single Commodity Transfers**[5] for beef indicate consistently high levels of protection, with market price support reflecting the substantial gap between EU market prices and global prices. In contrast, protection for pork has been negligible or negative for some years. The dairy sector, while benefiting from high tariff protection, operates differently—its strong export orientation means that EU market prices are effectively determined by global prices, rendering high tariff protection less impactful in practice (OECD, 2023).

e) Trade barriers in the form of sanitary measures also play a significant role in restricting competition for EU livestock products (European Commission, 2024h, 2024b). These measures are designed to protect human, animal, and plant health by preventing the spread of pests and diseases. For instance, strict regulations related to foot and mouth disease severely limit beef imports into the EU, and similar restrictions apply to pork and poultry due to African swine fever and avian flu, respectively (European Commission, 2024g, 2024a).

(8) Europe's dependence on protein feed imports, particularly soybeans, stems from historical trade agreements like the Dillon Round and the Blair House Agreements, along with policies prioritising cereal production. This dependence, coupled with the high demand for animal feed, has made Europe heavily reliant on protein imports to sustain its livestock population. These imports compound the pressure on EU agricultural land, much of which is already dedicated to feed production, either as grasslands or cultivated crops. Similarly, the EU imports about two-thirds of its seafood products to meet demand, prompting initiatives for increased domestic production of protein-rich crops and sustainable aquaculture expansion.

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[5] A single commodity transfer refers to a transaction or movement involving only one type of good or product–a single commodity–being transferred from one party or location to another.

a) The Dillon Round of the General Agreement on Tariffs and Trade in the 1960s granted the U.S. duty-free access to European markets for oilseeds, and the 1992 Blair House Agreement further restricted EU domestic support for oilseed and protein-rich crops (Bertheau & Davison, 2011). While agreements like the Blair House Agreement limited crop-specific subsidies for oilseeds rather than the overall cultivation area, other factors—such as the competitiveness of protein-rich crops in many European regions and the restriction on GM soybean varieties—have also contributed to limited local production, and more specifically low areas dedicated to protein-rich crops as a share of the agricultural land (Bertheau & Davison, 2011; Magrini et al., 2016).

b) Additionally, the EU's focus on cereal production, supported by intervention prices and import tariffs, led to limited domestic production of oilseeds, further increasing Europe's dependence on imports (Blandford & Tangermann, 2021; Boger, 1984). The livestock sector in Europe consumes about 72 million tons of protein feed annually, including cereal and protein-rich crops. Around 25% of this feed (corresponding to 18 million tons of protein) is imported, with a significant part being soybean (Statement (8c)) (European Commission, 2024i).

c) Today, the EU imports approximately 11.3 million tons of protein coming from soybeans annually (corresponding to around 20 million tons of soybeans), which are predominantly used for animal feed. This is a reliance that the European Commission and Parliament are actively seeking to reduce through domestic production initiatives (European Commission, 2018, 2024i).

d) Since the 1960s, the monogastric livestock sectors, particularly chickens and swine, have experienced significant growth. Between 1961 and 2021, the population of chickens increased by 104%, while swine populations grew by 50% in the EU (FAOSTAT, 2024b). This expansion has driven a higher demand for feed, intensifying the competition between food and feed for land use as monogastric cannot feed on grass and thus depend on crops that could be directly used for human consumption (Karlsson et al., 2021). In 2024, 67% of the protein produced from domestically grown crops in the EU was allocated to animal feed

(European Commission, 2024i).. This notably includes crops such as cereals, oilseeds, and pulses, (European Commission, 2024i).

e) Approximately two-thirds of the available seafood products in the EU are imported to meet current demand. However, even dietary recommendations for seafood consumption (Statement (34)d)) cannot be supplied nationally in more than half of the countries in Europe (Lofstedt et al., 2021).

(9) The protein-rich crop sector in Europe faces the challenges of underdeveloped value chains, limited economies of scale, low investment, and limited research attention in agronomic research and breeding. Therefore, farmers favour traditional crop production systems of cereals and oilseeds for food and animal feed over protein-rich crops. To overcome these challenges, EU and national governing bodies are increasingly allocating funds to research and innovation for these crops. Dietary changes and valuing certain crops beyond their economic returns can support the attractiveness of protein-rich crops.

a) European protein-rich crop value chains remain underdeveloped and comparatively less profitable for producers and actors in the value chain, particularly due to limited economies of scale, insufficient investment in agronomic research, and competition from imported soybeans (Balázs et al., 2021; Bues et al., 2013; European Commission, 2024i; Magrini et al., 2016). The small agricultural area dedicated to protein-rich crops (less than 2%) further restricts economies of scale, perpetuating a **technological lock-in**[6] where low production discourages investment in areas such as breeding, agronomic research, and processing infrastructure (Bues et al., 2013; European Commission, 2024i). This creates a threshold effect across the production and value chain, where protein-rich crop value chains face challenges in establishing themselves within the broader agricultural system. They struggle to achieve competitiveness as the financial returns across the value chain are insufficient to make these crops profitable compared to more established sectors (European Commission, 2024i).

[6] A technological lock-in occurs when an economy, industry, or society becomes dependent on a specific technology, making it difficult to transition to alternative options.

b) Increasing the share of locally produced protein-rich crops for food and feed purposes has been clearly stated multiple times by the European authorities, including the Parliament and the Commission (European Commission, 2018, 2024i; European Parliament, 2023a). This notably explains that research and development funds at European and national levels are increasingly directed toward research and innovation, not only in protein-rich crops for food and feed but also in novel proteins for broader applications (European Commission, 2024i).

c) Breaking the lock-in with traditional crop production systems remains challenging, as protein-rich crops are not yet as profitable or attractive to EU farmers as cereals and oilseeds (Richthofen et al., 2006). Farmers often report lower returns from crops like legumes, which lack the funding and market infrastructure that have historically supported cereals and oilseeds like rapeseed. Established cereal supply chains, being more lucrative and stable, are often favoured for both food and feed, further constraining the growth and competitiveness of the protein crop sector (Balázs et al., 2021; Bues et al., 2013). While investment in breeding programs, agronomy, and market development could enhance the competitiveness of protein-rich crops, climatic and soil conditions must also be considered (Sellami et al., 2019; Vollmann et al., 2000).

d) Dietary changes that reduce the consumption of animal products lead to a decrease in the demand for land used to produce feed while increasing the demand for land used to grow plant-based foods, including protein-rich crops (Röös et al., 2017). However, the land required for plant-based food production is generally lower than that needed for livestock feed, as producing 1 kg of terrestrial animal protein typically requires around 6 kg of plant protein (Aiking, 2014). Reducing feed protein imports without corresponding dietary adaptations could require reallocating land use, potentially increasing the share of agricultural land dedicated to feed production. This shift might involve replacing high-yield crops, such as wheat, with protein-rich crops, potentially decreasing overall agricultural efficiency (Freund et al., 2025). On a global level, this land-use adjustment could increase pressure on land as wheat production moves to less climate-efficient regions, potentially intensifying environmental impacts (Freund et al., 2025; Sellami et al., 2019).

e) While much of the scientific literature highlights the limited presence of protein-rich crops in cropping systems despite their environmental and nutritional benefits (Magrini et al., 2016), these discussions often frame the issue narrowly around profitability and agro-industrial pathways. Alternative pathways could include local, small-scale, or agroecological approaches that value multifunctional systems (Mawois et al., 2019).

2.2. Political context and power dynamics

(10) Agricultural and fisheries policies have been central to **European integration**[7] since its inception in the 1950s, reflecting a broader effort to unify the continent politically, economically, and socially. This integration was built on shared institutions, policies, and legal frameworks aiming to foster peace, stability, and cooperation in the post-war era. The establishment of the Common Agricultural Policy (CAP) in 1962 and the Common Fisheries Policy (CFP) in 1983 marked significant milestones, ensuring food security, stabilizing markets, and supporting aquaculture and agriculture.

a) Since the creation of the single market in the 1980s, several political domains influencing the food system—such as trade, fisheries, food safety, animal welfare, and environmental and climate policy—have become increasingly integrated at the European level (Jackson et al., 2020).

b) The CAP was established in 1962 as a cornerstone of European integration, aiming to ensure food security, stabilize markets, and improve agricultural productivity in the aftermath of World War II (European Commission, 2024k). It marked the beginning of a unified approach to agriculture within the European Economic Community , fostering economic development while supporting farmers through subsidies and market interventions (European Commission, 2024k).

c) Fishing policy entered EU law in 1958 through the Treaty of Rome, which was highly connected to agricultural policy, aiming at increasing

[7] European integration refers to the process through which European countries have increasingly coordinated and unified their policies, institutions, and economies to promote peace, stability, and prosperity across the continent. It involves deepening collaboration among European nations, particularly through the creation and development of supranational organizations such as the European Union (EU).

productivity, stabilising markets, providing healthy food and ensuring reasonable prices for consumers. The CFP, more focused on the conservation and management of wild stocks, was established in 1983 and has, over time, developed into a separate entity (European Parliament, 2024a). Aquaculture gained significant policy attention in the late 1970s as part of broader efforts to diversify seafood production and reduce reliance on wild fish stocks (European Parliament, 2024a). In 2013, the European Commission adopted strategic guidelines to enhance sustainable growth of aquaculture under the heading of the Blue Growth Strategy (Ulmann & Benros, 2017). This meant reducing administrative burdens, improving access to space and water, increasing competitiveness through innovations and research, and increasing compliance with high standards. Still, the EU aquaculture sector has not grown as intended, so new strategies have been developed in recent years to also align with the European Green Deal and Farm to Fork Strategy (European Commission, 2024c).

(11) Farming has traditionally been treated as an **exceptional sector**[8], receiving subsidies and policy protections to ensure food security, sustain rural livelihoods, and preserve cultural traditions. However, a shift toward agricultural post-exceptionalism emphasises market forces, environmental sustainability, and public health, aligning with the goals of the protein transition. Despite this, reforms often result in policy layering rather than transformative change, maintaining the influence of established agricultural frameworks and lobbies.

a) Farming has long been regarded as a unique sector deserving special support due to its role in ensuring food security, sustaining rural livelihoods, and preserving cultural traditions (Skogstad, 1998). This preferential treatment, known as agricultural exceptionalism, grants the agricultural sector extensive subsidies, policy protections, and regulatory exemptions not afforded to other sectors (Daugbjerg & Swinbank, 2009). In Europe, this privileged status has been further entrenched by the influence of powerful agricultural and industry lobbies, which have consistently steered reforms toward incremental

[8] Agriculture is regarded differently from most economic sectors in modern societies, considered to contribute to broader national interests and goals and to warrant extensive state intervention, resulting in a movement of "Agricultural exceptionalism" (Daugbjerg & Swinbank, 2009).

adjustments rather than transformative changes (Daugbjerg & Feindt, 2017).

b) In contrast, agricultural post-exceptionalism emphasises prioritising market forces, environmental sustainability, and public health, which aligns with the goals of the protein transition by reducing livestock subsidies and promoting less resource-intensive protein sources like protein-rich crops (Alons, 2017; Daugbjerg & Feindt, 2017). In practice, however, attempts at agricultural policy reform have typically resulted in policy layering — where new objectives are layered on top of existing frameworks without fundamentally transforming them (Daugbjerg & Swinbank, 2016; Feindt, 2010).

(12) The EU's transition towards alternative protein production and consumption is shaped by multiple, sometimes contradictory, objectives outlined in its legislative frameworks. This misalignment arises as policies across various domains—such as agriculture, fisheries, environmental legislation, and trade—fail to fully harmonise in addressing environmental sustainability, economic stability, and social goals.

a) On the one hand, the EU seeks to reduce the environmental, climate, and animal welfare impacts of protein production, particularly from animal production systems. On the other hand, it must balance the goals of safeguarding food security, supporting farmers' incomes, and maintaining the economic sustainability of the agricultural sector. This balancing act is complicated by the fact that several key EU legal frameworks that govern the protein transition are often driven by diverging stated priorities (Adams et al., 2024; Hundscheid et al., 2024). For example, while the CAP primarily focuses on protecting farmer incomes and stabilising agricultural markets—often through subsidies to livestock production—other policies, such as the Effort Sharing Regulation and Habitats Directive, prioritise reducing greenhouse gas emissions and minimising the environmental impacts of intensive farming (Boezeman et al., 2023; De Pue et al., 2017; Guyomard et al., 2021).

b) Following its official objectives in the Treaty on the Functioning of the European Union, the CAP primarily focuses on supporting farmer incomes, stabilising agricultural markets and ensuring low prices for consumers. CAP influences the protein transition by shaping agricultural production systems, subsidies, and research priorities across the EU (European Commission, 2024k).

c) The Common Fisheries Policy (CFP) significantly shapes fisheries production in the EU with a complex array of policy packages. The objectives centre around achieving long-term environmentally sustainable management that is aligned with economic, social, and employment benefits. Many policy objectives support eliminating **overcapacity**[9] and promoting sustainable practices such as using low-impact fishing gear.

d) Although regulated by EU rules for environmental protection and health, the EU aquaculture sector only has non-binding strategic guidelines, adopted in 2013, focusing on increasing the availability of nutritious, healthy, and tasty aquatic food with low environmental impact while creating economic opportunities and jobs (European Commission, 2024c).

e) Environmental legislation in the EU, much of which was introduced during the 1980s and 1990s, includes key directives such as the Habitats, the Birds, the Nitrates Directive, and frameworks like the Water Framework Directive and the Marine Strategy Framework Directive. These Directives aim to reduce the environmental impacts of fisheries, aquaculture, and agriculture. For example, the Nitrates Directive influences the protein transition by regulating agricultural practices to reduce water pollution caused by excessive nitrogen and nitrate runoff, which primarily originates from intensive livestock farming (Council Directive 91/676/EEC of 12 December 1991 Concerning the Protection of Waters against Pollution Caused by Nitrates from Agricultural Sources, 1991).

f) International agreements, particularly the **COP15 and COP28**[10] agreements, emphasise biodiversity and climate objectives that may

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[9] Overcapacity in the fishing sector refers to a situation where the fishing fleet (boats, equipment, and labor) has the capacity to catch more fish than is sustainable for fish stocks or the marine ecosystem to replenish. This often leads to overfishing, depletion of fish populations, economic inefficiencies, and environmental degradation.

[10] Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change: an international climate summit where global efforts to combat climate change are negotiated.

challenge agricultural, fisheries, and aquaculture production practices (UNFCCC, 2023).

g) The European Climate Law (Reg. (EU) 2021/1119) and the Nature Restoration Law (Reg. (EU) 2024/1991) lay down the goals set out by the EU Green Deal. The EU Green Deal is presented as “a roadmap for Europe to become climate-neutral by 2050” and has led to the adoption of several Directives and Regulations that should guide the EU to reach its climate targets in line with the commitments of the Climate Law (European Commission, 2021c). At the heart of the Green Deal are the Farm to Fork Strategy (European Commission, 2020) and the Biodiversity Strategy (European Commission, 2021a), which aim to align agriculture with broader sustainability targets. The Farm to Fork Strategy, for instance, emphasises the need to shift dietary patterns away from red and processed meats toward more plant-based alternatives, directly supporting the protein transition (European Commission, 2020).

h) The Regulation (EU) 2015/2283 on novel foods has a strong focus on the **precautionary principle**[11]. This regulation governs the approval of novel proteins such as cultured meat and insect-based foods (Regulation (EU) 2015/2283 of the European Parliament and of the Council of 25 November 2015 on Novel Foods, Amending Regulation (EU) No 1169/2011 of the European Parliament and of the Council and Repealing Regulation (EC) No 258/97 of the European Parliament and of the Council and Commission Regulation (EC) No 1852/2001, 2015).

(13) Vertical coherence challenges emerge from the division of responsibilities between the EU and its Member States. While production-side policies are primarily decided at the EU level, many competencies regarding consumption-side policies remain within the remit of national governments. This division is further shaped by the principle of subsidiarity, which allows member states to adapt and implement EU policies according to their national and regional contexts, enabling flexibility but complicating a harmonised approach across the EU.

a) While the EU establishes broad frameworks for production-focused policies like the CAP and environmental regulations, Member States

[11] A risk management approach that applies preventive measures to avoid potential harm to people or ecosystems when full scientific evidence about risks is not yet available.

retain substantial control over demand-side measures that contribute to reshaping physical and social food environments (Schebesta & Candel, 2020). These include food education, fiscal policies (e.g., taxes), public procurement, and regulations shaping consumer behaviour, such as zoning and advertising restrictions (SAPEA, 2023). The ensuing coordination challenge complicates the development of a harmonised food environment that can fully support the protein transition and a broader shift towards a more sustainable food system.

(14) National and local initiatives are key to advancing the protein transition in Europe. Countries like France, Germany, and the Netherlands have adopted strategies to reduce animal-based protein reliance, promote sustainable livestock, and support local protein-rich crops, though adoption varies, with resistance in some regions like Italy. At the local level, cities such as Ghent and Helsinki promote vegetarian meals in public canteens, while several cities has banned meat advertisements, highlighting the complementary role of subnational efforts in driving sustainable food systems.

a) At the national level, Member States such as France, Germany, Finland, the Netherlands, Denmark, and Flanders (Belgium) have introduced strategies to support the protein transition, including a wide range of objectives such as promoting the substitution of animal-based proteins with alternatives in diets, reducing reliance on imported animal-based proteins, promoting local protein-rich crops and value chains, and fostering more sustainable livestock systems (European Commission, 2024i). These efforts also include encouraging shifts towards climate- and animal-friendly farming practices. However, the adoption of these policies varies widely. While some member states have embraced the transition, others have been slower or have resisted it. For instance, Italy's ban on cultivated meats in December 2023 restricted both the production and marketing of lab-grown meat, citing the need to protect traditional food culture and agricultural heritage (Good Food Institute, 2023a). The law also introduced restrictions on labelling plant-based products with traditional meat-related terms like "salami" or "steak". Similarly, France and Austria are witnessing growing resistance to cultivated meat and other novel foods, driven by concerns over their impact on local farming and food traditions (Mambro, 2024).

b) Local-level policies are also playing a crucial role in supporting the protein transition. Cities like Ghent, Freiburg, Grenoble, and Helsinki have introduced vegetarian-only or default vegetarian meals in public canteens on certain days (Keyzer et al., 2012; Lombardini & Lankoski, 2013). At the same time, several cities in the world are banning meat adds. For example, Haarlem become the third Dutch city to implement a ban on meat advertisements, after Utrecht and Amsterdam (Protz, 2025; Wright, 2022). These subnational efforts highlight the importance of local strategies alongside EU-level policies in driving the protein transition across Europe (De Schutter et al., 2020).

(15) To achieve reduced consumption of animal-based foods and increased adoption of plant-based and novel foods, several demand-side policies, including financial, regulatory, informational, and behavioural strategies, can be investigated. Financial measures, such as taxing meat or subsidising plant-based alternatives, show potential but are constrained by limited empirical evidence and variability in price elasticity across products and contexts. Informational and behavioural interventions, like food labelling and nudges, are also frequently proposed but often demonstrate limited or temporary impacts on consumer behaviour. While these approaches hold promise, the lack of robust empirical data makes it challenging to establish a clear consensus on their effectiveness.

a) Financial measures, such as taxing meat or subsidising plant-based alternatives, are suggested to influence food choices and reshape market dynamics (Borthwick & Garnett, 2015). However, the purchasing effects of taxing meat products may be small because the price is not the main determinant influencing food choice for animal foods in high-income countries, and the price elasticity of animal products is variable and depends on the specific product and context (Vellinga et al., 2022). Subsidies of healthier food products such as fruits and vegetables may be effective, with a larger reduction in price showing increasing food purchases (An, 2013; French et al., 2001). In general, interventional studies on the effects of taxes and subsidies are scarce, and thus, solid empirical evidence is lacking (M. Siegrist et al., 2024). Moreover, most evidence on these interventional studies has been gained from modelling studies (e.g., Säll & Gren, 2015). Informational and behavioural interventions, such as food labelling and nudges in public catering, are frequently proposed as strategies to encourage consumers to adopt alternative protein sources (Bryant et al., 2024). However, research has shown that the impact of these interventions is often limited (Baptista et al., 2025; Grundy et al., 2022) or fails to produce lasting behavioural changes (Baptista et al., 2025; Nisa et al., 2019). Moreover, most research is focused on the effects of interventions on attitudes and intentions rather than actual consumption (Kwasny et al., 2022).

(16) Despite the EU's ambitions to accelerate the protein transition by fostering innovation towards more plant-based and alternative proteins, its policies continue to favour animal production systems. The influence of agricultural and industry lobbies, as seen in the pressure placed on the Farm to Fork Strategy, the Common Agricultural Policy and Common Fisheries Policy, highlights how entrenched priorities and frameworks in agricultural policy continue to support animal production and slow progress toward a broader protein transition. Moreover, regulation and restrictions on labelling further impede the market entry and diversification of the protein supply of alternative proteins.

a) The imbalance in public funding is stark, with the livestock sector receiving 1200 times more support than the alternative protein sector (Vallone & Lambin, 2023). This disparity is exacerbated by the **externalisation of environmental costs**[12] in livestock production and the weak enforcement of the "polluter pays" principle (Trinomics et al., 2023). Given that power is manifested largely in the form of capital (Vallone & Lambin, 2023), pathways for disruption will likely require a complex and context-specific combination of financial interventions to interrupt profit streams, such as taxation and the removal of meat subsidies (Baudish et al., 2024; Béné & Lundy, 2023).

b) EU fisheries receive significant subsidies, including fuel tax exemptions, which support energy-intensive practices (Ziegler & Hornborg, 2014). While substantial progress has been made in reforming these subsidies over the past decades, harmful incentives—such as those that encourage overcapacity in fishing fleets—persist (Skerritt et al., 2020).

[12] Externalisation of environmental costs is the practice of not including the costs of negative environmental impacts (e.g., health costs, biodiversity loss, climate change) into the market price of goods and services.

These subsidies not only undermine sustainable fisheries management but also hinder the critical energy transition needed to reduce the sector's environmental impact (Ziegler & Hornborg 2023).

c) Lobbying practices overwhelmingly favour animal protein, significantly shaping existing policy configurations. Lobbying efforts within the livestock industry are well-documented, encompassing strategies such as providing financial incentives to policymakers and advocating for pro-meat policies to shape legislative and regulatory outcomes in their favour . In comparison, lobbying expenditures by trade and non-profit organisations supporting innovation sectors, such as alternative proteins, are considerably smaller—reportedly three times less in the EU (Vallone & Lambin, 2023). This also extends to fishers, where lobbying is a common practice, both by environmental NGOs and the fishing industry (Orach et al., 2017). Inflating fishing quotas during political negotiations to permit higher catch volumes beyond scientific recommendations has been a significant barrier to achieving sustainable fisheries (G. Carpenter et al., 2016).

d) The Farm to Fork strategy and ensuing legislative agenda aimed to promote sustainable food systems, including reducing the environmental footprint of agriculture and encouraging shifts towards plant-based and alternative proteins (European Commission, 2020). However, its dismantling under pressure from agricultural and industry lobbies underscores the deep-rooted influence of the exceptionalist regime, which prioritises the protection of traditional farming practices, particularly livestock production, through subsidies and regulatory safeguards (Matthews et al., 2023). By preserving these protections and diluting efforts to incentivise alternative proteins, the exceptionalist regime effectively blocks meaningful progress toward achieving several dimensions of sustainability, demonstrating its capacity to absorb and weaken policy reforms that threaten the status quo (Matthews, 2024).

e) The scaling of potentially disruptive innovations such as novel proteins is also constrained by market accession procedures, particularly the

Novel Foods Regulation[13], which requires stringent safety assessments for foods not widely consumed before 1997. While the precautionary principle ensures high levels of food safety, existing procedures make innovative products like insect-based or lab-grown foods struggle to get accepted on the EU market, limiting their availability and slowing the diversification of the protein supply (Hermann, 2009).

f) Additionally, regulations restrict the use of dairy-related terms for plant-based alternatives and prohibit labels from using terms like "alternative" or "replacement" when directly referring to the animal-based product they aim to substitute, which is suggested to make it harder for alternative proteins to gain consumer acceptance and compete effectively (Lähteenmäki-Uutela et al., 2021; Leialohilani & de Boer, 2020).

(17) The issue of food access extends beyond considerations of availability (presence of a product) and affordability (referring to the cost of a product) (Statement (22(22)e)) to encompass power imbalances within global food systems. A "justice gap" exists where marginalised and poorer individuals lack equitable access to sufficient, healthy, and culturally appropriate protein sources, while wealthy individuals consume more than they need. Scholars argue that the focus in food sustainability discourse and action should shift from consumer-based strategies such as substituting and reducing animal-based proteins to tackling inequities in food distribution and governance. These include socio-economic disparities, corporate influence and market control, and cultural and positional barriers.

a) Socio-economic disparities and inequalities both within and between countries affect people's ability to access nutritious food, with huge disparities existing in the total global supply of protein (Baudish et al., 2024). Even if food is physically available in lower-income communities or nations, economic constraints often make it unaffordable (Barosh et al., 2014; Costlow et al., 2025). Additionally, the uneven global distribution of resources and infrastructure means some regions face

[13] See Regulation (EU) 2015/2283 of the European Parliament and of the Council of 25 November 2015 on Novel Foods, Amending Regulation (EU) No 1169/2011 of the European Parliament and of the Council and Repealing Regulation (EC) No 258/97 of the European Parliament and of the Council and Commission Regulation (EC) No 1852/2001, 2015.

chronic food insecurity while others waste food at alarming rates (FAO, 2024b). Distributional justice highlights the importance of ensuring that everyone has equitable access to food that is safe, healthy, culturally appropriate, produced under fair labour conditions, and free from environmental harm. Moreover, this food must be sufficient to meet individuals' dietary requirements (Baudish et al., 2024).

b) Large agribusinesses and multinational food corporations wield significant control over the production, distribution, and pricing of food (Clapp & Scrinis, 2017). Through practices such as vertical and horizontal integration, they dominate supply chains, often prioritising profits over equitable access (Guthman et al., 2022) (Statement (18)). Therefore, it is argued that greater emphasis should be put on setting clearly defined regulatory parameters to evaluate alternative proteins against their contribution to the public good (Baudish et al., 2024).

(18) Large agri-food companies increasingly dominate both animal and novel protein markets through strategies such as integration and market concentration, reducing competition and marginalising small-scale producers. This consolidation reflects and reinforces structural power, allowing these corporations to dictate prices, standards, and innovation priorities, raising concerns about reduced market diversity and stifling progress toward equitable food systems.

a) Large agrifood corporations have increasingly consolidated control over both animal and novel protein markets, often sidelining small-scale producers and consumers (Baudish et al., 2024; Fairbairn & Reisman, 2024; Howard, 2022; Österblom et al., 2015; Weis, 2016). They consolidate control through strategies like vertical and horizontal integration, geographical expansion, and concentric diversification (e.g., acquiring alternative protein start-ups) (Baudish et al., 2024). These consolidation strategies lead to market concentration, where a few dominant players hold significant control over livestock, aquaculture and novel protein markets (Baudish et al., 2024; Guthman et al., 2022; Österblom et al., 2015; Pandey et al., 2023; Schutter, 2019). As concentration grows, these corporations shape the market by dictating prices, standards, and innovation priorities, reducing diversity and limiting opportunities for smaller-scale producers to compete (Clapp &

Scrinis, 2017; Fairbairn & Reisman, 2024). As **corporate power**[14] expands, there is growing concern that it stifles technological innovation in sustainable, decentralised food systems, creating a corporate lock-in that restricts the transition toward more equitable and environmentally responsible food practices (Baudish et al., 2024; Sievert et al., 2024).

b) This market dominance generally give major firms an enhanced capacity to exercise political power, allowing these corporations to exert disproportionate influence over food and agriculture governance (Clapp et al., 2025). In concentrated industries, a small number of firms can more easily coordinate to lobby policymakers, fund favorable research, and shape regulatory standards- often through industry associations, public-private partnerships, and strategic participation in global governance platforms (Canfield et al., 2021; Clapp et al., 2025; Fuchs & Kalfagianni, 2010; iPES Food, 2023; Sherrington et al., 2023). This political influence is visible in sectors such as ultra-processed foods and animal agriculture, where dominant firms have shaped narratives around sustainability and nutrition, delayed regulatory actions (e.g., taxes on sugar-sweetened beverages), and promoted voluntary certification schemes that often lack democratic accountability (Hattersley et al., 2020; Lauber et al., 2022).

c) The combination of economic and political power not only entrenches corporate control but also undermines democratic participation and community agency in food systems (Clapp et al., 2025). Corporate lobbying, research sponsorship, and engagement in governance forums risk crowding out the voices of farmers, fishers, scientists, and consumers—particularly those advocating for more equitable, decentralized, and sustainable food systems (Canfield et al., 2021; HLPE-FSN, 2019). While these trends raise concerns about corporate lock-in and shrinking democratic space, they are increasingly being challenged by food sovereignty and agroecology movements, local food initiatives, and community-based governance experiments (Duncan et al., 2021; Hassanein, 2008; Hendrickson et al., 2017). These efforts

[14] Refers to the influence and authority that corporations wield over economic, social, political, and environmental systems.

signal alternative pathways that resist the concentration of market and political power, seeking to re-democratize food systems and reinstate the agency of producers and communities in shaping their food futures (Clapp et al., 2025).

(19) Competing narratives and the spread of (mis)information are critical in shaping perceptions and policies around protein production and consumption, reflecting the exercise of discursive power. Narratives of protein scarcity and food insecurity often drive policies that prioritise increased production, overshadowing issues of equitable distribution and access. Pro-livestock narratives emphasise efficiency and sovereignty to maintain current production systems, while pro-transition narratives present novel proteins as sustainable solutions to global challenges. Disinformation and misinformation, spread by various stakeholders, further complicate the debate by distorting facts to favor traditional or alternative proteins. Promissory narratives framing novel proteins as **silver bullet**[15] solutions risk creating unrealistic expectations, while recycled storylines like 'natural vs. processed' perpetuate entrenched perceptions. Collectively, these dynamics influence market trends, public opinion, and policymaker decisions, often neglecting broader systemic challenges of environmental sustainability and equity.

a) Discursive power refers to the ability to shape perceptions, beliefs, and actions through the use of language, narratives, and communication. It operates by framing ideas, setting agendas, and constructing meanings that influence how issues are understood and addressed (Anderson, 2024). Those wielding discursive power can amplify certain narratives while marginalizing others, thus shaping public opinion, policy decisions, and social norms (Clapp & Scrinis, 2017).

b) Narratives such as protein scarcity or food insecurity can influence policies that prioritise increasing protein production without addressing underlying distribution and access issues (Baudish et al., 2024; Guthman et al., 2022). Pro-livestock status quo narratives, such as those emphasising food security, sovereignty, efficiency, and comparative advantages, tend to support maintaining current livestock production levels (Duluins & Baret, 2024b; Hennessy et al., 2021) or the

[15] A silver bullet solution refers to a simple, single approach or quick fix that is proposed to solve a complex, multifaceted problem, often without addressing its underlying causes or broader context.

consumption of animal-based proteins such as red meat (Wood et al., 2025). In contrast, pro-protein transition narratives frame novel proteins as healthier, more sustainable solutions to health risks, environmental damage, food insecurity, and global protein shortages linked to population growth (Guthman & Biltekoff, 2023; Sexton et al., 2019). These narratives shape not only market dynamics but also public and policymaker perceptions, influencing the feasibility, desirability, and direction of future protein production and consumption systems (Lepore & Cunningham, 2024; Wood et al., 2025).

c) Disinformation refers to false information deliberately disseminated to mislead and manipulate public opinion. It acts as a significant barrier to informed public debate. While disinformation is not unique to the meat sector it is more prevalent compared to the novel protein sector, which is still emerging and has less representation in terms of lobbying efforts and vested interests (Vallone & Lambin, 2023). Disinformation can take various forms, such as downplaying the environmental impact of livestock farming by emphasising technological solutions like improved grazing practices or feed additives (Clare et al., 2022; Wood et al., 2025).

d) Misinformation refers to false or inaccurate information that is shared without the intent to deceive. Misinformation can happen when people share incorrect or incomplete information. It can involve overstating the environmental or health benefits of plant-based alternatives, potentially leading to unrealistic consumer expectations. Both the meat industry, NGOs, and social media influencers often employ similar strategies to shape consumer perceptions, either to favour animal-based proteins or to promote plant-based and alternative proteins (Sexton et al., 2019).

e) Promissory narratives often accompany the marketing and promotion of novel proteins. These narratives frame technological innovation, such as cultured meat, precision fermentation, or genetically engineered plant-based proteins, as “silver bullet” solutions for sustainable food systems (Guthman & Biltekoff, 2021; Hedberg, 2023; Sexton et al., 2019). These promises may neglect to address issues related to scalability, affordability, and broader social acceptance (Sexton et al., 2019).

f) Narratives around protein sources often undergo a process of 'recycling', where certain storylines are repeated across media channels, industry platforms, policy discussions, and scientific debates. For example, the narrative of 'protein scarcity' is frequently invoked (Hayes, 2023; K. Smith et al., 2024), creating a sense of urgency that prioritises increasing production. This focus frequently overshadows broader discussions about creating food systems that are safe, healthy, sustainable, and equitable (Baudish et al., 2024). Similarly, the dichotomy of 'natural meat' versus 'unnatural or processed alternatives' persists in both pro-meat and anti-plant-based rhetoric, fostering entrenched consumer perceptions that are difficult to change (Capper, 2020; Katz-Rosene et al., 2023) (Statements (20)-(24)).

2.3. Consumer considerations: dietary preferences, eating practices, and food environments

(20) Protein intake in Europe varies significantly across countries and regions (Statement (30)(30)) and is shaped by geographic and agricultural factors that shape production and consumption patterns. Choices between different protein sources are also shaped by cultural and socio-demographic factors such as age, social status, gender and religion. Accounting for these dietary preferences is essential for designing effective strategies to promote a protein transition that aligns with local cultural and environmental contexts.

a) Mediterranean countries like Greece, Italy, and Portugal exhibit diets with a more balanced mix of plant and animal proteins (de Boer et al., 2006; Westhoek et al., 2011). Seafood plays a prominent role in these regions, complemented by moderate consumption of red meat, which contrasts with the higher intake of animal proteins in Northern European countries such as the Netherlands, Sweden, and Finland (de Boer et al., 2006; Westhoek et al., 2011). In northern Europe, colder climates and agricultural practices have historically fostered diets rich in dairy products like milk and cheese, along with substantial amounts of meat, particularly pork and beef (de Boer et al., 2006; Westhoek et al., 2011).

b) Protein consumption is deeply intertwined with cultural, social, and gender dynamics, reflecting historical and contemporary systems of power and identity (Baudish et al., 2024). Animal-based proteins, particularly meat, have long been associated with social status and, in some regions, religion (Chiles & Fitzgerald, 2018). Historically, meat has carried significant cultural weight, symbolising identity and power structures, including patriarchy and neoliberalism (Chiles & Fitzgerald, 2018). For example, mid-20th century Western rationing policies reflected a gendered perception that women were “incapable” of handling substantial meat consumption, implicitly encouraging them not to consume it (Baudish et al., 2024). These policies highlighted meat’s role as an enduring symbol of masculinity and racial/national superiority (Chiles & Fitzgerald, 2018). The "real men eat meat" phenomenon, though relatively recent in the empirical literature, (Velzeboer et al., 2024) underscores the connection between meat consumption and masculinity. This association persists into the 21st century, with media often leveraging the cultural power of meat to reinforce traditional gender roles (Parry, 2010; Rogers, 2008). At the consumer level, narratives of change in food reinforcing austerity, individual moral responsibility, and the dichotomy of "good" versus "bad" consumers can reinforce socio-cultural resistance to dietary change (Caraher, 2011; Markowski & Roxburgh, 2019; Resare Sahlin, 2024).

c) Studies that categorise consumers into distinct groups aim to identify patterns in preferences, behaviours, and motivations to understand better and predict dietary choices. These classifications often consider factors such as health consciousness, environmental concerns, cultural traditions, socio-economic status, and openness to innovation (Dagevos, 2021; Verain & Dagevos, 2022). Together, these classifications underscore the diversity in consumer behaviours and motivations, providing a foundation for designing tailored strategies to encourage dietary transitions (Statement (22)).

(21) Historically, rising incomes and urbanisation have driven increased consumption of animal-based proteins as dietary patterns diversify with economic growth. However, emerging evidence challenges the linear relationship between income and meat consumption. Studies suggest that food culture, dietary habits, and societal factors may play a more significant role in shaping protein choices than income. Additionally, research highlights the potential for a nuanced, non-linear relationship, such as the

Kuznets curve, where higher income levels may eventually lead to a reduction in animal-based protein consumption.

a) Historically, the consumption of animal-based proteins has been driven by economic development and urbanisation (Gouel & Guimbard, 2019; Sans & Combris, 2015). Lower-income countries tend to rely on cereal grains and other plant-based proteins as the most affordable and accessible sources of dietary energy (Delgado, 2003; Qaim et al., 2024). As incomes rise, diets tend to diversify, leading to increased consumption of animal-source proteins—a trend consistently observed across all regions of the world (Mathijs, 2015; Qaim et al., 2024). Yet, this income-elastic relationship between income and meat consumption, where meat consumption increases in tandem with rising incomes, has been challenged in the literature, with findings suggesting that food culture and dietary habits, rather than income, are more influential in shaping meat protein choices (Berson, 2019; Cisternas et al., 2024).

b) There is evidence pointing to the idea that animal-based food consumption follows a U-shape with a turning point where a higher income can result in a reduction of animal-based protein consumption, i.e., the so-called Kuznets curve (Milford et al., 2019; Vranken et al., 2014). Yet, other studies show that while there is evidence supporting an inverted U-shaped relationship between income and animal protein consumption, the peak consumption level occurs at such high-income thresholds that economic growth alone may not be sufficient to curb animal protein consumption (Andreoli et al., 2021).

(22) Several factors shape consumer preferences towards different protein sources within present food systems. These factors can be classified under three broad categories—capability (e.g., knowledge and skills), opportunity (e.g., availability and affordability), and motivation (familiarity and taste)— as outlined by the widely recognised COM-B behaviour model. Importantly, these factors often interact in complex ways to influence behaviour.

a) The COM-B model is a behavioural framework that explains how three key categories of factors —Capability, Opportunity, and Motivation— interact to influence behaviour. Capability refers to the physical and psychological ability to perform a behaviour, Opportunity encompasses external factors like the environment or social context that enable or hinder behaviour, and Motivation involves both reflective processes (e.g., planning and goals) and automatic processes (e.g., habits and emotions) that drive actions (Michie et al., 2011; West & Michie, 2020). For a behaviour to occur, all three components must align, making the model a practical tool for designing targeted interventions to promote behaviour change in areas like health, policy, and organizational settings (Daly, 2020).

b) Capability factors/ i) Knowledge and skills: Many consumers lack the necessary information and skills to prepare plant-based meals, which is a barrier to transitioning from meat to plant-based diets, especially when knowledge skills are needed (e.g., how to cook pulses, adequate proportions, ingredient substitutions). Studies indicate that learning new cooking techniques and changing the composition of the plate is often a challenge for individuals shifting to plant-based diets (Biesbroek et al., 2023; Tufford et al., 2023). Additionally, perceived concerns about meeting nutritional requirements and perceived negative health outcomes due to processing often serve as a knowledge barrier (Statement (32)(37)) (Rickerby & Green, 2024; Spendrup & Hovmalm, 2022).

c) Capability factors /ii) Physical Sensitivity: Taste and texture remain influential factors in consumer decisions among different protein sources (Govzman et al., 2021). Consumers prefer protein foods that align with their sensory expectations, which is why so much effort is put into technological innovation and development to design novel proteins to mimic the sensorial characteristics of animal-based foods (Jahn et al., 2021; Michel et al., 2021; Pakseresht et al., 2022). Sensitivity to taste, particularly bitter flavors, has been identified as a factor that may drive some consumers away from vegetable-rich plant-based dishes (Drewnowski & Gomez-Carneros, 2000).

d) Opportunity factors/ i) Social Context and Social norms: Meat consumption holds a central role in food traditions across many European countries. This creates significant barriers to reducing its consumption, as established cultural and culinary practices often prioritize animal-based products as a primary component of meals (Fernqvist et al., 2024; Jahn et al., 2021; Onwezen et al., 2021)

(Statement (20)(20)). In addition, cultural identity and tradition shape protein preferences, with certain foods perceived as emblematic of social and cultural practices. For example, culturally relevant events and rituals, such as barbecues or festive meals, often revolve around animal-based products, making dietary changes more difficult (Daly, 2020). Stereotypes portraying vegans and vegetarians as judgmental or extreme can also be a barrier (Wehbe et al., 2024), with individuals who want to reduce their consumption of animal-based proteins often choosing omnivorous options in social settings to avoid potential stigma from others (Bolderdijk & Cornelissen, 2022). Religious practices and values also influence protein choices, with some faiths, such as Hinduism and Buddhism, promoting plant-based diets and others imposing restrictions on specific meats, such as pork or beef (Major-Smith et al., 2022). Beyond direct dietary restrictions, the influence of cultural norms in maintaining the status quo, where animal-based proteins are often seen as a symbol of wealth or masculinity, further reinforces its role ein the daily diet (Camilleri et al., 2023; Modlinska & Pisula, 2018) (Statment (20)b)). Social pressures, including concerns about deviating from traditional practices or the perceived social acceptability of plant-based and novel proteins, are additional factors that need to be considered for dietary transitions (Fernqvist et al., 2024). For example, implementing vegetarian meals as the default option in canteens and public procurement settings can significantly increase the uptake of plant-based meals (Statement (14)). This strategy leverages behavioural defaults to encourage more sustainable eating habits without restricting choice (Baptista et al., 2025).

e) Opportunity factors/ ii) Physical Opportunity: the availability (i.e., the presence of a product, service or resource) of alternatives significantly impacts consumer exploration of these options (Baptista et al., 2025). In many European countries, the limited presence of alternative protein options hampers their adoption. Moreover, the price disparity between animal-based products and novel protein sources influences consumer behaviour by making different protein sources more or less affordable (Govzman et al., 2021; Rickerby & Green, 2024; Rubiales et al., 2021). Across most European nations, novel (and part of plant-based) proteins are often priced higher than their animal-based counterparts (A. Siegrist et al., 2024). This pricing gap results from several factors, including high production costs, retail pricing strategies, and market power dynamics (Hirvonen et al., 2020). Beyond availability and price, the broader food environment encompasses factors such as convenience and product visibility, all of which collectively shape consumer choices (Downs et al., 2020; Zaleskiewicz et al., 2024). For example, nudging strategies, such as prominently displaying plant-based or novel protein sources in supermarkets, restaurants, and food service outlets, significantly increase the likelihood of consumers selecting these options, demonstrating the impact of choice architecture on dietary decisions (Akinmeye et al., 2024; Larson & Story, 2009).

f) Motivational factors/ i) Health, Environment, and Ethics: Motivational drivers include concerns about health, environmental sustainability, animal welfare, and other ethical concerns (Tufford et al., 2023). Many consumers are motivated by these factors to reduce their animal-based protein intake and adopt plant-forward diets. However, evidence has also shown a gap between intentions to change and actual actions, as observed in the “meat paradox” (Bastian & Loughnan, 2017) (Statement (24)).

g) Motivational factors/ ii) Familiarity and Taste: Familiarity with plant-based and novel proteins, along with positive taste experiences, are key enablers for dietary and behavioural change towards plant-forward diets (Graça et al., 2023). Consumers who perceive plant-based meals as convenient, tasty, and satisfying are more likely to transition (Graça, Truninger, et al., 2019). Conversely, negative associations with plant-based foods, such as unfamiliarity or expectations of poor taste, act as barriers (Daly, 2020). Food neophobia, a fear of trying unfamiliar foods or fear of change, and disgust may act as barriers to adopting plant-based and novel proteins (Malila et al., 2024a).

(23) Consumer behaviour and willingness to change dietary patterns vary significantly across protein sources. Overall, consumers tend to accept plant-based and novel plant- or fungi-based proteins more, followed by culture meat and, to a lesser extent, terrestrial invertebrates such as edible insects. The adoption of algae and seaweed remains limited.

a) Consumers are increasingly willing to purchase plant-based proteins in supermarkets due to their perceived health benefits, environmental advantages, and ethical considerations. Willingness to change to plant-based diets is higher among health-conscious individuals, young adults, females, and those living in urban areas. However, concerns about taste (Statement (22)g)), familiarity (Statement (22)g)), and preparation skills (Statement (22)b)) often act as barriers (Akinmeye et al., 2024; Graça, Godinho, et al., 2019; Lehmann et al., 2024; Onwezen et al., 2021).
b) Pulses such as beans, lentils, and chickpeas are among the most widely accepted protein foods, especially in regions with traditional vegetarian diets as mainstream in food culture (e.g., Mediterranean diets) (Statement (20)a)) (Jallinoja et al., 2016). Their health benefits, affordability, and familiarity make them a staple in many plant-based diets (Onwezen et al., 2021). In some European countries, less familiarity with the preparation of some legumes creates barriers to incorporation into daily food habits (Statement (22)g)) (Henn et al., 2022).
c) Consumer acceptance of cultured meat remains low (Pakseresht et al., 2022). Concerns about its unnatural production process, high cost, and potential health risks deter consumers. However, those with strong environmental values or familiarity with food technology are more willing to try it (Laestadius, 2015; Onwezen et al., 2021; Pakseresht et al., 2022; Verbeke et al., 2015).
d) Insects face high levels of resistance from Western consumers, primarily due to disgust and unfamiliarity (Graça, Godinho, et al., 2019; Laestadius, 2015; Onwezen et al., 2021). In addition, algae and seaweed are gaining traction for their environmental benefits and nutritional value, particularly in niche markets focused on environmental sustainability. However, their adoption also remains low due to unfamiliarity and concerns about taste (Statement (22)g)) (Embling et al., 2022).

(24) There is often a gap between consumers' expressed intentions (stated dietary preferences) and their actual behaviour regarding protein consumption (eating habits). This is, for example, the case of what is known as the meat paradox, highlighting the tension between dietary preferences and eating habits. Factors like product packaging that de-animalize food further disconnect consumers from the ethical implications, enabling justification of their choices.

a) While surveys reveal a growing interest in alternative proteins for health and environmental reasons, market behaviours show that many consumers still default to animal-based proteins (Good Food Institute, 2024b), and that purchases do not consistently substitute for animal-source proteins but can be bought in addition (Trewern et al., 2021). Even though many consumers express support for plant-based and novel alternative proteins, price sensitivity and habit often prevent them from switching (Michel et al., 2021; Su et al., 2024).

b) One example of this inconsistency is the "meat paradox," which refers to the conflicting attitudes where individuals express concern about the ethics of killing animals for food and a desire to reduce meat consumption, yet often continue to consume meat regularly (Loughnan et al., 2014a). Cognitive dissonance is central to this phenomenon, as consumers may reconcile the tension between their enjoyment of meat and concerns about its ethical or environmental implications by adjusting their beliefs, rationalising their choices, or downplaying the perceived negative consequences of meat consumption (Bastian & Loughnan, 2017; Loughnan et al., 2014b).

c) Masking or sterilising products for consumers, for example in the form of meat sales in shapes and packages which de-animalize the food, disconnect consumers from the reality of animal exploitation in animal foods, making it easier to justify their continued consumption despite ethical concerns (Tso et al., 2021).

2.4. Occupational health

This section explores how working in farming, livestock production, aquaculture and fisheries increases certain health risks. These risks include non-fatal acute risks like accidents and injuries, non-fatal chronic risks like cancer or respiratory diseases, fatal accidents, and mental health issues (including suicide). These risks should be considered, as a protein transition may lead to shifts in working practices — for example, a decrease in livestock farming and an increase in arable farming.

(25) Agriculture and fisheries are among the most hazardous economic activities in Europe. Workers' health in farming and fishing occupations is a relatively underreported topic. This is largely because self-employed workers do not fall under occupational health and safety regulations, and health hazards are not reported.

a) Agriculture, forestry, and fishing are among the most hazardous economic activities in Europe, with nearly 400 registered deaths and more than 115,000 non-fatal accidents in 2022 (Eurostat, 2024a). These statistics are likely even higher because accidents are reported voluntarily by self-employed people, and there is a lack of accident insurance coverage for family labor (Merisalu et al., 2019).
b) Multiple scholars and authorities have pointed out a lack of regulation on occupational health and safety for agriculture and fisheries in European frameworks (Cavalli et al., 2019; European Agency for Safety and Health at Work et al., 2020; Jakob et al., 2021; Shan, 2022; Thorvaldsen et al., 2022), specifically due to the lack of sector-specific regulations and the fact that these regulations do not apply to small-scale and family farms (Jakob et al., 2021).
c) Health hazards go beyond acute injuries or accidents and include work-related chronic illness. The typically occurring health hazards differ between livestock farmers, fishermen and arable farmers, due to their different activities (see Statement (10)). Moreover, health hazards can vary widely among farming and management practices (A. Dumont & Baret, 2017; Duval et al., 2021; Hagevoort et al., 2013; Molina & Ríos-Osorio, 2020; Soto Mas et al., 2018).
d) Sustainable/Alternative farming practices can decrease the risk of physical and mental health risks but come with other challenges. To this regard, organic and/or agroecological agriculture experiences less exposure to harmful substances, such as pesticides (Costa et al., 2014) but may come with a higher physical workload and more financial uncertainties causing mental stress (Soto Mas et al., 2018). On the other hand, agroecological and organic farmers may experience higher levels of control to make decisions and initiate innovations, resulting in a more pleasant work environment (A. Dumont & Baret, 2017).

(26) Farmers and fishermen are faced with work specific non-fatal and fatal accidents, as well as injuries, that relate to the environment they work in. Even more, chronic diseases originate from long term exposure of farmers to (toxic) substances.

a) Due to work in confinement buildings, livestock farmers are exposed to airborne dust, microbial agents like bacterial endotoxins, and gases, which can lead to work-related asthma and rhinitis and enhance lung function decline (Sigsgaard et al., 2020). Over the last two decades, relatively little improvement has been observed in the respiratory disease rate among livestock farmers (Sigsgaard et al., 2020). Often occurring health issues also include malignancies (cancer), musculoskeletal disorders, neurological diseases, skin disorders and hearing loss (Kouimintzis et al., 2007). Acute injuries from accidents are also not uncommon, for example, accidents around manure storage facilities (Beaver & and Field, 2007) or handling big animals (Dogan, 2012).
b) For fishermen and fish farmers, the most common acute accidents include fall and crush/impact accidents (Holen & Holmen, 2025), while musculoskeletal disorders like neck, shoulder, and arm pain are the most common chronic health hazards (Ngajilo & Jeebhay, 2019; Thorvaldsen et al., 2020). Musculoskeletal disorders mainly originate from heavy lifting, prolonged standing, awkward postures, and repetitive work (Moreau & Neis, 2009). In aquaculture, long-term exposure to chemicals may cause concern, with the common use of disinfectants, parasiticides, fungicides and antifoulants in aquaculture (Moreau & Neis, 2009). In addition, fish farming hazards also originate from water impoundments, night-time work and offshore operations (Myers, 2010). In capture fisheries, fatal accidents are more common compared to aquaculture, mainly due to vessel disasters, drowning after falling overboard and drowning in port (Thorvaldsen et al., 2022). Although rates are declining (Jensen et al., 2014), such accidents have been related to fatigue levels of being at sea for prolonged time (Gander et al., 2008; A. Smith, 2007).
c) Overall in agriculture, exposure to chemicals is the number one cause of chronic diseases (Molina & Ríos-Osorio, 2020). This is especially relevant for arable farmers and greenhouse workers, who frequently come into contact with pesticides, insecticides, fungicides and herbicides. This exposure can result in reproductive disorders, respiratory symptoms, neurological symptoms, and skin irritations

(Amoatey et al., 2020). Even more, occupational exposure has been associated with different forms of cancer (Alavanja & Bonner, 2012; Cavalier et al., 2023; Matich et al., 2021; Varghese et al., 2021).

(27) In addition to physical health hazards, there is increasing evidence that psychological issues among farmers and fishermen are a reason for concern. Threats to livelihoods such as climate change, changes in regulations, or financial uncertainties, can result in increased stress and mental health problems. Even more, suicide rates are relatively high among farmers and fishermen.

a) Mental health challenges are high among farmers and fishermen, which is often related to living in a rural area with a risk of disconnection and lack of access to mental health services (European Commission, 2023). In addition, awareness of mental health issues, intervention policies, and their efficacy are low (Younker & Radunovich, 2022). A literature study showed that 71% of the studies on farmer's mental health concluded that mental issues are more severe among farmers compared to the general population (Daghagh Yazd et al., 2019). On the other hand, research is lacking on the positive health outcomes of farming occupations (Hagen et al., 2019). It has been suggested that those working in organic farming systems are happier (Khan et al., 2018), but results among studies are inconsistent (Daghagh Yazd et al., 2019).

b) Mental health issues result from financial uncertainty, social isolation, chronic pain, weather/climate uncertainty, regulation compliance and paperwork, and a sense of marginalization and beleaguerment (Berry et al., 2011; Brew et al., 2016; Dearmond et al., 2006; Truchot & Andela, 2018). If pesticide exposure is high, it is a high risk for developing mental disorders since pesticides can be neurotoxic and directly affect neural systems, resulting in mental illness and depression (Daghagh Yazd et al., 2019; Richardson et al., 2019).

c) Mental health of fishermen and fish farmers is severely underrepresented in the literature (Woodhead et al., 2018). Still, existing studies suggest that the risks are similar to those experienced by farmers – i.e., financial uncertainty and uncertainty in government regulations (King et al., 2021; Woodhead et al., 2018). Specific for fisheries, however, is the stress originating from unexpected fishing access restrictions (Siddique et al., 2023), large scale environmental destruction (Cherry et al., 2017), and having to share their "workspace" with others, mainly recreational fishers (King et al., 2021).

d) Especially in some member states, suicide is an important cause of death among farmers and fishermen (Bossard et al., 2016). Several studies have found a significantly higher suicide rate among farmers and fishermen compared to other occupation groups (Kennedy et al., 2014; Klingelschmidt et al., 2018; Milner et al., 2013), calling for increased suicide prevention policies (Klingelschmidt et al., 2018).

(28) Specific considerations for slaughterhouse employees include the physical and mental strain of their work. Specifically, experienced trauma from killing animals and the physical effects of repetitive work are underestimated.

a) Repetitiveness of work, awkward positions, and working with cold/frozen objects are risk factors for developing musculoskeletal disorders in slaughterhouse employees (Dias et al., 2020; Reis et al., 2015). Specifically carpal tunnel syndrome is commonly observed for this type of work (Fitzgerald, 2010).

b) Different from other forms of killing animals (e.g., fishing or hunting), slaughterhouse work is personal and up close (Baran et al., 2016). This intentional way of killing can become traumatic (Slade & Alleyne, 2023). One study found that, compared to other occupations, working in a slaughterhouse was associated with increased alcohol consumption, feeling less rested in the morning after a day of work, reporting a lower likelihood of being able to perform the same job in 2 years, reporting a reduction in work ability due to sickness or accidents, and lower levels of meaning from work (Baran et al., 2016).

3. Impacts of the protein transition

This section describes the impacts that the protein transition could have across various dimensions of sustainability within food systems. We approach sustainability primarily in terms of outcomes. An alternative perspective would be to frame sustainability in terms of specific practices, such as defining what constitutes sustainable farming methods or identifying sustainable and healthier dietary patterns (Resare Sahlin, 2024). This distinction emphasizes the difference between assessing the impacts of changes, which is the focus of this paper, and examining the processes that drive those changes—an important area but beyond the scope of this analysis.

3.1. Human health

Health is approached here from a nutritionist perspective, focusing on nutrient composition and intake, and does not incorporate aspects of how foods are consumed, including cultural practices, eating behaviours, and the social dimensions of dietary habits, which are covered in Statements (20)-(24).

3.1.1. Protein recommendations versus current protein consumption

(29) Health authorities provide a recommendation for daily protein intake that is needed to compensate for bodily nitrogen losses. Actual protein needs vary widely within and between individuals, depending on age, body weight, physical activity, and physical status (e.g., pregnancy). The intake level that is in line with the Recommended Daily Allowance (RDA) is contested by some. Beneficial effects of consuming above or below the RDA are inconclusive and depend on the studied population.

a) With nitrogen being a main building block of protein, the recommended daily intake is set to compensate for nitrogen losses that occur through faeces, urine, and sweat (Rand et al., 2003). The point at which nitrogen balance is achieved, i.e., where nitrogen intake is equal to nitrogen loss, is assumed to reflect the Estimated Average Requirement (EAR). The EAR meets the requirement of 50% of the population. The RDA is higher than the EAR to ensure that the requirements of 97.5% of the population are met. RDA is, therefore, considered a *safe level* estimate (EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA), 2011).

b) Both the European Food Safety Authority (EFSA) and the World Health Organization (WHO) recommend a daily protein intake of 0.83g per kg bodyweight as the RDA (EFSA, 2012; FAO et al., 2007). This equates to 58 g per day for an adult weighing 70 kg. The EAR by WHO and EFSA is 0.66 g/kg bw/day. Pregnant women, physically active individuals, and older adults require more protein than the RDA of 0.83g per kg body weight (Joint FAO/WHO/UNU Expert Consultation on Protein and Amino Acid Requirements in Human Nutrition Geneva et al., 2007; Weiler et al., 2023). Although no formal recommendations for specific population groups exist, pregnant women are expected to need between 1.2 and 1.5 g/kg/day (T. V. Stephens et al., 2015) , and the requirement for older adults is suggested to be ≥1.2 g/kg/day to mitigate the decline in skeletal muscle mass and function (Nowson & O'Connell, 2015; Traylor et al., 2018). Requirements for athletes vary between sports and activity levels (Fielding & Parkington, 2002).

c) The underpinning concept of the RDA is that the increase in plasma amino acids observed in nitrogen balance studies reflects the saturation of amino acid needs and that the intake of additional amino acids beyond this point has no nutritional value (Layman, 2009). However, some studies suggest that protein intakes above 0.83 g/kg/day have a beneficial effect as they result in an increase in protein synthesis and the inhibition of protein breakdown (Pencharz et al., 2016).

d) Because higher protein intakes increase protein turnover, it is hypothesised that high protein intakes can reduce lifespan by higher rates of errors in **mRNA translation**[16], while low protein intake stimulates autophagy and thereby clean up damaged cells (Basisty et al., 2018). Protein restriction may, therefore, promote health and longevity (Fontana et al., 2010; Kitada et al., 2019), while long-term high protein intake can lead to increased all-cause mortality risk and affect kidney functioning, especially in individuals with already existing renal dysfunction (Pedersen et al., 2013). In addition, excessive protein consumption may increase the risk for hypertension, affect bone health and impact gut microbia negatively (Ortega et al., 2024). However, it should be noted that most of the evidence on the health effects of high

[16] mRNA translation is the biological process by which the genetic information encoded in messenger RNA (mRNA) is used to synthesise proteins.

protein intake is inconclusive and can be context-dependent with, for example, inverse (i.e., positive) outcomes for the elderly compared to healthy adults (Kitada et al., 2019).

(30) While accurately measuring individual protein consumption remains challenging, the majority of EU citizens consume sufficient protein, with underconsumption posing little concern, particularly among adults. The current average protein consumption in Europe exceeds the RDA of 0.83 g/kg body weight, with no single country consuming inadequate amounts on average. Protein consumption is highly variable between countries and among individuals, which should be taken into account when interpreting the average consumption.

a) Europe comprises approximately 7% of the global population but is estimated to consume 16% of the world's available protein (Westhoek et al., 2011). Although most available data are averages for Europe or per country, it is unlikely that adults in Europe consume protein below the RDA (Our World in Data, 2021; Prochazka et al., 2024; Tijhuis et al., 2011). Inadequate consumption of protein is more prevalent in the European elderly (Hengeveld et al., 2018).

b) In the EU, the average daily protein consumption among adults is approximately 82 grams (Simon et al., 2024), against an average body mass of 70.8 kg (Walpole et al., 2012). Protein consumption is not equally distributed among countries and within populations, both in terms of quantity and source (Reedy et al., 2019). Eastern European countries generally consume the lowest amounts, i.e., 58-82 grams per day (Westhoek et al., 2011). France, Denmark, Portugal, Sweden and Spain are among the highest protein-consuming countries (i.e., 85-96 g/day), consuming twice as much animal-based protein compared to the low-consuming countries (Andreoli et al., 2021; European Commission, 2024d; Westhoek et al., 2011). Moreover, females tend to consume less protein compared to males, and the latter generally consume more animal products (European Commission, 2024d). However, estimates of protein intake vary depending on how estimations were derived (K. G. Smith et al., 2021),

c) Two methods to quantify protein intake are commonly used: either using protein supply data from the FAO food balance sheets corrected for food waste and losses (e.g., Simon et al., 2024; Smith et al., 2021; Westhoek et al., 2011) or using intake data from dietary surveys (e.g., Halkjaer et al., 2009; Lin et al., 2015; Miller et al., 2022). The correction factor used in the previous method accounts for losses during distribution and consumption stages, but it introduces a degree of uncertainty (Meybeck et al., 2011). Dietary surveys, on the other hand, can be affected by recall bias and inaccuracies, as participants may misremember or misreport their intake (Hebert et al., 1995; Livingstone & Black, 2003; Subar et al., 2015).

(31) Although there is a difference between protein from animal and plant sources regarding protein quality, there are no recommendations or solid evidence for which share of total protein intake should be from animal or plant sources. Most studies concluding that protein intake is adequate for individuals or populations do not account for the difference in protein quality between animal and plant sources, which can mask an inadequate intake of some indispensable amino acids. Studies that do account for protein quality are inconclusive on whether diets with a high share of plant-based protein provide adequate protein. A minimally required share of protein from animal sources is more likely driven to meet micronutrient requirements than to meet protein requirements.

a) Although the EFSA and WHO define general recommendations for total protein intake, they do not provide specific recommendations for animal-based protein intake (EFSA, 2012; Joint FAO/WHO/UNU Expert Consultation on Protein and Amino Acid Requirements in Human Nutrition (2002 : Geneva et al., 2007). In Europe, the largest share of protein intake comes from animal sources, with approximately 50 g sourced from animal products, including aquatic animal sources, followed by 30 g from plant-based products (Prochazka et al., 2024; Simon et al., 2024). Based on the FAO Food Balance Sheets, the main sources of protein are poultry, milk, and wheat, in descending order (FAO, 2024a).

b) Animal proteins generally provide a complete amino acid profile, i.e., they include all indispensable amino acids (Hoffman & Falvo, 2004). Conversely, plant proteins such as cereals and legumes may lack certain essential amino acids such as lysine and methionine, respectively, indicating the need for combining different plant proteins to ensure adequate amino acid intake (Rojas Conzuelo et al., 2022;

Vissamsetti et al., 2023). Protein requirements can be met without consuming animal-based foods by combining different types of plant-based foods to help boost the intake of those indispensable amino acids present in lower quantities (Bakaloudi et al., 2021; Mariotti & Gardner, 2019). However, long-term clinical studies in humans are limited, and these are needed to address concerns about foetal growth for mothers on fully plant-based diets (Bali & Naik, 2023), as well as to study growth and development in infants on a vegan diet (Alexy, 2023).

c) In addition, amino acids from plant proteins are less accessible for uptake in the body, i.e., they have a lower digestibility (Day et al., 2022; Holland et al., 2020), although digestibility also depends on processing. This difference in digestibility is due to antinutritional factors in plant-based foods that inhibit digestive enzymes and/or binding protein/amino acids and the extent to which digestive enzymes can access the protein in animal versus plant cells (Day et al., 2022; Holland et al., 2020). Consuming a higher volume of plant-based foods may be required to provide all indispensable amino acids in utilisable quantities (Pinckaers et al., 2021), but consuming this volume may not be feasible for certain population groups (e.g., children with a smaller stomach or elderly with reduced appetite) (Domić et al., 2022). Independent of a food's source, protein quantity, quality, and availability are highly variable among foods (Day et al., 2022) even within food types such as seafood (Golden et al., 2021).

d) As protein-rich foods contain additional important micronutrients, going below a 40% share of total protein from animal sources has been suggested to risk micronutrient inadequacies, but not inadequate protein intake (Simon et al., 2024; Vieux et al., 2022).

(32) Since the consumption of protein in high-income countries is well above the RDA of 0.83g/kg body weight, there is room to reduce total protein intake without running into risks of nutritional protein inadequacy. A high-protein diet can be beneficial as a weight loss strategy, but there are potential health risks of excessive protein consumption. Some argue that there should be a focus on reducing overall protein intake, while others suggest a focus on replacing animal protein with plant protein is of higher relevance.

a) From a weight loss perspective, there is caution against reducing total protein intake, as a high protein intake (i.e., well above the RDA) can result in diets that are satiating while low in energy density (Gosby et al., 2014; Martínez Steele et al., 2018). Therefore, diets high in protein are posited as an effective way to reduce obesity (Gosby et al., 2014; Leidy et al., 2015; Simpson & Raubenheimer, 2005; Westerterp-Plantenga et al., 2012). However, dietary behaviour and its effects on energy intake and body weight are highly complex and individual, and this hypothesis may not be universally applicable (Gosby et al., 2011; Martens et al., 2013; Saner et al., 2020).

b) Diets with high terrestrial animal-source protein consumption, particularly red and processed meat, have been linked to adverse effects on insulin action and are associated with an increased type 2 diabetes risk (Z. Chen et al., 2020; Mittendorfer et al., 2020; Shang et al., 2016; Sluijs et al., 2010). In addition to some concerns about excessive protein intake (29)b), scholars warn that the side effects of high-protein processed foods are not fully understood (Kårlund et al., 2019; Ortega et al., 2024). This emphasizes the importance of considering the type of protein food.

c) In light of the protein transition, many scholars advocate reducing protein consumption to levels that match recommended daily intakes and adhere to environmental boundaries (Clark et al., 2020; de Boer & Aiking, 2019; Ivanovich et al., 2023; Simon et al., 2024; Springmann et al., 2018; Verkuijl et al., 2024; Willett et al., 2019). Even if total protein intake is reduced and the ratio of animal- to plant-based protein is maintained, the level of animal-based protein may still come with relatively high impacts on human health and the environment (Simon et al., 2024). However, the type of animal-source protein consumed can make a large difference. For example, a much smaller volume of bivalves may fulfill many nutritional needs compared to larger volumes of, e.g., cod, against lower environmental impacts (Bianchi et al., 2022).

d) From a nutritional standpoint, substituting animal-based proteins for plant-based proteins can be nutritionally adequate, provided that the substitutes' quality and overall macro- and micro-nutrient profiles are carefully considered (Chalupa-Krebzdak et al., 2018; Guillin et al., 2021; Mariotti & Gardner, 2019). This notion of substitutability emphasizes the need to evaluate protein sources not only based on their protein content and the presence and balance of indispensable amino acids but also considering other crucial nutrients such as vitamins, minerals, and fibber, as well as their digestibility and **bioavailability**[17] (Vissamsetti et al., 2023). However, evaluating the substitutability of animal-based proteins with plant-based proteins is complex due to the significant variability in nutrient profiles across the wide range of both plant- and animal-based proteins (Ranganathan et al., 2016; Bianchi et al. 2022).

e) Alternatively, substituting red- and processed meat for seafood is advocated as a way to reduce health risks associated with red- and processed meat while maintaining sufficient nutrient intakes (Thomsen et al., 2018; Xia et al., 2023). Provided this concerns individuals that have a risk of inadequate nutrient intake when omitting terrestrial meat, seafood – with its highly diverse nutritional profiles – deserves attention as a sustainable protein alternative (Tlusty et al., 2019).

3.1.2. Dietary role of protein foods

(33) In addition to protein, foods such as meat, dairy, eggs, seafood, legumes, nuts and grains provide a wide range of other nutrients. All of these foods can therefore contribute to nutrient-dense diets, and (without considering fortified products or supplementation) some foods are essential for meeting nutrient recommendations. However, discussion remains about the differences in the nutrient bioavailability among different protein foods and how this affects the nutrient adequacy of a diet. In addition to whole foods, some plant-based analogues and novel alternative proteins can also be part of healthy and nutrient-dense diets. However, their novelty and existing research gaps have led to some controversy.

a) Animal-based foods are rich in iron, zinc, folate, calcium, and vitamins A, B12, and D (Beal, 2021; Chalupa-Krebzdak et al., 2018). Plant-based foods, on the other hand, provide a wide range of minerals and are generally the main source of vitamin C, carbohydrates, and fibber in the diet (Comerford et al., 2021). In addition, plant-based foods contain antioxidants and anti-inflammatory components (Carlsen et al., 2010).

[17] Bioavailability refers to the proportion of a nutrient or compound that is absorbed and utilized by the body after consumption. It indicates how effectively a substance is digested, absorbed into the bloodstream, and made available for physiological functions.

In this regard, animal- and plant-based foods can be considered largely complementary in terms of nutrients (Comerford et al., 2021). The nutrient bioavailability of plant-based foods is generally lower compared to animal-based foods (Chungchunlam & Moughan, 2023). This is due to the nutrients being more difficult to access, **antinutrients**[18] that hamper uptake and/or the form in which nutrients are present in the food source (Platel & Srinivasan, 2016). However, common processing methods such as soaking and cooking aid in reducing antinutrients (Dahdouh et al., 2019).

b) The "meat factor" or "meat effect" is described as the positive effect of consuming meat on overall micronutrient absorption (Consalez et al., 2022; Layrisse et al., 1968). Several studies have shown increased absorption of iron and zinc from plant sources when plant-source foods are consumed together with meat (Consalez et al., 2022). This effect has only been observed for different meat types, i.e., red meat, poultry, and seafood, but not for milk and egg products. It seems like only a small amount is sufficient to achieve the meat effect, but it remains unclear which component in meat is responsible for the enhanced absorption (Consalez et al., 2022).

c) Although it is feasible to consume a diet that is adequate in protein solely from plant-source foods, studies show that the RDA is not always met in practice (Aaslyng et al., 2023; Dietrich et al., 2022; Kristensen et al., 2015; Mariotti & Gardner, 2019). Moreover, due to bioavailability differences between animal- and plant-based proteins, the actual fraction available for consumption may not be sufficient (Chungchunlam & Moughan, 2023; Moughan et al., 2024). In this regard, as the RDA is based on nitrogen balance studies combined with omnivorous diets, the RDA for individuals following a plant-based diet may actually be higher (Bartholomae & Johnston, 2023). This is also relevant for other nutrients, such as calcium, iron and vitamin B12, for which low intakes are observed in individuals following a fully plant-based diet (Bakaloudi et al., 2021; Schüpbach et al., 2017). Among other

[18] Antinutrients are naturally occurring compounds found in plant and animal foods that can interfere with the absorption or utilization of essential nutrients by the body.

things, this can increase the risk of poor bone health (Menzel et al., 2021; Zheng et al., 2023). Studies that investigate the potential (environmental) benefits of shifting to plant-based diets often lack nutritional detail, i.e., protein quality and bioavailability of nutrients are not considered (Dussiot et al., 2022; Leonard & Kiely, 2024).

d) Fortification and supplementation may be used to mitigate nutrient deficiencies, but the evidence of their efficacy is not consistent (Malézieux et al., 2024). However, supplements may not be sufficiently effective because the food matrix is missing, their bioavailability and kinetics are less efficient and the absence of bioactive compounds (Fardet, 2015). It is therefore important to understand the nutritional profile of novel alternative proteins and how these can supply essential nutrients, either with or without fortification.

e) Vitamin B12 is synthesized by microorganisms, mainly in the intestines of humans and other animals. Since humans cannot absorb their own synthesized vitamin B12, it needs to be obtained from food. More specifically, without considering supplementation and fortification, animal-source foods are the main sources of vitamin B12 (Boutron-Ruault et al., 2017; Gille & Schmid, 2015). Dried purple laver, or nori, has been identified as the only plant source with a considerable vitamin B12 content (Takenaka et al., 2001; Watanabe et al., 2014). However, plant-based foods can be fortified with vitamin B12 via microbial fermentation (Xie et al., 2021), or by enabling symbiotic relations between algae and cobalamin-producing bacteria (A. G. Smith et al., 2007).

f) Omega-3 fatty acids play an important role in maintaining normal vision, brain functions, cardiac functions and blood pressure (EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA), 2011). Naturally, they are found in aquatic plants that are consumed by aquatic animals and consequently end up in their tissue. Omega-3 fatty acids can be effectively extracted from algae for supplementation (Craddock et al., 2017). However, consuming algae directly may not suffice due to low bioavailability and content of omega-3 fatty acid (Bonfanti et al., 2018; USDA, n.d.), and may pose risks of iodine toxicity if consumed in large amounts (Aakre et al., 2021).

g) Novel protein foods, such as insects, mealworms, or algae, have their own unique nutrient profile, and a mixture of different novel protein foods could contribute to human requirements of all the essential macro-and micronutrients (Parodi et al., 2018). For example, insects have a similar iron content to beef (Latunde-Dada et al., 2016). However, the bioavailability of nutrients from these food sources has not been well studied in humans, and safety and efficacy need to be proven before they are allowed on the EU market (Ververis et al., 2020).

h) The category of novel plant-based meat and dairy analogs encompasses a wide array of product types with different ingredients and processing methods, resulting in diverse nutrient profiles (Bryngelsson et al., 2022; Shanmugam et al., 2023). However, in general, the fibber and sugar content are higher compared to their meat counterpart, while fat and protein content are slightly lower (Drewnowski et al., 2024; Gastaldello et al., 2022; Yang et al., 2023). Often, these alternatives are fortified with calcium, iron, iodine, B12 and/or vitamin D to resemble the nutrient profile of animal products. However the use and level of fortification is inconsistent across products, brands and countries (Lindberg et al., 2024; Nájera Espinosa et al., 2024; ProVeg International, 2024). Although some cases micronutrient content may be lower than the animal counterpart, in other cases, some of these products can also provide micronutrients that are not present in the animal counterpart (e.g., soy-milk fortified with calcium can have similar fractional absorption as milk (Shkembi & Huppertz, 2022). However, it remains unclear how the fortification of multiple nutrients in high concentrations may impact absorption (Swing et al., 2021).

i) Compounds accumulate in an animal's muscle tissue as part of their feed after being eaten, digested, and modified in the animal's body. Therefore, cell-based meat can only achieve the same nutritional composition as meat produced from livestock systems when these nutritional compounds are added to the culture medium (Fraeye et al., 2020). It is likely that, with the right culture medium, the nutrient content of cell-based meat resembles conventional meat or may even contain higher concentrations (Fraeye et al., 2020). However, nutritional assessments for cell-based meat are currently scarce.

3.1.3. Protein foods and health outcomes

(34) How and in which quantity (protein) foods are combined into diets on a daily basis predicts the increased or decreased risk for chronic diseases. However, caution is warranted when interpreting epidemiological studies that identify these health impacts because the methodology cannot prove causation. In addition, health impacts are difficult to generalise for a group of foods, as not always all the foods belonging to a single food group will have the same (negative or positive) impact.

a) Dietary patterns, rather than single isolated nutrients, are most relevant for predicting chronic disease risk (Mozaffarian, 2016). The Global Burden of Disease study gathers data from epidemiological studies to define risks that impact human health (Murray, 2022). Dietary risks that negatively impact health include the consumption of red and processed meat (Afshin et al., 2019). Factors that positively impact health include the consumption of nuts, legumes, milk and omega-3 fatty acids from seafood (Afshin et al., 2019).

b) There is discussion about the robustness of conclusions drawn from nutritional epidemiological studies (Qian et al., 2020). One aspect of the debate pertains to the methodology of these studies, with some critics pointing out that many of the studies are observational, which can show associations but cannot prove causation (Johnston et al., 2023). These studies are sensitive to confounding factors that hamper distinguishing the effect of lifestyle factors from dietary factors (Robinson & Jones, 2024). This, in addition to the lack of mid- to long-term randomized clinical trials to provide the hard-needed evidence, seems to be the main reason why the debate on whether or not animal-source proteins should be part of the human diet at all has not been settled yet (N. D. Barnard & Leroy, 2020).

c) The positive health impacts of foods or food components are easily taken up by the industry when marketing its products. However, health claims in the food industry are strictly regulated in Europe by EFSA (European Commission, 2024e). Claims that are authorized by EFSA include the contribution of seafood and meat to iron absorption and the need for protein, calcium and vitamin D for bone development (*Food and Feed Information Portal Database | FIP*, n.d.). Other claims, such as a positive link between dairy foods and dental health, are not authorized (European Commission, 2024f).

d) National Food Based Dietary Guidelines (FBDGs) provide a general guideline for healthy diets that are tailored to a population, i.e., including cultural preferences or traditional food consumption habits (EFSA Panel on Dietetic Products, Nutrition, and Allergies (NDA), 2010). In general, FBDGs provide recommendations for daily quantities of food groups, such as fruits and vegetables, meat or dairy, based on evidence of health outcomes when consuming foods that belong to these food groups. It is often recommended that milk or other dairy products be consumed on a daily basis to ascertain calcium intake. In most countries, seafood is recommended to be consumed twice a week to ensure the consumption of healthy fatty acids, while red meat is discouraged and white meat is favoured (Herforth et al., 2019). More recently, certain FBDGs have included novel meat and dairy alternatives in their guidelines to promote more plant-based diets (Klapp et al., 2022).

(35) From all protein foods, the health impact of the consumption of red and processed meat may be the most debated. There is existing evidence from long-term perspective cohort studies that the consumption of red and processed meat increases the risk of non-communicable diseases. However, the uncertainty around these studies is considered high within the research community. There is, therefore, a call for more conclusive evidence from long-term randomised controlled trials to establish an evident cause-and-effect relationship between red meat intake and specific health outcomes.

a) Ample evidence exists that the consumption of red and processed meat increases the risk of colorectal and breast cancer (Cross et al., 2010; Farvid et al., 2015; Wolk, 2017), heart disease, particularly cardiovascular disease (G.-C. Chen et al., 2013; Craig et al., 2021) and coronary heart disease (Al-Shaar et al., 2020), type 2 diabetes (Feskens et al., 2013; Kunutsor et al., 2013; Viguiliouk et al., 2015), obesity (Rouhani et al., 2014), chronic kidney disease (Mirmiran et al., 2020), and a risk of increased mortality (Etemadi et al., 2017; Pan et al., 2012; Sinha et al., 2009). Red meat contains high levels of saturated fat and cholesterol, which have been linked to an increased risk of heart disease, stroke, and certain types of cancer, particularly colorectal cancer (Razmaitė et al., 2020). Processed meats often contain added sodium, nitrates, and nitrites, which enhance flavour and shelf-life but impact human health negatively (Crowe et al., 2019; Lee et al., 2021).

b) Some researchers argue that the magnitude of the risk associated with red and processed meat consumption might be overestimated or misrepresented (Händel et al., 2021; Nouri-Majd et al., 2022). The evidence for a link between red meat intake and certain types of cancer, such as prostate cancer, has been described by some as limited, with no definitive conclusions about a causal relationship (T. S. Allen et al., 2022; Händel et al., 2021; Nouri-Majd et al., 2022). Above all, more evidence from long-term **randomised clinical trials**[19], with factors other than diet kept as similar as possible, is needed (N. D. Barnard & Leroy, 2020).

c) Yet, numerous scholars continue to recommend dietary patterns that are relatively low in red and processed meats in favour of higher consumption of plant-based foods. This is based on cumulative evidence indicating the potential human health risks associated with these meats, i.e., a lower risk of NCDs, as well as the environmental benefits of their alternatives (Clark et al., 2020; Ivanovich et al., 2023; Springmann et al., 2018; Verkuijl et al., 2024; Willett et al., 2019).

(36) No strong evidence suggests negative health impacts from consuming alternative protein foods. Consumption of milk and fermented dairy products, seafood, legumes, nuts and seeds is associated with positive health outcomes. Ample studies show positive outcomes for reduced disease risks when individuals follow a vegetarian or vegan diet. Still, it remains difficult to separate these health effects from not consuming animal foods and healthy lifestyle factors.

a) A compilation of prospective cohort studies suggests a positive impact of dairy intake on the risk of type 2 diabetes, coronary heart disease, and stroke (Soedamah-Muthu & de Goede, 2018). The main benefits seem to originate from the calcium and potassium content in milk and the probiotic bacteria in fermented dairy products. Cheese shows

[19] A Randomised Clinical Trial is a scientific study designed to evaluate the effectiveness and safety of medical interventions, such as drugs, treatments, or behavioral changes, by randomly assigning participants to an intervention and a control group. Applying randomization and concealing group assignment for participants, researchers, or data analysts, minimizes bias through conscious or unconscious influence on results.

contradicting effects on health outcomes (Soedamah-Muthu & de Goede, 2018) while substituting butter with unsaturated fats has been shown to have positive effects on cardiovascular diseases (Lichtenstein et al., 2003; Liu et al., 2017).

b) Seafood consumption is associated with a lower risk of all-cause and cardiovascular mortality, coronary heart disease, myocardial infarction, stroke, heart failure, and depression (Hellberg et al., 2012; Jayedi & Shab-Bidar, 2020). However, the consumption of seafood comes with health risks related to contamination of the flesh by toxins such as mercury or dioxins (Hellberg et al., 2012), which is why consumption is discouraged for certain population groups (i.e., pregnant and lactating women, infants and young children). For individuals outside these groups, the benefits of consuming seafood twice a week are suggested to outweigh those risks (Hellberg et al., 2012).

c) Consumption of nuts, seeds and legumes has either a protective or neutral effect on chronic diseases (Fardet & Boirie, 2014).

d) The consumption of soya-based products potentially reduces the risk for cardiovascular diseases, cancer, and diabetes type 2 diseases (Nagata, 2021; Yip et al., 2023). The health impacts of fermented versus unfermented soy may be different, with a higher risk of stomach and/or digestive cancers of the former (Fardet & Boirie, 2014) but a lower risk of cardiovascular diseases (Nagata, 2021).

e) Plant-based diets, such as veganism and vegetarianism, are associated with a favourable cardio- metabolic profile compared to an omnivorous diet (Benatar & Stewart, 2018). Consequently, vegetarian and vegan diets are linked to a reduced risk of cardiovascular disease, including hyperlipidemia, ischemic heart disease, hypertension, and stroke (Craig et al., 2021). They are also associated with lower incidences of type-2 diabetes (Satija et al., 2016; Tonstad et al., 2009, 2013), various forms of cancer (Key et al., 2014; Orlich et al., 2014), and lower rates of overweight and obesity (Craig et al., 2021). However, many individuals choose to follow a vegetarian or vegan diet for health reasons and are therefore already more health conscious (e.g., Alewaeters et al., 2005; Bedford & Barr, 2005; Waldmann et al., 2003) which should be accounted for in observational studies.

(37) The health impacts of novel proteins seem promising but are not yet well-studied. While several claims are being made, there is a lack of solid consolidation of evidence to back these claims Insects and algae, which have long been traditional components of healthy diets in various cultures, are increasingly recognized for their multiple potential benefits as alternative protein sources. Other alternative proteins, i.e., meat-based analogues, generally require a high degree of processing, which is controversial, and some can be considered healthier than others.

a) Insects are promoted for their role in gastrointestinal health, antioxidant and anti-inflammatory properties, and potential to reduce cardiovascular diseases (Nowakowski et al., 2022; Stull, 2021).

b) The consumption of algae and their extracts could be beneficial for a number of health markers, among which body mass index, total cholesterol levels, fasting blood glucose levels, and blood pressure (Trigo et al., 2023; C. Wang et al., 2024). In addition, certain algae extracts are suggested to have anti-cancer properties (Lordan et al., 2011). However, the lack of randomized controlled trials implies careful interpretation of the existing evidence (Trigo et al., 2023). For pregnant women, however, consumption of algae is discouraged by some health agencies based on the high iodine content (e.g., Swedish Food Agency, 2021).

c) Novel plant- and fungi-based meat proteins, derived from textured vegetable protein, are often promoted as healthier compared to their animal-based counterparts, mainly based on the devoid of health risks associated with meat (Sexton et al., 2019). A recent systematic review found that consuming plant- and fungi-based meat alternatives is associated with positive health outcomes, including weight maintenance, improved gut health, muscle synthesis, lower glycemic markers, and reduced risk factors for cardiovascular diseases (Nájera Espinosa et al., 2024). Novel plant-based drinks showed a glycemic response similar to milk but were associated with micronutrient deficiencies (Nájera Espinosa et al., 2024). Some concerns arise from the degree of processing that these meat analogues require (Toh et al., 2022; Wickramasinghe et al., 2021). However, this discussion is complicated by poor categorization of these products: while some have a nutrient profile that would result in positive health impacts (e.g., high in fibber, low in saturated fat), others are high in sodium, saturated fat and free sugars with negative implications for health (Gesng et al., 2021; Monteiro et al., 2019; Nájera Espinosa et al., 2024).

d) Studies suggest that vegetarian and vegan diets are associated with a higher intake of ultra-processed foods (Gehring et al., 2021), while the health benefits of plant-based diets observed in epidemiological studies mainly come from the increased consumption of whole foods. From a health perspective, it can be argued that promoting meat and dairy replacers to support the shift to more plant-based diets may be undesirable (Santo et al., 2020). However, there is no convincing evidence that novel plant and fungi based meat alternatives are associated with negative health outcomes (Cordova et al., 2023)

e) Because cell-based meat is produced in controlled environments, the nutritional content can be adjusted to hypothetically reduce the risk for chronic diseases (e.g., replacing saturated with unsaturated fat or reducing cholesterol content) (Chriki & Hocquette, 2020). However, the highest health benefits are suggested to come from lower exposure to contamination and antibiotics that occur in traditionally produced meat (Post et al., 2020). Furthermore, no nutritional data are available, and there is no definitive proof that it can produce safe, healthy, and flavorful products (Chriki et al., 2022).

3.1.4. Food safety

(38) Animal-based food production is associated with the emergence of **zoonotic diseases**[20] and **antimicrobial resistance**[21], driven by factors like intensive farming, habitat destruction, and antibiotic overuse. While plant-based and novel proteins generally present lower risks, contamination through polluted water or improper handling can still introduce antimicrobial-resistant bacteria. Additionally, using insects

[20] Zoonotic diseases are infections that spread from animals to humans. These diseases can be caused by bacteria, viruses, fungi, or parasites and can be transmitted through direct contact with animals, contaminated food or water, insect bites, or the environment.

[21] Antimicrobial resistance (AMR) occurs when microorganisms (bacteria, viruses, fungi, and parasites) evolve to resist the effects of drugs that were once effective against them. This makes infections harder to treat, increasing the risk of disease spread, severe illness, and death.

as a protein source poses potential public health risks, as they can carry zoonotic diseases and antibiotic-resistant bacteria.

a) Factors such as intensive farming practices, habitat destruction, high livestock densities, wildlife hunting and the overuse of antibiotics in livestock and aquaculture drive the emergence of zoonotic diseases and antimicrobial resistance (Dafale et al., 2020; Malila et al., 2024b; Shepon et al., 2023). The occurrence of zoonoses poses significant threats to public health and global food security if not managed appropriately (Murray et al., 2022). In addition, (over)use of antibiotics in the livestock sector can ultimately make it difficult to treat infections in humans as resistant bacteria can transfer from animals to humans, and antibiotic residues can be present in animal-source foods (Van Boeckel et al., 2015). Food can also become contaminated during processing, post-processing, and through improper handling by consumers (Verraes et al., 2013).
b) Diets with higher rates of plant-based or novel proteins are typically considered to lower or minimize the risk of zoonotic diseases and antimicrobial resistance since they do not rely on antibiotics for production (Shepon et al., 2023). However, if plant material — often the raw ingredient for some novel proteins — is not carefully managed, it may become contaminated with antimicrobial-resistant bacteria due to polluted irrigation water containing animal or human waste (Verraes et al., 2013). Yet, this contamination stems from the broader impacts of animal farming and improper management of human waste, which can pollute irrigation water (Erickson & Doyle, 2012).
c) In the case of terrestrial invertebrates, edible insects, in particular, pose significant public health concerns if they were to become a large protein source. This is because insects are vectors for various zoonotic diseases (e.g., parasitic infections, bacterial and virus pathogens) (Belluco et al., 2015; Bertola & Mutinelli, 2021; Gałęcki & Sokół, 2019; Gwenzi et al., 2021). Some studies have identified various antibiotic-resistant bacteria in edible insects, potentially increasing the risk of antimicrobial resistance (Gwenzi et al., 2021; Osimani et al., 2018).
d) The rates of zoonoses and foodborne diseases in Europe are relatively low compared to low-income countries, due to stringent regulations,

strong healthcare systems, and improved hygiene standards. However, due to the globalisation of agriculture, the emergence and spread of diseases becomes a growing concern (van der Giessen et al., 2004). Zoonoses and food-borne diseases are monitored via Council Directive 2003/99/EC. Based on monitoring and surveillance data, EFSA publishes a yearly summary of the occurrence of zoonoses, zoonotic agents and food-borne outbreaks in Europe. In 2023, Campylobacter was the most commonly reported zoonose, with 148181 confirmed human cases across 14 member states (EFSA & ECDE, 2024). For food-borne diseases, 9210 cases of Salmonellosis were reported in 2023 (EFSA & ECDE, 2024).

3.2. Environment

Environmental impacts are understood here using an indicator-based approach, aligning with the paradigm that environmental sustainability can be (partially) understood and measured through tools such as the Environmental Footprint (EF) and Life Cycle Assessment (LCA), thus aligning with a more (post-)**positivist ontology**[22]. While this approach discretely bounds and allows for quantitative evaluation of environmental impacts across dimensions, it contrasts with worldviews and paradigms centring the social constructivist nature of social-ecological systems, as well as understandings of realities as circular, continuums, and encompassing the more-than-human (Sakellariou, 2018; Tukker, 2000; Turnhout et al., 2014).

This section begins by addressing key methodological considerations, particularly focusing on LCA. It then delves into general environmental aspects, followed by a comparison of animal-based and alternative proteins across various environmental dimensions, including global warming, nitrogen cycling, resource use (energy, land, and water), and biodiversity.

[22] Positivism is a philosophical approach that asserts that valid knowledge is derived from objective, empirical observation and the scientific method, emphasizing measurable, observable phenomena and universal laws. In contrast, post-positivism acknowledges the limitations of objectivity, recognizing that all observations are influenced by human perspectives and biases. While still valuing empirical research, post-positivism emphasizes critical reflection, the provisional nature of knowledge, and the importance of integrating multiple perspectives to understand complex realities.

3.2.1. Methodological considerations

(39) To make things measurable, problems and tools must be structured so that information can be categorised, quantified, and standardised using indicators, metrics, and monitoring systems, enabling consistent comparisons and evaluations (Turnhout et al., 2014). This process inherently prioritises aspects that are easier to measure, potentially overlooking complex or qualitative dimensions, which can limit the scope of understanding and the comprehensiveness of assessments (Resare Sahlin, 2024). The impact categories often used are those with established impact assessment methods, such as global warming impact, water use, land use, eutrophication and acidification, and biodiversity to a certain extent. These environmental indicators will be discussed in the following sections.

(40) Most studies that compare the environmental impacts of foods (and proteins) use LCA. LCA is a systematic method for evaluating the environmental impacts associated with a product, process, or service throughout its life cycle, based on harmonised guidelines. Modelling choices, e.g., the systems boundary or the way impacts are allocated, can result in different impact values. LCA also presents several challenges, some of which are more generally related to robust assessments of food products and diets, that are relevant to consider when using LCA data.

a) LCA is a valuable tool for evaluating the environmental impact of a product, process, or service throughout its entire life cycle—from raw material extraction to production, use, and disposal (Cardinaals et al., 2024; Thoma et al., 2022). One of its strengths lies in its ability to provide a comprehensive and holistic understanding of environmental impacts across multiple dimensions (Finnveden & Potting, 2014). By standardising assessments, LCAs enable comparability between products, processes, and services, making them a robust decision-support tool. Moreover, they help identify hotspots of environmental impact, enabling targeted improvements (Pryshlakivsky & Searcy, 2021).

b) Most LCA studies on food focus on single products, assessing specific environmental aspects like greenhouse gas emissions, water use, and land use. Thus, by nature, they do not account for the broader systemic implications of dietary changes on agricultural systems (Statement

(41)). **Consequential LCA**[23] approaches attempt to address these limitations by incorporating changes in demand and indirect land use but still fall short of considering aspects such as co-product inclusion (Thomassen et al., 2008).

c) The outcomes of LCA studies are highly influenced by methodological choices, such as system boundaries and impact allocation, which can affect the comparability and interpretation of results. Therefore, interpreting LCA results requires caution due to variability in methodologies, data quality, and context (Henriksson et al., 2021; Ziegler et al., 2022).

d) The lack of publicly available data for some novel proteins, such as cultured meat, presents a significant challenge for comparing different products (Freidberg, 2015; Gheewala et al., 2020; Parodi et al., 2018). This can be attributed to two main factors: first, the technologies and production processes are new and have not been scaled up to a level that would yield reliable LCA results (N. Stephens et al., 2018), and secondly, companies' strategies to protect their intellectual property rights result in a reluctance to disclose their data (Guthman & Biltekoff, 2021).

e) LCA also face challenges in addressing biogenic carbon stock changes and their climate impacts, such as carbon dynamics in grazing systems or fisheries' effects on carbon storage (Sala et al., 2021). Ongoing methods are being developed to include impacts for climate impacts from changes in biogenic carbon stocks, such as carbon dynamics in grazing systems (Sevenster et al., 2020) and the effects of bottom trawl fisheries on carbon storage and sequestration (Muñoz et al., 2023). However, many knowledge gaps remain, particularly regarding the impacts of fisheries (Epstein et al., 2022; Tiano et al., 2024).

f) While LCA studies often compare the environmental impacts of animal-based foods with plant-based or novel food based on mass, protein or calorie content (so-called functional units), these studies often overlook

[23] Consequential Life Cycle Assessment (LCA) is an LCA approach that evaluates the environmental consequences of changes in a system or decisions, such as increased production, new technologies, or policy changes. It thereby accounts for the broader, indirect impacts that result from these changes, in addition to the direct effects within the system boundaries.

differences in protein quality, amino acid profiles, nutrient density and other functional aspects that impact human nutrition and health outcomes (Statements (31), (32), (33) and (37)) (Clark & Tilman, 2017; Poore & Nemecek, 2018). To further support the shift towards alternative protein sources, a Nutritional Life Cycle Assessment (nLCA) can provide guidance by evaluating both the nutritional and environmental impact of foods (McLaren et al., 2021). Most commonly, nLCAs apply a functional unit that accounts for the nutrient content of the food in scope, e.g., by expressing the environmental impact per 100 kilocalories or 100 grams of protein. To date, nLCAs have largely underutilized the assessment of disease risks associated with under- or overconsuming certain nutrients, foods, or food groups (Cardinaals et al., 2024).

(41) Modelling approaches can play a crucial role in understanding and designing strategies for the protein transition, and the impacts these strategies would have on food systems in the broadest sense. However, caution is warranted as food system-level models can easily become complex and difficult to interpret.

a) System Dynamic Models are able to explore complex agroecological systems (Walters et al., 2016). For example, in food systems, it can be explored how dietary shifts, particularly reductions in animal protein consumption, impact environmental sustainability, land use, greenhouse gas (GHG) emissions, and food system resilience (Simon et al., 2024). Among the many studies available, examples of how modelling has contributed to the state of knowledge include how reduced animal protein consumption and diversified landscapes can restore biodiversity, cut GHG emissions by 40%, and sustain Europe’s nutritional needs by 2050 (Poux & Aubert, 2018) or evaluating diverse dietary scenarios, showing that plant-based and artificial protein (corresponding here to in-vitro produced meat and dairy) diets can cut land use by 86% and emissions by 90%, and emphasising the potential for afforestation to enhance carbon sequestration.

b) Unlike LCAs (Statement (40)a)), which focus on the environmental footprint of individual products, services or processes, System Dynamic Models evaluate interconnected elements such as changes in agricultural land allocation, resource distribution, food security, and scalability of alternative protein sources. However, due to the complexity of the food system, these models can have such high data requirements that questionable assumptions may be required, ultimately generating results with a high degree of uncertainty (Refsgaard et al., 2007).

c) Although LCA data can theoretically also be included in dynamic models, this is controversial as the environmental impact values are dependent on characteristics of the food system (e.g., fertilization methods, animal stocking density or cropping practices) and thereby also dynamic (Berardy et al., 2020), in addition to having a temporal component (Laratte et al., 2014). By endogenously calculating impacts within dynamic models, interactions among system components and how they change environmental impacts can be accounted for (e.g., García-Gusano et al., 2016; Stehfest et al., 2014; Zhao et al., 2021). Thereby, studies applying such models can complement LCA in understanding and designing strategies for the protein transition at the food system level and evaluating the impacts different strategies or interventions would have on food systems in the broadest sense.

d) One of the pioneering efforts to model the impacts of a protein transition was conducted by **Solagro**[24], under the framework of IDDRI (Institute for Sustainable Development and International Relations) (Couturier et al., 2016). The **Afterrees2050 scenario**[25] explicitly considered a reduction in animal protein intake as a significant shift in dietary practices and explored its broader effects on agricultural and environmental systems (e.g., looking at the impacts in terms of GHG emissions and resource use).

3.2.2. Overall environmental comparison

(42) Plant-source and novel foods generally have lower environmental impacts– i.e., GHG emissions, land degradation, acidification, eutrophication, biodiversity loss - compared to terrestrial animal-source foods, which are associated with inefficient

[24] Solagro is a research organization focusing on energy, climate, agroecological and food transitions (www.solagro.org).

[25] The Afterres2050 scenario, developed by Solagro, is a forward-looking plan for agriculture and food systems in France, aiming for sustainability by 2050. The first version was released in 2011 and has since been updated to reflect new insights and data. (https://afterres2050.solagro.org/decouvrir/scenario/)

resource use, methane emissions, nitrous oxide from manure, and deforestation. Foods from aquaculture and wild fisheries tend to have impacts that fall in between those from plant-source and terrestrial anima-source, although there is high variability among different types of seafood.

a) Plant-based and novel proteins are generally associated with lower environmental impacts than terrestrial animal-based protein sources (Clark et al., 2022; Liao et al., 2020; Nájera Espinosa et al., 2024; Poore & Nemecek, 2018; Smetana et al., 2015). The environmental impacts of seafoods are more variable and less studied (Gephart et al., 2021; Koehn et al., 2022). Novel alternatives like cultured meat and mycoprotein, while promising, introduce additional concerns, particularly their high energy consumption (Sinke et al., 2023; Smetana et al., 2015; N. Stephens et al., 2018). The higher environmental impact of animal-based foods stems largely from the inefficiency of converting plant protein (animal feed) into animal protein (Statement (50)), methane emissions from ruminants, nitrous oxide from manure management, and deforestation driven by feed crop cultivation and grazing (Statements (43) and (50)) (Gerber et al., 2013; Searchinger et al., 2021; Steinfeld et al., 2006). In contrast, aquaculture and wild-capture fisheries have lower overall environmental impacts, with aquaculture primarily contributing to eutrophication and wild fisheries impacted by fuel use (Bohnes et al., 2019; Parker et al., 2018). Still, some environmental impacts of seafood (e.g., wild-caught small pelagic fish, farmed carp and bivalves) are equivalent to some plant-based foods (Koehn et al., 2022). However, this does not account for biodiversity loss and damage to ecosystems (Statement (53)(55)).
b) Because the environmental impacts of food products depend on how food is produced, they cannot be generalised, i.e., not all tomatoes are responsible for the same kilogram CO_2-equivalent (M. de Vries et al., 2015; Riera et al., 2023). The variability of values within one product group depends on the environmental indicator studied. Still, it seems largest for terrestrial as well as aquatic animal foods and lower for plant-based foods (Poore & Nemecek, 2018) (Statement (43)e)). Therefore, generalisation of environmental impacts across animal-based foods is

often criticised (e.g., Meier et al., 2015; Ridoutt et al., 2012) but at best addressed by incorporating uncertainty analyses (Lloyd & Ries, 2007).

3.2.3. Global warming

(43) Global Warming Potential (GWP) is the most widely used indicator to assess the climate impacts of greenhouse gases. Consequently, estimations of GWP (or GHG emissions) are more widely available compared to other environmental impact indicators. GWP has limitations in capturing the effects of short-lived pollutants like methane, which is why GWP*, a more dynamic method that considers emission rate changes and cumulative effects, has been introduced. Debates on the application of GWP* and equity implications remain unresolved.

a) Climate impact is often assessed using Global Warming Potential (GWP), which reflects the capacity of total GHGs to trap heat in Earth's atmosphere (Lynch, 2019). GWP relates the climate impact of various gases to that of CO_2 over a selected time period, often 100 years (GWP100). To achieve a "CO_2-equivalent" value for GWP, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are multiplied by 1, 28 and 265, respectively. However, these values are updated in **IPCC Assessment Reports**[26] and can therefore differ between studies.

b) GWP has been contested for not accurately estimating the cumulative effect of short-lived flow gases. These gases do not accumulate over time but instead their concentration remains stagnant as they are destroyed at the same rate of emission (Mitloehner et al., 2020). Alternatives have been developed, among which is GWP* (del Prado et al., 2023). However, this metric may be used to the advantage of sectors with high CH4 emissions, such as ruminant production (Cusworth et al., 2023). IPCC also states that "potential application in wider climate policy (e.g., to inform equitable and ambitious emission targets or to support sector-specific mitigation policies) is contested and relevant literature still limited." (Pathak et al., 2022). The production of terrestrial animal foods is a significant driver of global warming due to the emission of GHG, mainly CO_2, CH_4, and N_2O. Primary sources of these GHG include enteric fermentation (CH_4), manure management (N_2O),

[26] https://www.ipcc.ch/reports/

fertiliser manufacturing and application (CO_2 and N_2O), energy use in stables and for feed production and processing (CO_2), and land conversion for grazing or feed cultivation (CO_2). The types and amounts of GHG emissions are highly variable depending on production systems, animal types, and geographic contexts. Grazing systems may provide climate benefits through carbon sequestration under specific conditions.

c) Estimates on the contribution of the livestock sector (Box 1) to total global GHG emissions vary depending on, for example, the inclusion of emissions from feed production in cropland and grazing land or supply chain coverage. Livestock has been estimated to account for 12 percent, representing 6.2 gigatonnes of CO_2 eq, of the world's total GHG emissions (GLEAM v3, 2023). In another study, GHG emissions from the livestock sector are estimated to be approximately 10 gigatonnes, or 20 percent of total global greenhouse gas emissions (Xu et al., 2021). These discrepancies highlight how variations in system boundaries and assumptions can significantly influence reported estimates. Estimates for EU27 show around 500 million tonnes of CO_2 eq are emitted by livestock (approximately 8.2 percent of the global 6.2 gigatonnes), with ruminants contributing 70 percent and monogastric animals 30 percent of these emissions (GLEAM v3, 2023).

d) GHG emissions from fisheries are almost exclusively driven by the use of fossil fuels, contributing to only 4% of emissions from global food production in 2011 but increasing over recent years (Parker et al., 2018). Global emissions from aquaculture are driven mainly by feed production and, to an unknown extent, by **biogenic emissions**[27] from different aquatic farming systems. GHG emissions from aquaculture have been suggested to be in the same magnitude as GHG emissions from global sheep production, i.e., 0.49% of total anthropogenic emissions in 2017 (MacLeod et al., 2020). However, the GHG emissions estimate for aquaculture is highly uncertain and does not include potential methane emissions (Rosentreter et al., 2021).

[27] Biogenic emissions are gases and particles released into the atmosphere from natural biological processes in living organisms and ecosystems.

e) The hotspots of GHG emissions vary along the production chain for different animals (e.g., pigs vs cows) and production systems (e.g., grain-fed vs grass-fed) (M. de Vries et al., 2015; Poore & Nemecek, 2018). Pigs and poultry have larger shares of feed-related emissions, while ruminants' major share is methane from **enteric fermentation**[28] (Cheng et al., 2022). For aquatic animals, general differences arise from fed or non-fed aquaculture practices as feed demand and composition drive higher GHG emissions or from the different fuel use intensities behind different targeted species and fishing gear for fisheries (Gephart et al., 2021). Further, for aquatic animal production, the potential contribution of biogenic emissions from ponds (e.g., Dong et al., 2023; Fang et al., 2022; Hu et al., 2012) and carbon cycle effects from seafloor disturbance by bottom trawl fisheries (e.g., Epstein et al., 2022; Erhard et al., 2024; Sala et al., 2021) have been under intensive investigation in recent years.

f) GHG emissions per 100 grams of protein at the retail gate are estimated to be an average of 50 for beef (beef herd), 17 for beef (dairy herd), 11 for cheese, 9.5 for milk, 5.7 for poultry meat, 4.2 for eggs, 6.0 for farmed fish and 18 for crustaceans (Poore & Nemecek, 2018). These figures represent an average across different production system types, each of which perform differently within a given animal category (M. de Vries et al., 2015) (Statement (42)b) and 43g) and 43h)) .

g) Emissions vary between and within animal-based protein categories due to the substantial diversity inherent in animal production systems (Jordon et al., 2024; Riera et al., 2023). For terrestrial production systems, the diversity encompasses a range of factors, such as housing conditions and feeding practices (Krystallis et al., 2009; Riera et al., 2023; Shalloo et al., 2018). For example, grass-fed livestock systems are generally associated with increased NH_4 emissions and require more overall land use than grain-fed systems, though they need less cropland

[28] The natural digestive process that occurs in the stomachs of ruminant animals—such as cows, sheep, and goats—where microbes break down and ferment food in the rumen (a specialized stomach chamber). This microbial fermentation produces methane (CH_4) as a by-product, which the animal then releases primarily through belching.

(Jordon et al., 2024). Conversely, N_2O and CO_2 emissions tend to be higher in systems where livestock are grain-fed (Jordon et al., 2024).

h) For grazing-based livestock production, it is sometimes claimed that a net benefit for climate change can be obtained through carbon sequestration by grasslands but this is highly contingent on contexts (Conant et al., 2017; B. B. Henderson et al., 2015; Jordon et al., 2024). The potential of grasslands to function as carbon reservoirs depends on the existing soil organic carbon (SOC) level. This carbon stock can be increased by sequestration, which removes CO_2 from the atmosphere. However, this is offset by carbon losses through leaching, microbial respiration, and other soil processes (Rui et al., 2016). The balance of SOC additions and losses determines whether grasslands store or release carbon. Moreover, grazing-based livestock production systems can contribute to biodiversity preservation (Statement (54)). Yet, grasslands represent significant carbon stocks. If these grasslands were to disappear due to land-use changes, the carbon stored within them would be released into the atmosphere, contributing to increased GHG emissions (Offermanns et al., 2023).

(44) GHG emissions from plant-based and novel protein alternatives primarily arise from crop production (e.g., N_2O, CH_4, and CO_2 emissions) and energy-intensive processing, with the climate impact varying based on the type of crop, processing efficiency, and energy source, where minimally processed plant-based proteins have a lower impact compared to highly processed or emerging protein technologies like cultured meat.

a) GHG emissions from producing plant-based alternatives occur mainly in cropping and processing (Shahid et al., 2024). GHG emissions during cropping are mainly in the form of N_2O and CH_4 emissions from soil and CO_2 emissions from fuel use in fieldwork, as well as from the production of inputs such as mineral fertilizers. Post-harvest processing steps use energy that contributes to GHG emissions (depending on energy type) and other ingredients or chemicals that are also associated with GHG emissions (Shahid et al., 2024). The climate impact of plant-based alternatives, therefore, depends on factors like the type of crop used, how efficiently the crop is converted into the product (i.e., how much of the crop is needed per unit of product), and the amount and type of energy used in processing (Järviö et al., 2021).

b) GHG emissions per 100 grams of protein at the retail gate are estimated to be 0.8 kg CO_2 eq for peas, 1.4 kg CO_2 eq for other pulses, and 2.6 kg CO_2 eq for tofu (Poore & Nemecek, 2018). In a recent review, a climate impact for novel plant-based alternatives (based on soy, pea, lupin, and buckwheat) was estimated to be 0.4-1.2 kg CO_2 eq per 100 g protein at the factory gate (Shanmugam et al., 2023). Protein sources with a lower degree of processing, such as beans and lentils, usually have a lower climate impact than the novel plant-based alternatives (per kg product) (Potter et al., 2020; Springmann, 2024).

c) Few studies have examined the climate impact of other novel proteins, such as cultured meat or mycoprotein, but these proteins tend to have a lower climate impact than animal-based proteins. However, LCA studies on emerging technologies are generally associated with high uncertainty as it is unknown how this technology will be performed when up-scaled (Springmann, 2024). As an indication, the estimated impact of cultured meat is somewhere between 5 and 25 kg CO_2 eq per kg, depending on factors like energy source and growth medium (Tuomisto et al., 2022a) and the estimated impact of mycoprotein between 5 and 6 kg CO_2eq per kg (Smetana et al., 2015) or 3 kg CO_2eq per kg when produced from agricultural resides (Upcraft et al., 2021). For mycoprotein and cultured meat, the energy needed in the production process plays a big role in the product's total climate impact (Järviö et al., 2021; Tuomisto et al., 2022b).

3.2.4. Nitrogen cycles

(45) Agricultural systems are dependent on the supply of crop nutrients, most notably nitrogen, phosphorus, and potassium. Nitrogen is specifically important in producing protein foods as it is a fundamental component of amino acids which are the building blocks of proteins. Animals have a key role in the nitrogen cycle by recycling nitrogen from plants into food products and manure and returning it to the system. Because animal production systems can have low nitrogen efficiency, re-coupling animal- and plant-production systems such that manure can be used as fertiliser is suggested as a way to enhance the environmental sustainability of food production.

a) Nitrogen is a nutrient for crops, from which they synthesise protein and other organic N compounds (Barbieri et al., 2021). Nitrogen is cycled in the agri-food system: from uptake by the plant, consumption by animals or humans, excretion of manure or human excreta and food waste, back to the soil and atmosphere (TABLE Debates, 2024). The plant can take up nitrogen through **biological N fixation**[29], **atmospheric deposition**[30], and application of nitrogen to the soil. In the agri-food system, nitrogen can be present in a range of organic and inorganic forms, i.e., dinitrogen (N_2), ammonia (NH_3), ammonium (NH_4), nitrate (NO_3^-), nitrogen oxides (NO and NO_2, collectively NO_x), and nitrous oxide (N_2O) (Näsholm et al., 2009).

b) Without animals as recyclers of nitrogen, soil management has to change considerably, as animals directly contribute to soil fertility through manure production (Chang et al., 2021; Gu, 2022). Green manures are used by some farmers as an alternative to animal manure (Nygaard Sorensen & Thorup-Kristensen, 2011). Green manure crops are not harvested for food or other purposes; instead, they are ploughed under or left on the soil surface to decompose, enriching the soil naturally (Fageria, 2007).

c) Nitrogen Use Efficiency (NUE) is a measure of how effectively supplied or applied nitrogen can be converted into a product. Compared to plant production systems, animal production systems have low NUE (Oenema & Tamminga, 2005). This is because only part of the nitrogen consumed by livestock is retained in meat, milk, or eggs, while the majority is excreted into the environment through faeces and urine (Gerber et al., 2014; Godfray et al., 2018). However, in indoor production systems, these excretions are often collected and used. Some authors calculate that (re)coupling cropping and livestock systems can enhance

[29] Biological nitrogen fixation is the process by which atmospheric nitrogen gas (N_2), which is inert and unusable by most living organisms, is converted into ammonia (NH_3) or related nitrogenous compounds by specific microorganisms. These compounds are then accessible for use by plants and other organisms in the ecosystem.

[30] Nitrogen atmospheric deposition is the process by which nitrogen compounds in the atmosphere are deposited onto Earth's surface, including soil, water, and vegetation. These compounds come from natural sources (e.g., wildfires) as well as human activities (e.g., emissions from the combustion of fossil fuels), and their deposition plays a key role in the nitrogen cycle.

NUE as manure can be used by crops for fertilisation . Nevertheless, in livestock-intensive regions, the amount of manure produced often exceeds the fertilization requirements of crops, limiting its effective use and contributing to environmental challenges such as eutrophication (Statement (47)) (van Selm et al., 2023).

(46) The global nitrogen cycle has been significantly altered by the use of synthetic nitrogen fertilisers and the international trade of agricultural products, resulting in regional imbalances.

a) The use of synthetic nitrogen fertilisers has partly replaced the role of animal manure in cropping systems and thereby decoupled animal manure from nitrogen cycles (Le Noë et al., 2017; J. Wang et al., 2018). This shift away from manure has allowed geographical specialisation, resulting in nitrogen surpluses in regions with high livestock densities due to excess manure. Conversely, areas supplying animal feed often face nitrogen (and phosphorus) deficits, necessitating external fertilizer inputs to compensate for nutrient exports (Le Noë et al., 2017; Papangelou & Mathijs, 2021; H. Wang et al., 2018).

b) The international trade of food and feed has grown substantially since the 1950s, representing significant nitrogen flows embedded in crops for feed and food or animal-based protein within and between continents (Lassaletta et al., 2014, 2016; J. Wang et al., 2018). Trade of nitrogen in agricultural products among major regions has increased from 1.6 to 12.1 billion kilograms annually between 1961 and 2009 (Lassaletta et al., 2016). Animal feed, particularly soybean and maise, accounts for approximately 60% of traded nitrogen. North and South American countries produce significant amounts of nitrogen (and other nutrients) in the form of soy crops for livestock feed in other regions of the world (Billen et al., 2014, p. 201; Karlsson et al., 2021).

(47) Excessive nitrogen application causes surpluses that can lead to eutrophication, soil and atmospheric acidification, significantly impacting aquatic and terrestrial ecosystems, human health, and climate change. These environmental issues are even more problematic in regions with high livestock densities and for aquaculture whose practices depend on feed crops.

a) When more nitrogen is applied than can be taken up by the soil or plant, a nitrogen surplus occurs, which can cause nitrogen to run off into water bodies, leading to **eutrophication**[31] (Chislock et al., 2013). In addition, a surplus of nitrogen can cause **acidification**[32] of soils, oceans and atmosphere, which also disrupts ecosystems and has potential negative health effects for humans (W. de Vries, 2021; Rice & Herman, 2012).

b) Regions with high livestock densities often face such localized environmental problems from nitrogen surplus, i.e., water, air, and soil pollution (McAllister & Topp, 2012), primarily due to the alteration of nutrient cycles. In addition to the cascading effects locally, these issues play a significant role in exacerbating climate change globally (Buckwell & Nadeu, 2018) or can have large-scale polluting effects, such as the eutrophication of the Baltic Sea (European Court of Auditors, 2020).

c) Soil contamination is another adverse effect of high livestock concentrations, marked by the accumulation of heavy metals (H. Wang et al., 2018). These metals can originate from various sources, such as animal feed, water, supplements, and veterinary medicines. Common heavy metals found in livestock waste include arsenic, cadmium, lead, mercury, and copper (Nicholson et al., 2003).

d) Eutrophication pressures from aquaculture that require feed are closely tied to those of livestock, as many of the crop ingredients used, such as soy and wheat, are the same. This means that aquaculture relying on feed shares similar production pressures associated with feed crop cultivation. However, in the case of farmed aquatic animals, the main driver of eutrophication is the application of feed, as it is often used in watersheds where aquaculture operations are located (Bohnes et al., 2019). In contrast, aquaculture practices that do not require feed inputs, such as mussel farming, actively remove nutrients from the water, contributing to nutrient balance and reducing eutrophication risks.

(48) A shift from animal-based proteins towards plant-based, novel plant-based and fungi-based proteins reduces nitrogen use in agriculture (Billen et al., 2015; Springmann et al., 2018), lowering the risks of mineral fertilizer-related emissions and environmental

[31] Eutrophication is the process by which aquatic ecosystems become overly enriched with nutrients, leading to excessive growth of algae and other aquatic plants, ultimately harming water quality, aquatic life and overall biodiversity

[32] Nitrogen acidification is the process by which nitrogen compounds, such as ammonia (NH_3) and nitrogen oxides (NO_x), lead to increased acidity in soils, water bodies, and the atmosphere.

nitrogen losses. In the case of other novel proteins, such as edible insects and microalgae, cultivation can use agricultural by-products to enhance nitrogen use efficiency by converting organic residues into human-edible protein (Siddiqui et al., 2023).

(49) Many crops used to produce plant-based foods, such as soybeans, peas, and lentils play an important role in agriculture due to their capacity to fixate nitrogen from the air. These crops, also known as legumes, reduce the need for nitrogen fertilization in the succeeding crop within the rotation and improve soil health due to their capacity to fix atmospheric nitrogen through symbiotic relationships with bacteria, reducing the need for synthetic fertilisers (Guo et al., 2022; Jangir et al., 2022). However, legume crops are not commonly integrated into European cropping systems due to their lack of attractiveness for farmers (Statement (9)), and potentially exacerbate nitrogen leaching when there is already sufficient, or an excess of, nitrogen in the system (Tripolskaja et al., 2023).

3.2.5. Land and water use

(50) Monogastric animals and farmed aquatic species compete directly with humans for cropland to produce feed including grains, legumes, and fish. Ruminants, on the other hand, can be raised solely on non-competitive feed sources like grass but this would make them less productive compared to when high-quality grains are incorporated in their feed ration. Converting by-products into food using technologies like fermentation or edible insects can spare land and water compared to livestock production. Aquatic animal farming generally uses less land than monogastric production, but capture fisheries rely on finite natural resources and require rebuilding depleted seafood stocks to increase production.

a) Land use varies between monogastric and ruminants (Box 1) mainly due to their distinct feeding habits and digestive systems. Monogastric animals, such as pigs and poultry, have a single-chambered stomach, while ruminant animals, like cows, sheep, goats, and fish, have a more complex digestive system with a four-chambered stomach.

b) Monogastric animals and some farmed aquatic animals compete directly with humans for food resources, as they rely on grains, legumes, and fish from capture fisheries as feed—all of which are also suitable for human consumption, creating a direct competition between food and feed use (Chary et al., 2024; Troell et al., 2014). While shifting monogastric diets to non-edible feed sources (e.g., by-products) could help, current industrial systems rely to a certain extent on high-quality feed. While their diets could potentially incorporate non-edible feed sources, such as by-products, roughage feeds, and crops residues, current industrial systems remain dependent on high-quality feed to meet nutritional demands (Mottet et al., 2017; van Zanten et al., 2018). In contrast, ruminants can graze on grasslands and convert inedible plant matter into protein (Mottet et al., 2017; van Zanten et al., 2018). However, most production systems also rely on concentrates, including cereal grains and soybean, particularly during finishing periods to enhance beef yield (Rowe et al., 2025). If ruminants were limited solely to grazing, the number of animals would need to decrease, leading to drastic reductions in meat and dairy products compared to current production levels (Röös et al., 2017; van Selm et al., 2022). Furthermore, current production levels might decrease, as the proposed grazing feeding practices may not adequately meet the nutritional requirements of highly productive animals (see for example, (Y. Wang et al., 2024). This production would be limited even further if low-intensity practices such as low-intensity grazing were implemented (Resare Sahlin et al., 2024). For both ruminant and monogastric, implementing the principle of restricting livestock to feed sources such as grass and food by-products, which do not compete with human food production, would necessitate a dramatic reduction in livestock numbers as these feedstocks are limited (Röös et al., 2017; van Selm et al., 2022).

c) Instead of using by-products or waste streams as feed, by-products or waste streams can, in some cases, be upgraded to food using for example, edible insects (Leni et al., 2021), emerging food processing technology (Dey et al., 2021) and fermentation (Verni et al., 2019) that can potentially improve the efficiency in converting by-products to food compared to using livestock

d) Most farmed aquatic animals require less land use than chicken per kilogram of edible product, although large variability is seen (Gephart et al., 2021). Capture fisheries produce proteins that do not require land but are based on a limited natural resource, i.e., food from the sea is capable of being depleted. Different views exist on the status of global fisheries and estimates on the potential for growth (e.g., Costello et al., 2020; Roberts et al., 2024), but any significant increase in production would require rebuilding depleted stocks and improving catch efficiency by prioritizing human consumption over industrial uses like feed production. In 2022, around 11% of global landings were estimated to be destined for non-food uses (FAO, 2024c) , but this data is uncertain due to, e.g., lack of data on the use of different parts of the live-weight volume during processing. Currently, domestic aquatic animal production from both fisheries and aquaculture in many European countries falls short of meeting dietary recommendations (Statement (34)d)) (Lofstedt et al., 2021; Thurstan & Roberts, 2014), while a substantial portion of global seafood catches is directed toward the European market.

(51) Plant-based proteins, fungi-based proteins, and novel proteins like cultured meat generally require significantly less land per product unit and per kg of protein than terrestrial animal-based proteins. Terrestrial invertebrates, such as insects, are particularly efficient regarding land use and resource conversion.

a) Plant-based proteins use less land per kg product than terrestrial animal-based proteins (Poore & Nemecek, 2018). A study on plant-based protein products on the Swedish market (including, for example, legumes, tofu, tempeh and seitan, as well as novel plant-based proteins) shows that most products are associated with lower land use than beef, pork, and chicken (Karlsson Potter et al., 2020). This aligns with a recent systematic review in high-income countries showing that novel plant-based and fungi-based proteins can reduce land use by more than 70% per unit of product compared to their terrestrial animal-based protein counterparts (Nájera Espinosa et al., 2024). Results for novel proteins such as cultured meat indicate that they can be produced using less land than beef and are comparable to chicken (European Parliament, 2024b; Smetana et al., 2023).

b) Insects can produce protein much more efficiently than livestock. For example, mealworms require 102 times less land than beef (Malila et al., 2024a). Like aquatic animals, novel algae-based proteins have a remarkable land use efficiency as the raw materials are cultivated in seawater (European Parliament, 2024b). Insects and algae-based proteins are especially efficient, with mealworms using 102 times less land per kg of protein than beef and algae, leveraging seawater cultivation for remarkable land-use efficiency (Malila et al., 2024a; Smetana et al., 2023).

(52) Animal-based proteins have a higher overall water footprint than plant-based and novel proteins, largely due to significant green water use, whereas plant-based proteins and novel protein sources generally require less **blue and green water**[33], though variations depend on crop type and production systems. Transitioning to diets lower in animal-based foods has the potential to reduce green water use but may increase blue water consumption, especially with diets increasing fruit and vegetable intake. Novel proteins, such as mycoprotein, show promise for lower water usage, though more research is needed to fully understand their green water impact across different regions and production systems.

a) The water footprint of animal-based proteins is, in general, higher than plant-based protein sources, mainly due to high green water use (Mekonnen & Hoekstra, 2012, 2011). Some protein-rich crops can be associated with relatively high green water use, such as lentils and dry beans, depending on where these are produced. Further, blue water use can be relatively high if the crop is irrigated (Mekonnen & Hoekstra, 2011).

b) Terrestrial animal-based proteins are often associated with higher green water use, while cereals, fruits, and nuts have higher blue water use (Harris et al., 2020). A transition to a healthy diet following nutritional guidelines, which is associated with lower animal food consumption, could lower green water use, but not necessarily blue water (Harris et al., 2020; Vanham et al., 2018). A similar finding was observed in the UK, where adhering to the national dietary recommendations of fruits and vegetables would increase blue water consumption (Scheelbeek et al., 2020).

c) A study indicates that novel protein sources consume less blue water than terrestrial animal-based proteins (Malila et al., 2024a). However, more research is required to assess green water. While most novel plant-

[33] Blue water refers to freshwater resources from rivers, lakes, reservoirs and aquifers, which is available for human use, while green water refers to the water that originates from precipitation and is stored in the top layers of the soil, which is available for plant uptake.

based proteins require less blue water, reducing or increasing blue water use is usually subject to feed types, rearing systems, and farm efficiency across countries. For example, a recent study found that Swedish novel-fungi-based proteins (e.g., mycoprotein) required more water than Swedish chicken breast, while the opposite was found in the UK (Nájera Espinosa et al., 2024).

3.2.6. Biodiversity

(53) The global livestock system is a major driver of habitat loss, deforestation, and biodiversity degradation, with significant impacts in Europe linked to animal-based food production. European countries also outsource much of their biodiversity footprint to regions like Central and South America, heavily relying on imports of high-impact products such as dairy, beef, and processed foods.

a) The global livestock system is the largest user of agricultural land and has thereby been a major driver for habitat loss, deforestation, and ecosystem degradation up until the present time (Hald-Mortensen, 2023; Machovina et al., 2015; Ritchie & Roser, 2021). In Europe, significant biodiversity impacts are driven by food production and consumption, with both land-driven (i.e., the loss of biodiversity caused by land changes) and GHG-driven biodiversity loss (i.e., the loss of biodiversity caused by GHG emissions), most of which are caused by the production of animal-source foods (Boakes et al., 2024). It has been estimated that up to 70% of the total GHG-driven biodiversity footprint of foods stems from methane (Boakes et al., 2024).

b) European countries are major net importers of biodiversity loss, outsourcing much of their environmental impact to biodiversity-rich regions such as Central and South Americas (Amahnui et al., 2025; Boakes et al., 2024). Products like dairy, beef, and processed foods are key drivers of European biodiversity impacts, with the region importing up to 90% of its embedded biodiversity footprint for certain food categories (Boakes et al., 2024).

(54) Grazing and aquaculture practices can have both positive and negative impacts on biodiversity and ecosystem health, depending on their intensity, management, and context. Livestock grazing, when practised at low to moderate intensities, can enhance biodiversity, soil health, and water quality by maintaining open grasslands, supporting diverse plant and animal species, and creating microhabitats. Conversely, overgrazing and land conversion for grazing can degrade vegetation, reduce biodiversity, and disrupt critical ecosystem services. In marine systems, aquaculture and fisheries have mixed impacts: while certain practices, like bivalve farming, provide ecosystem benefits such as water filtration, others, including habitat conversion and overfishing, contribute significantly to biodiversity loss and ecosystem degradation.

a) The grazing of some types of land areas, such as semi-natural pastures, can enhance biodiversity, soil health, and water quality, offering environmental benefits (B. Dumont et al., 2019; Rodríguez-Ortega et al., 2014). Practices such as well-balanced and/or rotational grazing can have positive ecological impacts, such as improved soil health through enhanced soil structure and fertility through organic matter retention and reduced erosion (Rodríguez-Ortega et al., 2014; Zhang et al., 2022). However, there is no consensus on the effects of grazing on the presence of other animals, and negative effects may occur (e.g., crowding out other herbivores) (Filazzola et al., 2020).

b) Livestock grazing is constitutive of grassland ecosystems by preventing shrub encroachment and promoting plant diversity (Metera et al., 2010). In countries like the UK, France, Slovenia, Austria, Sweden, Finland, and Germany, livestock rearing on grazing practices appropriate for the areas help maintain open areas in forest biomes, supporting the persistence of habitats that many plant species depend on (Metera et al., 2010). Predominantly low and mid-intensity grazing creates a variety of microhabitats in landscapes, such as areas of short grass, taller tussocks, and bare ground, supporting a wide range of species, including insects, birds, and small mammals (Pulungan et al., 2019; Tubay et al., 2015). Different animal species graze selectively, which can enhance plant species diversity by preventing dominant species from outcompeting others. For example, mixed grazing with cattle and sheep can promote a more diverse plant community than grazing with a single species (Fraser, 2008a).

c) Furthermore, livestock grazing aids the dispersal of plant seeds through their hooves and dung, helping maintain and enhance plant diversity in grassland ecosystems (Pulungan et al., 2019). Areas maintained by grazing support diverse invertebrate communities, which serve as food for birds and other wildlife. The structure of grazed areas provides habitats for pollinators and other beneficial insects (Fraser, 2008a). Many ground-nesting birds, such as the skylark and lapwing, thrive in grazing lands, where grazing helps maintain the open habitats these birds require for nesting and feeding (Pulungan et al., 2019).

d) Traditional animal husbandry practices, including through grazing, has also shaped culturally significant landscapes in Europe, such as the alpine meadows in Switzerland and Austria, and the upland pastures in the UK (European Environment Agency, 2004) as well as semi-natural (forest) pastures in northern Europe (Herzon et al., 2021). These landscapes are important for biodiversity, cultural heritage, and tourism. European agri-environment schemes often support traditional grazing practices to maintain grassland habitats (Ronchi & Ramanzin, 2024; Runge et al., 2022). The preservation of such landscapes relies on the continuation of traditional practices, including maintaining low livestock densities, producing specific foods, and, in certain contexts, moving animals along historical routes or patterns (Ronchi & Ramanzin, 2024).

e) In densely stocked areas, overgrazing can lead to vegetation degradation, reducing plant diversity and negatively affecting species that depend on those plants (Rutherford & Powrie, 2013). Moreover, converting forests, wetlands, and other natural habitats into grazing lands or croplands can lead to habitat loss and fragmentation depending on the performed change (Semenchuk et al., 2022). The destruction of natural habitats can result in the loss of crucial ecosystem services such as pollination, water purification, and carbon sequestration (Adla et al., 2022; IPBES, 2018).

f) The biodiversity pressures associated with aquaculture vary depending on the species being farmed and the production systems used. These pressures include a risk of invasive species spreading, the release of effluents from farms, the conversion of valuable habitats such as mangroves into aquaculture ponds, and the spread of diseases and parasites (Diana, 2009). Some practices may have a positive effect on biodiversity, especially if restorative aquaculture principles are applied (Alleway et al., 2023). Farming of bivalves (e.g., mussels, clams, oysters) provides many ecosystem services, such as the uptake of nutrients through filtering water (van der Schatte Olivier et al., 2020).

g) Direct exploitation (fisheries) is the main driver for biodiversity loss in marine ecosystems (Jaureguiberry et al., 2022). Biodiversity pressures of fisheries are many – sprung from direct capture, incidental bycatches discarded at sea dead or alive and habitat conversion - with complex interactions that alter ecosystem structures and functions. Different perspectives exist on the current state of global fisheries and how to interpret trends (e.g. (Pauly et al., 2013)), but in essence, vast differences in performance exist which are driven by the status and vulnerability of the species targeted, the use of different fishing gears and fishery management in different regions (e.g.,Fulton et al., 2019).

(55) Diets with higher rates of plant-based or novel proteins are less land- and resource-intensive, typically resulting in lower biodiversity impacts from land (Kozicka et al., 2023; Kyttä et al., 2023; Röös et al., 2015).

3.3. Animal health and welfare

Using animals for food raises ethical concerns from both human and non-human perspectives, particularly in the context of a protein transition that could change which animals are used, as well as practices such as breeding, feeding, transport, and slaughter. A key driver of the protein transition is concern over animal welfare in conventional livestock systems. The protein transition could imply two shifts in relation to animal welfare: i) phasing out animal-based food production entirely, and ii) shifting toward production systems that uphold higher animal welfare standards. The different issues related to animal welfare are extremely broad. Thereby, the examples provided in the subsections below are not exhaustive.

(56) Animal welfare can be framed through multiple perspectives. Most commonly, there is a utilitarian view that aims to improve welfare through better practices if there are no better alternatives or options to reduce animal consumption; that is, that welfare can be maximised through continued use of animals for food, but with the best possible conditions for the animals; and an abolitionist perspective that fundamentally questions the ethics of using animals for food. Thereby, measuring animal welfare and seeking improvements in animal production systems is inherently based on a utilitarian view.

a) Animal welfare has been identified as one of the main drivers of the protein transition (Duluins & Baret, 2024a). Although consumers are increasingly aware of, and concerned about, animal welfare issues related to production systems (Alonso et al., 2020; de Araújo et al., 2022), it is still a topic that is often considered to be underrepresented in discussions of environmental, social, or economic sustainability (Torpman & Röcklinsberg, 2021).

b) Framing animals as units of production remains common in welfare discussions that rely on quantifiable parameters (Arcari, 2017; Harfeld et al., 2016). Within the context of a protein transition, animal welfare indicators can be used to assess the current welfare status in animal production systems, enabling comparisons (Scherer et al., 2018) and assessing where improvements are needed (Lanzoni et al., 2023). However, some argue that this approach reinforces and normalises the objectification of animals (Arcari, 2017; Pierce, 2019). Even more, in the literature on sustainable food systems, animals are generally materialised, as meat or protein (Arcari, 2017), and many scholars advocate for making animals “visible” in the discussion around sustainable food systems (Arcari, 2017; Arcari et al., 2021; Vinnari & Vinnari, 2022).

c) The utilitarian perspective seeks to minimise suffering and maximise well-being, allowing the use of animals if the overall benefits of producing food outweigh the harms, and no better alternatives exist to achieve those benefits (Blaxter et al., 2024; Kuruc & McFadden, 2023). This view emphasises the need to transform production systems to improve welfare standards, thus allowing continued use of animals for food as long as their suffering is minimised (Buller et al., 2018). Going one step further, the "less but better" approach, which can be considered as an extension of the utilitarian view, captures a dual aim: advocating for decreased consumption of animal-based proteins alongside improving the conditions under which animals are raised (Mazac et al., 2025). It appraises gradual welfare reforms and supports practices such as food labelling and “better” farming practices for higher animal welfare standards (Zwolińska & Żakowska-Biemans, 2020). Different perspectives on animal welfare and ethics can lead to conflicting recommendations, as there is no universally accepted way to balance these diverse perspectives (Veit & Browning, 2020).

d) Adjacent to approaches to animal welfare, which focus on minimising negative experiences for animals, are positive animal welfare perspectives. This emphasises the essence of not only avoiding negative experiences, but ensuring (1) positive emotions of animals; (2) linking these emotions of motivation to engage in activities; (3) finding an appropriate balance between positives and negatives, and (4) happiness, or a full life perspective of animals (Lawrence et al., 2019; Zapata-Cardona et al., 2024). As such, a positive animal welfare perspective argues for the right to 'a life worth living' of farmed animals, argued to constitute an animal-based perspective as opposed to the anthropocentric utilitarian perspective (Yeates, 2011).

e) Lastly, the abolitionist approach argues that animals possess intrinsic moral rights that should not be violated, regardless of human benefit (Blaxter et al., 2024). It challenges the assumption that animals can ethically be kept and consumed at all, arguing that such use perpetuates their objectification (Francione, 2020; Schmidt, 2011). This view thereby rejects the use of animals altogether and pushes for systemic change (Blaxter et al., 2024). In addition, this view contends that framing welfare in terms of minimal harm can normalise ongoing exploitation rather than dismantling it.

(57) The welfare of terrestrial farm animals in food production systems varies greatly depending on the species, their biological and behavioural needs, and the specific practices used to breed, house, transport, and slaughter them—highlighting that welfare concerns are not uniform but shaped by how each animal is integrated into human food systems. From a utilitarian perspective, animal welfare in farming and food production is commonly evaluated by three main factors: ensuring animal health, supporting natural behaviours, and promoting mental well-being by minimising stress. These factors are influenced by different conditions, though addressing only one is insufficient to ensure comprehensive welfare.

a) Different animals experience pain and stress in distinct ways due to species-specific physiology and behavior; for example, pigs are intelligent and social, exhibiting clear signs of experiencing pain (Animals, 1992; Marino & Colvin, 2015; Vullo et al., 2020), while broiler chickens experience pain but may not express it in ways that are immediately obvious to humans (McIlhone et al., 2018; Schlegel et al., 2024). Although invertebrates do not have a central brain, and their capacity to experience pain is debated (Adamo, 2016; Delvendahl et al., 2022; Mather, 2023), invertebrates possess a decentralised nervous system with a series of ganglia, which leads to uncertainty regarding how they experience pain compared to vertebrates (De Goede et al., 2013). Vertebrates, in contrast, possess a well-developed central nervous system—including a brain and spinal cord—along with nociceptors, which are specialised sensory neurons responsible for detecting and transmitting signals of noxious (potentially harmful) stimuli. This anatomical and physiological structure allows vertebrates not only to detect injury but also to process pain in a way that likely includes a conscious experience of suffering (Sneddon et al., 2014).

b) Animal welfare in farming and food production contexts can be understood by using three key components: (1) basic health and functioning (disease prevention, nutrition, injury care), (2) natural living (providing conditions that allow animals to express species-specific behaviors such as foraging, socialising, or nesting), and (3) affective states (mental well-being, minimising stress, and promoting positive experiences) (Fraser, 2008b; Veit & Browning, 2020). However, the weighing of these three indicators can be subjective, as it often relies on expert judgment (Veit & Browning, 2020).

c) Basic health indicators include mortality rates, disease incidence, injury frequency, and **body condition scores**[34], all of which provide insight into an animal's physical state (EFSA et al., 2023). Natural living is assessed by evaluating factors such as access to environmental enrichment, adequate space, and opportunities to engage in species-specific behaviours like foraging, nesting, or social interaction (Meehan & Mench, 2007). Affective states, reflecting the animals' emotional well-being, are measured through behavioural indicators of stress or discomfort, the presence of **stereotypic behaviours**[35], and

[34] Body condition scoring is a crucial tool in animal welfare, used to assess an animal's fat reserves and overall health. It helps determine whether an animal is underweight, overweight, or at an optimal condition.
[35] Stereotypic behavior in animals refers to repetitive, invariant actions that serve no obvious function. These behaviors often arise in captive animals due to stress, frustration, or an inability to express natural

physiological markers like cortisol levels (Boissy et al., 2007). These indicators are systematically integrated into comprehensive welfare assessment protocols such as those developed by **Welfare Quality**[36]®, which combine both animal-based and resource-based measures to provide comparable evaluation of welfare conditions within production systems (Welfare Quality, 2009).

d) Assessing welfare of fish and other seafood has for long been limited by a lack of consensus on how welfare should be defined and measured (Ashley, 2007). However, it is currently rapidly evolving, especially for key species like salmon, shrimp, and seabass (Barreto et al., 2021; Pedrazzani et al., 2024). The basic health indicators (mortality, disease, injury) are in a more mature stage compared to behavioural and emotional indicators that are still a work in progress (EFSA, 2022). Assessment frameworks for assessing fish welfare in aquaculture have been developed, such as SWIM (salmon welfare index model), FISHWELL, and MYFISHCHECK (Browning, 2023). These frameworks encounter similar limitations as discussed above of subjective weighing, being incomplete, and setting appropriate thresholds for “poor”, “acceptable”, or “good” welfare (Browning, 2023). Welfare assessments are uncommon in wild capture fisheries as they are not living in human-controlled environments before capture, although welfare during and post capture can be measured (Breen et al., 2020).

e) Following the approach that animal welfare can be measured, ongoing work attempts to include indicators for animal welfare in LCA, with indicators such as lifespan under human care or intensity of confinement (Scherer et al., 2018). Complicating such assessments, animal welfare is challenging to evaluate because it involves multiple levels of observation, including the well-being of individual animals, groups within a herd or tank, and the overall conditions on a farm

behaviors. In terms of animal welfare, stereotypies are commonly used as indicators of poor well-being, particularly in zoo and farm animals.

[36] Welfare Quality® protocol is one of the most widely used animal welfare assessment frameworks in Europe, particularly within the EU. It was developed through a major EU-funded research project and is designed to provide standardized, science-based, on-farm welfare assessments for cattle, pigs, and poultry.

(Lanzoni et al., 2023; Reimert et al., 2023). Additionally, the selection of indicators is inevitably directed by the underlying perspective and definition of welfare (Lanzoni et al., 2023). Without clarification, various quantitative measures of animal welfare may seem comparable, while in fact indicating differing interpretations of what welfare means. However, Bartlett et al., (2023) argue that it is possible to measure animal welfare empirically and transparently, and that "lack of consensus on relatively inconsequential details" should not keep animal welfare from being included in LCA.

f) Various assessment tools, metrics, and labels have been developed to quantify animal welfare, aiming to reflect the welfare standards in animal production (e.g., **Beter Leven in the Netherlands**[37] or **KRAV in Sweden**[38]) (Heinola et al., 2021). These have been shown to positively influence consumer choices and willingness to pay, although this may only be relevant for a consumer group for which price is less important in decision-making (Cornish et al., 2020; Gorton et al., 2023). Yet, farmers may be sceptical about changing farming practices in favour of certification or labelling for improved animal welfare because animal welfare is perceived as sufficient, negative outcomes are easily alleviated with medication, and the benefits of certification do not outweigh the additional work (Albernaz-Gonçalves et al., 2021; Balzani & Hanlon, 2020).

(58) Among all factors, housing is often considered to play the most important role for establishing the status of animal welfare. Specifically high stocking densities, a lack of enrichment, and environments that keep animals from expressing natural behaviors, leads to poor welfare and health issues. Although intensive production systems tend to be more distant form natural environments compared to extensive production systems, each of those come with their own concerns for animal welfare.

a) The animal's living environment plays a crucial role, with factors like sufficient space, clean and safe conditions, and appropriate shelter and

[37] The Beter Leven label is a Dutch certification focused on animal welfare. It applies to products like meat, eggs, and dairy, ensuring better living conditions for animals. The label has three levels (stars)—the more stars, the higher the welfare standards.

[38] KRAV is a Swedish organic certification where animal welfare is conceptualised and assessed through for example requirements around individual space for animals, physical spatial possibilities to exercise natural behaviours, feeding patterns and rules around how to perform painful procedures going beyond both national and EU legislation.

enrichment directly affecting welfare (Scherer et al., 2018). High stocking densities restrict movement and are linked to increased stress and a higher susceptibility to diseases, including a greater risk of infections such as salmonella in broilers (Tahamtani et al., 2019). The absence of natural environmental and/or enrichment, such as perches or foraging materials, limits the expression of natural behaviours and generates a lack of mental stimulation eventually causing behavioral problems (Mason et al., 2007; Riber et al., 2018). Ruminants reared in indoor confined environments without access to pasture cannot exercise their natural instinct to roam and graze, which cows have indicated to find equally important as fresh feed through **motivation tests**[39] (von Keyserlingk et al., 2017). Access to pasture also reduces lameness for dairy cows (Hernandez-Mendo et al., 2007). In commercial pig production, breeding sows are commonly housed in gestation crates[40] during pregnancy to manage individual feeding and reduce aggression among animals in group housing systems (Schuck-Paim & Alonso, 2022). Following birth, farrowing crates are used to reduce the risk of piglets being accidentally crushed by the sow — a leading cause of piglet mortality in loose housing systems. However, gestation and farrowing crates restrict movement and interaction with offspring, which has been associated with physical issues such as pressure sores and joint strain, as well as repetitive behaviours that may indicate frustration or lack of stimulation (Schuck-Paim & Alonso, 2022(Ko et al., 2022; Plush et al., 2024).

b) Although attention generally focuses on animal welfare in intensive production systems for valid reasons, welfare status is not directly related to production systems being intensive or extensive (Temple & Manteca, 2020). Intensive systems can promote good animal welfare by ensuring controlled environments, proper healthcare and stress-reducing practices. On the other hand, these systems are generally far

[39] Motivation tests are used in animal behavior studies to assess how much effort an animal will make to gain access to a resource. The effort might be measured by how many times they press a lever, how far they push a weighted door, or how long they wait.

[40] A gestation crate (also known as a sow stall) is a metal enclosure used in industrial pig farming to confine pregnant sows. These crates typically measure about 2 feet wide by 7 feet long (0.6 m by 2.1 m), which is roughly the same length as a sow but too narrow for her to turn around or move freely. In contrast, a typical adult sow can weigh between 400–600 pounds (180–270 kg) and needs more space to express natural behaviors like nesting or turning.

off from natural environments, clashing with the fundamental needs of animals (Broom & Fraser, 2007b). On the contrary, while animals may interact in a more natural environment in extensive systems, some have argued these systems can lack proper care, where animals are exposed to extreme weather and can face other challenges such as inadequate food or water (Temple & Manteca, 2020).

c) **Precision farming**[41] has been promoted as a way to improve animal welfare conditions by enabling close monitoring of health and welfare parameters (Simitzis et al., 2022). However, practice shows that while it has potential to improve animal health by reducing the occurrence of diseases and injuries, it does not directly promote animal welfare (Schillings et al., 2021). This is largely linked to a lack of understanding of what animals actually need and want, while with that understanding technology could be developed that provide autonomy to animals to receive what they want (Dawkins, 2021; Werkheiser, 2020). Even ore, precision farming is linked to adverse effects on animal welfare due to impairing human-animal relationships, the technologies being obtrusive and causing stress, or interfering with natural behavior (Werkheiser, 2020).

(59) Beyond housing conditions, animals' health and welfare is shaped by a strong focus on convenience and productivity. How animals are kept drives the need for practices such as tail docking, dehorning, or teeth clipping. Breeding and selection procedures can create animals that are performing well from a production perspective, but at the same time creates animal health and welfare issues. Lastly, direct human-animal interactions during handling and transportation can be stressors with long-lasting side-effects.

a) The faith and life cycle of farmed animals is shaped by their convenience for human use and a strong focus on productivity. Intensive feeding practices may be applied to achieve high yields or a certain body composition faster. For example, for **heifers**[42] to reach breeding size earlier and thereby increase lifetime productivity and decrease costs associated with raising replacement heifers (Rincker et al., 2011), while

[41] A data-driven and technology-enhanced approach to agriculture that applies site-specific or animal-specific management practices based on real-time information.

[42] Young cows that have not yet given birth to a calf

this can lead to metabolic disorders (FAO, 2011). Dairy cows usually live 5–6 years as opposed to their natural lifespan of 15–20 (De Vries & Marcondes, 2020), while broiler chickens are slaughtered at 5–7 weeks old (Cicek & Tandogan, 2016). Typically, in dairy production systems, calves are removed from their mothers shortly after birth (Flower & Weary, 2003; Stěhulová et al., 2008), which can lead to behavioural issues, stress-induced illness, and emotional distress (Boissy & Le Neindre, 1997; Meagher et al., 2019). Male calves not used for milk production are either slaughtered at a young age or raised for veal (Alley et al., 2021; Webb et al., 2023). Male chicks, as they do not lay eggs and are not typically raised for meat production, are commonly culled shortly after hatching using methods such as maceration or gas exposure (de Haas et al., 2021), shown to cause distress (Foote, 2019).

b) Handling and transport practices can create additional welfare issues (Broom & Fraser, 2007a). For example, piglets may undergo tail docking, teeth clipping, and castration—procedures intended to prevent future injuries and manage meat quality. These are often performed without anaesthesia and result in short-term pain and potential long-term effects (Sutherland, 2015). Similarly, castrating, dehorning and branding (beef) cattle causes acute pain, stress, and potentially long-term discomfort (Sutherland et al., 2013). Broilers often experience transport-related stress due to feed and water withdrawal, handling, and transport conditions, which can lead to dehydration and increased mortality rates upon arrival at processing facilities (Saraiva et al., 2020). Specialised training in, and maintenance of good handling practices among handling personnel and drivers can reduce stress for animals during transit (Isbrandt et al., 2022; Nicolaisen et al., 2023; Werner et al., 2007).

c) Some species may experience negative consequences due to human breeding practices. For example, in poultry meat production, selective and productivism breeding for broilers has led to rapid growth rates. This accelerated growth is associated with health issues such as lameness, leg disorders, and sudden death syndrome, due to the birds' skeletal and cardiovascular systems struggling to support increased body mass (Kestin et al., 2001; Tahamtani et al., 2019).

(60) The welfare of fish in farming systems (aquaculture) and those captured at sea is an increasingly critical concern. Fish are sentient beings capable of experiencing stress, pain, and suffering, though their needs and welfare issues have often been overlooked and underrepresented in traditional animal welfare discussions. However, scientific research indicates the challenges for fish welfare in both aquaculture (fish farming) and capture fisheries. Aquatic invertebrates, such as cephalopods and crustaceans, suffer from similar welfare issues related to farming conditions, capture methods, transportation and handling, while evidence shows a cognitive ability to experience pain.

a) Consumers are increasingly concerned about the welfare of aquatic animals farmed in aquaculture or wild-caught in fisheries, but the basic scientific knowledge bases, monitoring practices, and regulations for aquatic animals are less mature than those for terrestrial animal-based foods (Röcklinsberg et al., 2019). Partly because the range of aquatic species is so divers and welfare information for 70% of species is lacking (Franks et al., 2021).

b) In aquaculture, fish are often kept in high-density, confined environments that cause stress, aggression, and injury due to overcrowding (Champneys et al., 2018; Laursen et al., 2013). Diseases and parasites, such as sea lice in salmon, spread quickly in these environments, leading to high antibiotic use, and harmful side-effects for fish (Previti et al., 2025). Additionally, fish are often slaughtered in ways that cause unnecessary suffering, such as poor stunning or suffocation (Clemente et al., 2023). However, aquaculture management, and related fish welfare issues, vary considerably between species and countries (van de Vis et al., 2020). For example, with regards to diseases and parasites, Norway has replaced antibiotic use largely by applying vaccination (Gudding & Van Muiswinkel, 2013).

c) Fishing methods like trawling and longlining can cause prolonged suffering and injury of the targeted species and entangle non-target species, leading to bycatch and death (Clarke et al., 2014; Tomás et al., 2024). After capture, fish often endure rough handling, exposure to poor conditions, and overcrowding in holding tanks, causing stress, injury and death (Portz et al., 2006; Veldhuizen et al., 2018).

d) Similar to fish, the welfare of aquatic invertebrates, mainly crustaceans and cephalopods used for food production, is also threatened by farming conditions and capture methods (Browning et al., 2025). In addition, crustaceans are commonly transported alive and exposed to "rough handling", both leading to physical injury (Browning et al., 2025). At the same time, evidence shows that cephalopods have a primary consciousness, as well as remarkable mental capabilities (Mather, 2008; Ponte et al., 2022). In addition, crustaceans show rapid avoidance learning and prolonged memory which are indicative of experiencing pain (Elwood, 2019).

(61) While much attention in welfare discussions focuses on housing, feeding, and the ability to express natural behaviours, the way in which slaughter is conducted can either undermine or reinforce these welfare standards. Slaughter methods vary considerably across species and are influenced by technological, regulatory, and cultural factors, each with distinct animal welfare implications. Despite regulations aimed at improving welfare, actual outcomes are highly uneven due to differences in enforcement, species practices, and infrastructure biases. Industrial efficiency often takes precedence over low-tech or decentralised alternatives that may offer better welfare outcomes, highlighting the tension between welfare ambitions and production realities.

a) The global meat industry slaughters approximately 83 billion land animals annually, with chickens making up the overwhelming majority of these fatalities (Ritchie et al., 2023). In Europe alone, the 2023 figures include 6 billion chickens, 222 million pigs, 160 million turkeys, 123 million ducks, 34 million sheep, 23 million cattle, and 5 million goats (*FAOSTAT*, 2024a).

b) The number of animals slaughtered to produce the same quantity of meat varies across species, creating a notable trade-off with respect to animal welfare. Chickens, for example, are much smaller than cattle or pigs, meaning more individual chickens must be killed to produce an equivalent amount of meat (Ritchie et al., 2023). Higher slaughter numbers imply greater cumulative welfare impacts, including more individuals subjected to potentially stressful conditions such as overcrowding, transport, and stunning (Lambooij, 2024). In contrast, while cows and pigs represent fewer individual deaths, their longer lifespans and more complex cognitive and emotional capacities may raise other ethical concerns (Marino & Allen, 2017).

c) For cattle, the most common method in slaughterhouses involves captive bolt stunning[43]—either penetrative or non-penetrative—followed by exsanguination[44], which is generally effective in reducing pain when performed correctly (Grandin, 2010). In contrast, religious slaughter practices such as Halal and Kosher often exclude pre-slaughter stunning, raising concerns about prolonged consciousness and pain (Gregory et al., 2010). Pigs are typically rendered unconscious using either electrical stunning or CO_2 gas exposure, though the latter is controversial due to evidence of respiratory distress and aversive behaviours prior to unconsciousness (Raj et al., 1997; Velarde & Dalmau, 2012). Poultry are frequently stunned using electrified water baths, a method associated with significant welfare issues due to inversion, shackling, and inconsistent stunning (Berg & Raj, 2015). More recently tested alternatives, such as the gunshot method (Hultgren et al., 2022), mobile abattoirs (Eriksen et al., 2013) or controlled atmosphere stunning (CAS) using inert gases (e.g., argon or nitrogen), can offer improved welfare outcomes by reducing handling stress and avoiding inversion (Fuseini et al., 2023). For sheep and goats, both captive bolt and electrical stunning are used, with similar welfare debates surrounding religious slaughter (Farouk et al., 2014). Fish, though less regulated, are often slaughtered through asphyxiation or immersion in ice slurry, methods widely criticised for causing prolonged suffering (Cottee, 2008; Lines & Spence, 2012). Alternatives such as percussive or electrical stunning are gaining attention but remain less utilised and studied (Clemente et al., 2023).

d) A well-designed slaughterhouse facility, as well as less invasive stunning methods can help reduce negative welfare impacts by using gentle handling, clear paths, and smooth transitions to the slaughter area (Riaz et al., 2021). Still, any stunning method can cause distress if not properly applied (Kamenik et al., 2019). Slaughterhouses design can reduce

[43] Bolt stunning is a method used to render animals unconscious before slaughter. It involves using a captive bolt pistol that fires a metal rod into the animal's skull, causing immediate loss of consciousness and insensibility to pain.
[44] Exsanguination is the process of bleeding out an animal after stunning. It is done by cutting major blood vessels, typically in the neck or chest, to cause death through blood loss. This step is considered necessary to ensure the animal dies quickly and to drain the blood from the carcass for processing.

stress by minimising noise, providing even lighting, ensuring adequate space for animals to move without overcrowding, the use of anti-slip floors and well-structure holding pens (Grandin, 2010). Behaviors and ethics of the people handling animals is also key, where gentle handling reduce stress (Riaz et al., 2021).

e) The emphasis on technically advanced slaughterhouse facilities often reinforces the notion that “animal-friendly” conditions depend on specialised, high-investment infrastructure, thereby sidelining decentralised alternatives, even when such approaches may offer improved welfare outcomes. For instance, studies on the so-called "gun-shot method" in which cattle are shot in the field while surrounded by their herd have shown reduced pre-slaughter stress compared to conventional slaughter at the abattoir using captive-bolt stunning (Friedrich et al., 2015). Yet, such practices are rarely considered viable within the logic of industrial production, which relies on centralized, scalable systems. As a result, animal welfare becomes increasingly entangled with and limited by the imperatives of industrial efficiency (Guarnido-López et al., 2022).

f) The European Union has a unified legal framework for animal welfare at slaughter, primarily governed by Council Regulation (EC) No 1099/2009 (European Commission, 2009), which mandates pre-slaughter stunning, proper handling, and trained personnel to minimize animal suffering. However, implementation and enforcement of these standards vary significantly across member states as member states are responsible for their national set of rules and dedicated policies for improving and monitoring the welfare of farm animals (Miele et al., 2015). Religious exemptions for non-stun slaughter—such as in Halal and Kosher practices—are permitted in several countries, contributing further to regional differences (European Parliament, 2023b).

(62) Novel protein sources are often considered a promising solution to animal welfare concerns in livestock production by reducing or eliminating the need for animal rearing and slaughter. However, the degree to which this claim holds depends on the definition and components of animal welfare, as well as the novel protein source.

a) Novel protein sources generally eliminate the need to raise or slaughter animals (Gil et al., 2024). Most being non-animal foods, some argue that these proteins constitute the most ethical options for animals and that opting away from animal-based proteins removes cognitive dissonances between care for animals and the exploitative nature of eating animals (Docherty & Jasper, 2023).

b) Cultured meat production, although requiring only a small sample of animal cells, still depends on **fetal bovine serum**[45] for cell growth and may involve terrestrial animal-based protein additives, like collagen or gelatin to enhance meat-like flavor, raising ethical concerns for animals (Benny et al., 2022; Bryant, 2020; Chriki et al., 2022; Tso et al., 2021). Researchers are working on developing animal-free serum media, but widespread use has yet to be achieved (Dai et al., 2024; Young et al., 2024).

c) Insect welfare is an emerging field gaining attention as insect farming for food and feed expands (Barrett & Fischer, 2023; Delvendahl et al., 2022). Although invertebrates lack a central brain, they have a decentralized nervous system with ganglia, creating uncertainty about how they experience pain compared to vertebrates (Statement (57)a)). As the capacity of insects to feel pain remains debated, the broader ethical questions on using insects for human benefit remain unaddressed (Gamborg et al., 2018) and bring to the fore the same concerns of the number of individuals affected as for conventionally farmed animals. Common welfare concerns include overcrowding, poor environmental conditions, starvation of adults, spatial and environmental conditions inappropriate for the completion of natural behaviours and inhumane slaughter methods such as freezing or shredding (Barrett et al., 2023).

3.4. Economy

This section examines the *economic impacts* of existing food systems, regimes, and paradigms, with a particular focus on the implications of the protein transition. Unlike the previous section, which provided the *economic context*—including the current positioning of terrestrial, aquatic,

[45] Fetal bovine serum (FBS) is a common supplement used in cell culture media, particularly in biotechnology and lab-grown meat production. It is derived from the blood of bovine fetuses, typically collected from pregnant cows during slaughter. The collection process and the use of FBS raise significant ethical and animal welfare concerns due to the invasive nature of the extraction and the sourcing from unborn animals.

and alternative protein sectors within the economy, the role of the Common Agricultural Policy (CAP), and path dependencies contributing to systemic "lock-in"—this section shifts to explore the *potential consequences* of change. It focuses on aspects such as the implications of the protein transition on employment levels and economic performance, measured in monetary terms. Framing farms as "businesses" centred on profit generation reflects a neoliberal perspective on food systems, a viewpoint that is not critically challenged in this paper.

(63) The livestock and seafood industries collectively employ millions across the EU, with significant contributions to rural economies. A transition to alternative proteins on a dietary and food systems scale would impact the actors who depend on animal production for their livelihood especially in regions where farming or fisheries are particularly important and options to shift to production systems for alternative proteins or sectors beyond agriculture are limited. The concerns surrounding potential job losses, economic impacts on farmers, and the sunk costs of existing investments emphasize the critical need for well-designed policy interventions.

a) In 2020, the livestock sector employed 4 million farm workers in the EU (people working and making a salary on the farm), with an average of 1 or 2 workers per farm (Matthews et al., 2023; Peyraud & MacLeod, 2020). This workforce is spread across a variety of farm types, with mixed crop and livestock farms and dairy farms employing the largest shares (37% and 25%, respectively) (European Commission, 2024i). In the seafood sector, nearly 550 thousand people are employed in either primary production, processing and/or distribution of seafood products (European Commission et al., 2024). There are nearly 57 thousand aquaculture producers and nearly 120 thousand fishers make a living from wild captures (JRC, 2024; JRC et al., 2023).

b) The meat industry (excluding farmers) is estimated to provide employment to around 1 million industry workers in Europe (European Trade Union Institute, 2021). However, it is unclear whether this figure includes all roles beyond the farm gate—such as processing, distribution, and logistics—or if it also accounts for workers involved in retail and grocery store meat sales. The workforce in the meat industry sector increasingly consists of temporary non-national workers who are sometimes employed under deplorable working conditions and abusive subcontracting practices (Fasani & Mazza, 2023; Hashem et al., 2020).

c) There are concerns in many European countries about potential economic losses from a transition away from animal farming and fisheries (Pais et al., 2020). A primary concern is the future of animal farmers and fishers, many of whom may face ceased roles in a "successful" protein transition scenario in which the consumption of animal-source proteins is reduced (A. E. Barnard, 2024; Geibel & Freund, 2023; Rieger et al., 2023).

d) In particular, countries heavily dependent on animal farming or fisheries, such as Ireland and Denmark, are likely to experience substantial reductions in incomes from agriculture, especially for beef and dairy producers (Geibel & Freund, 2023). For instance, if the dietary changes recommended by the EAT-Lancet Commission were implemented in Europe, beef production in countries like Ireland and Denmark could decrease by over 40% to 60%, with corresponding income losses for livestock farmers reaching as high as 61% (Geibel & Freund, 2023). However, this could be offset to varying degrees by gains in crop and horticulture and trade dynamics or by policy interventions, leading to different outcomes across regions (Geibel & Freund, 2023; Mehrabi et al., 2020; Rieger et al., 2023).

e) The capital-intensive nature of animal farming and some alternative protein options, which require significant long-term financial commitments, potential access to patented technology, and advanced infrastructure, further complicate shifts toward alternative protein systems (Matthews et al., 2023). A range of emerging initiatives and organizations are working to support animal farmers in shifting toward plant-based agriculture and alternative economic models. Examples include Viva!'s Vegan Farming campaign, the Transfarmation Project, Farmers for Stock-Free Farming, Refarm'd, the Vegan Society's Grow Green campaign, and The Little Mushroom Company[46]. These efforts provide hands-on assistance—ranging from financial aid and business planning to training and technical support—showing that with

[46] Viva https://vivafarming.org.uk/; Transfarmation Project https://thetransfarmationproject.org/; Farmers for Stock Free Farming https://stockfreefarming.org/; Refarm'd https://en.refarmd.com/en; The Vegan Society's Grow Green campaign https://www.vegansociety.com/take-action/campaigns/grow-green; The Little Mushroom Company https://thelittlemushroomcompany.co.uk/

appropriate guidance and resources, such transitions are not only possible but increasingly practical and accessible.

(64) The alternative protein sector is rapidly expanding, attracting significant investments globally and within the EU, though it remains comparatively small alongside the established animal production sector. Initially dominated by startups, the sector has seen increasing involvement from major meat industry players diversifying into plant-based and cultivated protein markets. Despite its promising potential, the sector's reported growth is heavily reliant on consultancy-driven data, which often carries vested interests, underscoring the critical need for greater transparency and more precise market definitions.

a) The exact market share of the alternative protein sector is difficult to quantify because shares dedicated to food versus feed remain unclear. In addition, the sector is, in reality, not unified, with a diverse use of the term 'alternative protein sector' in existing documents, scientific literature, and across organisations, e.g., the EU Commission versus the Good Food Institute (European Commission, 2018; Good Food Institute, 2022).

b) When defining the alternative protein sector as encompassing plant-based, fermentation-derived, and cultivated protein innovations such as lab-grown meat designed to replicate or enhance traditional animal-based products, the sector secured $3.1 billion of funding in 2020 at the global level (corresponding to €2.6 billion euros), three times more than in 2019 and nearly five times more than in 2018 (Good Food Institute, 2021). However, by 2023, global investments had dropped to around $1.67 billion (Good Food Institute, 2024a). This decline is mainly attributed to broader slower economic growth affecting venture capital globally, with many sectors, including food tech, experiencing a pullback in funding (Good Food Institute, 2024a). In Europe, this sector has seen growth, with companies raising €579 million in investments during 2022 (Good Food Institute, 2023b).

c) Financial inflows to the alternative protein sector are coming from venture capitalists and food-tech investors but also from large multinational corporations like Nestlé and Unilever, who are rapidly expanding their portfolios of plant-based and novel protein products (Good Food Institute, 2024c; Guthman et al., 2022). New initiatives, like the $30 million Bezos Center for Sustainable Protein at Imperial College London, aim to advance innovation in sustainable protein solutions (Bezos Earth Fund, 2024). However, much of the published numbers for this market are from consultancy reports, which often have a vested interest in promoting the sector's success (Good Food Institute, 2024a).

d) Although the alternative protein sector is growing in terms of the number of companies, investment levels, and economic returns, its overall scale remains relatively minor compared to the livestock sector. The disparity in production value is striking, with the alternative protein sector attracting investments of approximately €2.6 billion in 2020, of which 500 million in Europe, while the production value generated by the livestock sector was €214 billion in 2023 (Statement (6)).

(65) The European Commission recognises the economic importance of the livestock sector but puts comparatively less emphasis on protein-rich crops. In 2024, protein-rich crops occupied less than 3% of Europe's agricultural area, with production levels far below staple crops like wheat. To address this, EU policies, including CAP reforms and targeted support measures, aim to promote the cultivation of protein-rich crops by reducing financial risks through breeding programs and incentives such as coupled income support and crop diversification rules.

a) Although the European Commission highlights the significance of the livestock sector within the agricultural economy, no comparable emphasis is provided for the role of protein-rich crops (European Commission, 2024i). This sector could expand further due to dietary shifts, including more plant-based proteins or a higher demand for protein-rich crops produced within Europe for feed purposes.

b) Production of protein-rich crops for human food (Box 1) is low in Europe, covering less than 3% of utilised agricultural area (Eurostat, 2024c). The production covers 2.4, 1.8, 1.1 and 0.4 million tonnes of soybean, field peas, broad beans and lupins, respectively, compared to 112 million tonnes of wheat (European Commission, 2024j). Although not all protein-rich crops can be easily grown under Europe's climatic conditions, investments in breeding efforts for cultivars that match climatic conditions can reduce the financial risks associated with cultivating protein-rich crops (Rubiales et al., 2021).

c) The EU has encouraged the cultivation of protein-rich crops since the 2013 CAP reform through measures such as **Voluntary Coupled Support** (VCS)[47], including protein-rich crops in Ecological Focus Areas (EFAs), and crop diversification rules such as voluntary coupled support, (EU CAP Network, 2013). Building on these efforts, a 2018 report proposed additional strategies that significantly influenced the CAP strategic plans for 2021-2027, emphasising the continued promotion of protein-rich crop cultivation, particularly through mechanisms such as coupled income support (European Commission, 2018, 2024i).

(66) The prospect of transitioning from animal production to alternative (agricultural) sectors faces significant resistance from farmers and farming lobbies, as experienced in the Netherlands following a proposal in parliament to halve the country's livestock in an attempt to limit agricultural pollution. Moreover, it raises complex discussions about a "just transition" for farmers who would be impacted? These discussions are particularly challenging because there is no single definition of sustainability or just transition, and substantial disagreements exist regarding what such a future should look like, how it should be implemented, and who should be involved.

a) Just transitions emphasise socio-economic fairness in shifts to environmental sustainability, focusing on incentivising change, supporting those adversely affected, and ensuring fairness as both a principle and practical strategy (IEEP, 2022). In the context of a protein transition, governments would aim to achieve the targets they set for shifting diets towards more alternative sources and addressing long-term climate and biodiversity crises while preventing resistance from those who bear short-term costs (IEEP, 2022).

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[47] Voluntary coupled support (VCS) refers to financial subsidies provided under agricultural policy frameworks to support specific types of agricultural production. These payments are "coupled" because they are directly linked to the level of production of a particular crop or livestock, meaning farmers receive subsidies based on how much they produce. They are "voluntary" because countries within the policy framework can choose whether or not to implement these supports and to what extent. Compared to the traditional Coupled Support (Statement (7)), which was a mandatory mechanism applied more broadly, VCS offers more flexibility, allowing governments to target vulnerable agricultural sectors while ensuring compliance with broader CAP objectives.

b) There has been limited scientific discussion about just protein transitions in European agriculture, though this is gradually evolving with emerging research and initiatives (IEEP, 2022). A study by Aubert et al., (2021) modelled a sustainable transition within the French dairy sector, aiming to balance environmental objectives with the preservation of agricultural employment, demonstrating how targeted strategies can address multiple sustainability dimensions simultaneously.
c) In the Netherlands, the issue of excessive nitrogen and ammonia emissions, primarily from its highly concentrated livestock sector, illustrates the complexities of a just protein transition in agriculture. To address this, the Dutch government introduced the "National Programme for Rural Areas", which aims to reduce nitrogen emissions by 50% by 2030 through measures such as cutting livestock numbers, investing in emission-reducing technologies, and allocating €25 billion through 2035 to compensate affected farmers, some of whom may cease production (Levitt, 2021). However, the Dutch government's response faced significant challenges, including widespread protests from farmers, underscoring the difficulty of balancing ambitious environmental goals with the socio-economic costs to farmers (Tullis, 2023). These protests highlight the complexities of building trust among stakeholders and addressing concerns about **production leakage**[48] to other EU countries and outside the EU, which could conflict with union-wide sustainability objectives.
d) A protein transition can be viewed as a threat by farmers, based on distrust of the envisioned changes (Koole, 2022). This is also reflected by the skepticism with which the production of protein crops is approached (Degieter et al., 2023). While farmers often see a need for change and may be willing to change, they will not do so due to the perceived riskiness (Craft & Pitt, 2024). This suggests that it would not suffice to meet farmers with financial incentives as they need to gain trust in the

[48] Production leakage refers to the shift of production activities from one region, country, or sector to another, often as a result of regulatory, economic, or environmental pressures. While the term is commonly used in the context of climate change, agriculture, and trade, it generally describes situations where efforts to reduce environmental or social impacts in one area leads to increased impacts elsewhere.

success of alternative production systems, which may require time and enough pioneers in the field.

(67) A transition to more healthy and sustainable diets that generally contain higher levels of fruits, vegetables, and other plant-source foods and less meat compared to current diets tends to increase the costs of the total food basket for consumers compared to current diets. Affordability could, therefore, become a concern for a larger share of the population. However, the affordability of diets varies depending on the individual food choices that would result from switching to a more healthy and sustainable diet, making comparisons across studies difficult. In addition, indirect costs such as those for health care are rarely considered in affordability calculations, underscoring the importance of considering the level of analysis in economic evaluations of protein transition (e.g., consumer vs national level and including externalities or not).

a) Compared to current diets, healthier diets and those with a higher share of plant-sourced foods have shown to be more expensive for consumers (Chungchunlam & Moughan, 2024; Darmon et al., 2004; Hirvonen et al., 2020; Springmann et al., 2021; Verly-Jr et al., 2022). However, this largely depends on the region studied and the costs of the current diet (Springmann et al., 2021). Most studies agree that replacing a certain share of animal-source foods with plant-sourced foods does not have to be more expensive (Hohoff et al., 2022) but that such diets are more likely to become unaffordable for populations in low-income regions where nutritional insufficiencies are also most prevalent (Gatto et al., 2023). In that regard, observational studies show that individuals on a plant-based diet can spend both less (Lusk & Norwood, 2016; Pais et al., 2022) and more (Hohoff et al., 2022; Pais et al., 2022) on food than omnivorous consumers. Still, vegan diets are often more expensive than vegetarian diets (Berners-Lee et al., 2012; Hohoff et al., 2022).

b) Internalising costs of so-called externalities, e.g., climate change or health care costs, reduce the costs of a plant-based food basket (Springmann et al., 2021). Estimations show that, based on the health benefits of reducing meat and increasing unprocessed plant-source foods, healthcare costs can be substantially reduced (Crosland et al., 2019; Lo et al., 2024; Lucas et al., 2023), e.g., costs related to poor diet have been estimated at £5.8 billion in the UK (Scarborough et al., 2011).

In addition, policy instruments that account for external costs of animal production (Statement (13)a)) lead to reduced prices of plant-sourced food baskets. However, the extent to which internalising costs can reduce the food basket is difficult to predict as this relies on factors that are difficult to quantify.

(68) Value chains of commodities with high-income elasticity demand require carefully designed interventions to prevent unintended consequences such as leakage effects.

a) Several scholars have explored the theoretical effects of measures that could be implemented under the guise of a protein transition extending to the food system. The impacts of the Green Deal's Farm to Fork (F2F) and Biodiversity Strategies are investigated under different scenarios (e.g., Barreiro Hurle et al., 2021; Beckman et al., 2020; Schiavo et al., 2023). Among other measures, such strategies advocate for a shift toward healthier, more sustainable diets with increased consumption of plant-based foods. These studies suggest that implementing production measures that are part of the F2F and Biodiversity strategies, without corresponding shifts in consumption patterns, could lead to reductions in the EU's agricultural production, a decline in EU export shares, and an increase in food imports to the EU (Barreiro Hurle et al., 2021; Beckman et al., 2020). Moreover, such production measures without the changes in consumption patterns in the EU risk increasing global food prices, thereby accelerating food insecurity outside of the EU (Beckman et al., 2020; Schiavo et al., 2023)

b) Another risk in value chains with high price elasticity is the displacement of production to regions with less stringent environmental regulations and less resource- and climate-efficient systems, a phenomenon known as leakage (European Court of Auditors, 2021; Jansson et al., 2021; Zech & Schneider, 2019). Such leakage effects would imply higher total resource inputs to food production and greater emissions per kilogram of product, undermining overall improvements of transboundary environmental sustainability issues (European Court of Auditors, 2021; B. Henderson & Verma, 2021). For example, 75% of the GHG emissions reduction from VCS for ruminant sectors in the EU would theoretically be offset by emission leakages through production increases (to meet constant demand) in countries like Brazil and India, where production methods are more commonly emission-intensive than in the EU (Jansson et al., 2021). Similarly, applying GHG emissions taxes on meat in the EU has been shown to alter trade dynamics, such as increasing exports, which can dilute the expected environmental benefits (Zech & Schneider, 2019). Addressing this risk requires coordinated international efforts and policies to prevent displacement of environmental and social burdens across borders (B. Henderson & Verma, 2021; Jansson et al., 2021).

Bibliography

Aakre, I., Solli, D. D., Markhus, M. W., Mæhre, H. K., Dahl, L., Henjum, S., Alexander, J., Korneliussen, P.-A., Madsen, L., & Kjellevold, M. (2021). Commercially available kelp and seaweed products – valuable iodine source or risk of excess intake? *Food & Nutrition Research*, *65*, 10.29219/fnr.v65.7584. https://doi.org/10.29219/fnr.v65.7584

Aaslyng, M. D., Dam, A. B., Petersen, I. L., & Christoffersen, T. (2023). Protein content and amino acid composition in the diet of Danish vegans: A cross-sectional study. *BMC Nutrition*, *9*(1), 131. https://doi.org/10.1186/s40795-023-00793-y

Adamo, S. A. (2016). Do insects feel pain? A question at the intersection of animal behaviour, philosophy and robotics. *Animal Behaviour*, *118*, 75–79. https://doi.org/10.1016/j.anbehav.2016.05.005

Adams, N., Sans, A., Trier Kreutzfeldt, K.-E., Arias Escobar, M. A., Oudshoorn, F. W., Bolduc, N., Aubert, P.-M., & Smith, L. G. (2024). Assessing the impacts of EU agricultural policies on the sustainability of the livestock sector: A review of the recent literature. *Agriculture and Human Values*. https://doi.org/10.1007/s10460-024-10595-y

Adla, K., Dejan, K., Neira, D., & Dragana, Š. (2022). Chapter 9—Degradation of ecosystems and loss of ecosystem services. In J. C. Prata, A. I. Ribeiro, & T. Rocha-Santos (Eds.), *One Health* (pp. 281–327). Academic Press. https://doi.org/10.1016/B978-0-12-822794-7.00008-3

Afshin, A., Sur, P. J., Fay, K. A., Cornaby, L., Ferrara, G., Salama, J. S., Mullany, E. C., Abate, K. H., Abbafati, C., Abebe, Z., Afarideh, M., Aggarwal, A., Agrawal, S., Akinyemiju, T., Alahdab, F., Bacha, U., Bachman, V. F., Badali, H., Badawi, A., … Murray, C. J. L. (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. https://doi.org/10.1016/S0140-6736(19)30041-8

Aiking, H. (2014). Protein production: Planet, profit, plus people? *The American Journal of Clinical Nutrition*, *100*(suppl_1), 483S-489S. https://doi.org/10.3945/ajcn.113.071209

Akinmeye, F., Chriki, S., Liu, C., Zhao, J., & Ghnimi, S. (2024). What factors influence consumer attitudes towards alternative proteins? *Food and Humanity*, 100349. https://doi.org/10.1016/j.foohum.2024.100349

Alavanja, M. C. R., & Bonner, M. R. (2012). Occupational Pesticide Exposures and Cancer Risk: A Review. *Journal of Toxicology and Environmental Health, Part B*. https://www.tandfonline.com/doi/abs/10.1080/10937404.2012.632358

Albernaz-Gonçalves, R., Olmos, G., & Hötzel, M. J. (2021). My pigs are ok, why change? – Animal welfare accounts of pig farmers. *Animal*, *15*(3), 100154. https://doi.org/10.1016/j.animal.2020.100154

Alewaeters, K., Clarys, P., Hebbelinck, M., Deriemaeker, P., & Clarys, J. P. (2005). Cross-sectional analysis of BMI and some lifestyle variables in Flemish vegetarians compared with non-vegetarians. *Ergonomics*, *48*(11–14), 1433–1444. https://doi.org/10.1080/00140130500101031

Alexy, U. (2023). Diet and growth of vegetarian and vegan children. *BMJ Nutrition, Prevention & Health*, *6*(Suppl 2). https://doi.org/10.1136/bmjnph-2023-000697

Allen, M. R., Shine, K. P., Fuglestvedt, J. S., Millar, R. J., Cain, M., Frame, D. J., & Macey, A. H. (2018). A solution to the misrepresentations of CO2-equivalent emissions of short-lived climate pollutants under ambitious mitigation. *Npj Climate and Atmospheric Science*, *1*(1), 1–8. https://doi.org/10.1038/s41612-018-0026-8

Allen, T. S., Bhatia, H. S., Wood, A. C., Momin, S. R., & Allison, M. A. (2022). State-of-the-Art Review: Evidence on Red Meat Consumption and Hypertension Outcomes. *American Journal of Hypertension*, *35*(8), 679–687. https://doi.org/10.1093/ajh/hpac064

Alleway, H. K., Waters, T. J., Brummett, R., Cai, J., Cao, L., Cayten, M. R., Costa-Pierce, B. A., Dong, Y.-W., Brandstrup Hansen, S. C., Liu, S., Liu, Q., Shelley, C., Theuerkauf, S. J., Tucker, L., Wang, Y., & Jones, R. C. (2023). Global principles for restorative aquaculture to foster aquaculture practices that benefit the environment. *Conservation Science and Practice*, *5*(8), e12982. https://doi.org/10.1111/csp2.12982

Alley, M. L., Smith, G. W., Pairis-Garcia, M. D., Wagner, B., & Cramer, M. C. (2021). Welfare implications for dairy bull calves. *CABI Reviews*, *2020*. https://doi.org/10.1079/PAVSNNR202015058

Alons, G. (2017). Environmental policy integration in the EU's common agricultural policy: Greening or greenwashing? *Journal of European Public Policy*, *24*(11), 1604–1622. https://doi.org/10.1080/13501763.2017.1334085

Alonso, M. E., González-Montaña, J. R., & Lomillos, J. M. (2020). Consumers' Concerns and Perceptions of Farm Animal Welfare. *Animals*, *10*(3), Article 3. https://doi.org/10.3390/ani10030385

Al-Shaar, L., Satija, A., Wang, D. D., Rimm, E. B., Smith-Warner, S. A., Stampfer, M. J., Hu, F. B., & Willett, W. C. (2020). Red meat intake and risk of coronary heart disease among US men: Prospective cohort study. *BMJ*, *371*, m4141. https://doi.org/10.1136/bmj.m4141

Amahnui, G. A., Vanegas, M., Verchot, L., & Castro-Nunez, A. (2025). Achieving the paris agreement goals by transitioning to low-emissions food systems: A comprehensive review of countries' actions. *Environmental Science & Policy*, *163*, 103968. https://doi.org/10.1016/j.envsci.2024.103968

Amoatey, P., Al-Mayahi, A., Omidvarborna, H., Baawain, M. S., & Sulaiman, H. (2020). Occupational exposure to pesticides and associated health effects among greenhouse farm workers. *Environmental Science and Pollution Research*, *27*(18), 22251–22270. https://doi.org/10.1007/s11356-020-08754-9

An, R. (2013). Effectiveness of subsidies in promoting healthy food purchases and consumption: A review of field experiments. *Public Health Nutrition*, *16*(7), 1215–1228. https://doi.org/10.1017/S1368980012004715

Anderson, M. D. (2024). *Transforming Food Systems: Narratives of Power*. Routledge.

Andreoli, V., Bagliani, M., Corsi, A., & Frontuto, V. (2021). Drivers of protein consumption: A cross-country analysis. *Sustainability (Switzerland)*, *13*(13). Scopus. https://doi.org/10.3390/su13137399

Animals, N. R. C. (US) C. on P. and D. in L. (1992). Recognition and Assessment of Pain, Stress, and Distress. In *Recognition and Alleviation of Pain and Distress in Laboratory Animals*. National Academies Press (US). https://www.ncbi.nlm.nih.gov/books/NBK235435/

Arcari, P. (2017). Normalised, human-centric discourses of meat and animals in climate change, sustainability and food security literature. *Agriculture and Human Values*, *34*(1), 69–86. https://doi.org/10.1007/s10460-016-9697-0

Arcari, P., Probyn-Rapsey, F., & Singer, H. (2021). Where species don't meet: Invisibilized animals, urban nature and city limits. *Environment and Planning E*, *4*(3), 940–965. https://doi.org/10.1177/2514848620939870

Ashley, P. J. (2007). Fish welfare: Current issues in aquaculture. *Applied Animal Behaviour Science*, *104*(3), 199–235. https://doi.org/10.1016/j.applanim.2006.09.001

Aubert, P.-M., Gardin, B., Schiavo, M., & Alliot, C. (2021). *Towards a just transition of food systems—Challenges and policy levers for France*. IDDRI. https://www.iddri.org/en/publications-and-events/report/towards-just-transition-food-systems-challenges-and-policy-levers

Bakaloudi, D. R., Halloran, A., Rippin, H. L., Oikonomidou, A. C., Dardavesis, T. I., Williams, J., Wickramasinghe, K., Breda, J., & Chourdakis, M. (2021). Intake and adequacy of the vegan diet. A systematic review of the evidence. *Clinical Nutrition*, *40*(5), 3503–3521. https://doi.org/10.1016/j.clnu.2020.11.035

Balázs, B., Kelemen, E., Centofanti, T., Vasconcelos, M. W., & Iannetta, P. P. M. (2021). Policy Interventions Promoting Sustainable Food- and Feed-Systems: A Delphi Study of Legume

Production and Consumption. *Sustainability*, *13*(14), Article 14. https://doi.org/10.3390/su13147597

Bali, A., & Naik, R. (2023). The Impact of a Vegan Diet on Many Aspects of Health: The Overlooked Side of Veganism. *Cureus*, *15*(2), e35148. https://doi.org/10.7759/cureus.35148

Balzani, A., & Hanlon, A. (2020). Factors that Influence Farmers' Views on Farm Animal Welfare: A Semi-Systematic Review and Thematic Analysis. *Animals*, *10*(9), Article 9. https://doi.org/10.3390/ani10091524

Baptista, I., Garnett, E., & Öström, Å. (2025). How can consumer science help the foodservice industry replace meat? A critical review. *Appetite*, 107861. https://doi.org/10.1016/j.appet.2025.107861

Baran, B. E., Rogelberg, S. G., & Clausen, T. (2016). Routinized killing of animals: Going beyond dirty work and prestige to understand the well-being of slaughterhouse workers. *Organization*, *23*(3), 351–369. https://doi.org/10.1177/1350508416629456

Barbieri, P., Pellerin, S., Seufert, V., Smith, L., Ramankutty, N., & Nesme, T. (2021). Global option space for organic agriculture is delimited by nitrogen availability. *Nature Food*, *2*(5), 363–372. https://doi.org/10.1038/s43016-021-00276-y

Barnard, A. E. (2024). *Farmers' perspectives on transitions away from animal agriculture food systems*. https://hdl.handle.net/1828/20891

Barnard, N. D., & Leroy, F. (2020). Children and adults should avoid consuming animal products to reduce the risk for chronic disease: Debate Consensus. *The American Journal of Clinical Nutrition*, *112*(4), 937–940. https://doi.org/10.1093/ajcn/nqaa237

Barosh, L., Friel, S., Engelhardt, K., & Chan, L. (2014). The cost of a healthy and sustainable diet – who can afford it? *Australian and New Zealand Journal of Public Health*, *38*(1), 7–12. https://doi.org/10.1111/1753-6405.12158

Barreiro Hurle, J., Bogonos, M., Himics, M., Hristov, J., Perez Dominguez, I., Sahoo, A., Salputra, G., Weiss, F., Baldoni, E., & Elleby, C. (2021). *Modelling environmental and climate ambition in the agricultural sector with the CAPRI model* (JRC Research Reports No. JRC121368). Joint Research Centre (Seville site). https://econpapers.repec.org/paper/iptiptwpa/jrc121368.htm

Barreto, M., Rey Planellas, S., Yang, Y., Phillips, C., & Descovich, K. (2021). Emerging indicators of fish welfare in aquaculture. *Reviews in Aquaculture*, *14*. https://doi.org/10.1111/raq.12601

Barrett, M., Chia, S. Y., Fischer, B., & Tomberlin, J. K. (2023). *Welfare considerations for farming black soldier flies,Hermetia illucens (Diptera: Stratiomyidae): a model for the insects as food and feed industry*. https://doi.org/10.3920/JIFF2022.0041

Barrett, M., & Fischer, B. (2023). Challenges in farmed insect welfare: Beyond the question of sentience. *Animal Welfare*, *32*, e4. https://doi.org/10.1017/awf.2022.5

Bartholomae, E., & Johnston, C. S. (2023). Nitrogen Balance at the Recommended Dietary Allowance for Protein in Minimally Active Male Vegans. *Nutrients*, *15*(14), 3159. https://doi.org/10.3390/nu15143159

Bartlett, H., Balmford, A., Holmes, M., & Wood, J. (2023). Advancing the quantitative characterization of farm animal welfare. *Proceedings. Biological Sciences*, *290*, 20230120. https://doi.org/10.1098/rspb.2023.0120

Basisty, N., Meyer, J. G., & Schilling, B. (2018). Protein Turnover in Aging and Longevity. *Proteomics*, *18*(5–6), 1700108. https://doi.org/10.1002/pmic.201700108

Bastian, B., & Loughnan, S. (2017). Resolving the Meat-Paradox: A Motivational Account of Morally Troublesome Behavior and Its Maintenance. *Personality and Social Psychology Review*, *21*(3), 278–299. https://doi.org/10.1177/1088868316647562

Baudish, I., Resare Sahlin, K., Béné, C., Oosterveer, P., Prins, H., & Pereira, L. (2024). Power & protein—Closing the 'justice gap' for food system transformation. *Environmental Research Letters*, *19*. https://doi.org/10.1088/1748-9326/ad3d6f

Beal, T. (2021). Achieving dietary micronutrient adequacy in a finite world. *One Earth*, *4*(9), 1197–1200. https://doi.org/10.1016/j.oneear.2021.08.019

Beaver, R. L., & and Field, W. E. (2007). Summary of Documented Fatalities in Livestock Manure Storage and Handling Facilities-1975-2004. *Journal of Agromedicine*, *12*(2), 3–23. https://doi.org/10.1300/J096v12n02_02

Beckman, J., Ivanic, M., Jelliffe, J. L., Baquedano, F. G., & Scott, S. G. (Eds.). (2020). *Economic and Food Security Impacts of Agricultural Input Reduction Under the European Union Green Deal's Farm to Fork and Biodiversity Strategies*. https://doi.org/10.22004/ag.econ.307277

Bedford, J. L., & Barr, S. I. (2005). Diets and selected lifestyle practices of self-defined adult vegetarians from a population-based sample suggest they are more "health conscious." *The International Journal of Behavioral Nutrition and Physical Activity*, *2*, 4. https://doi.org/10.1186/1479-5868-2-4

Bell, J., Paula, L., Dodd, T., Németh, S., Nanou, C., Mega, V., & Campos, P. (2018). EU ambition to build the world's leading bioeconomy—Uncertain times demand innovative and sustainable solutions. *New Biotechnology*, *40*, 25–30. https://doi.org/10.1016/j.nbt.2017.06.010

Belluco, S., Losasso, C., Maggioletti, M., Alonzi, C., Ricci, A., & Paoletti, M. G. (2015). Edible insects: A food security solution or a food safety concern? *Animal Frontiers*, *5*(2), 25–30. https://doi.org/10.2527/af.2015-0016

Benatar, J. R., & Stewart, R. A. H. (2018). Cardiometabolic risk factors in vegans; A meta-analysis of observational studies. *PLOS ONE*, *13*(12), e0209086. https://doi.org/10.1371/journal.pone.0209086

Béné, C., & Lundy, M. (2023). Political economy of protein transition: Battles of power, framings and narratives around a false wicked problem. *Frontiers in Sustainability*, *4*. https://www.frontiersin.org/articles/10.3389/frsus.2023.1098011

Benny, A., Pandi, K., & Upadhyay, R. (2022). Techniques, challenges and future prospects for cell-based meat. *Food Science and Biotechnology*, *31*(10), 1225–1242. https://doi.org/10.1007/s10068-022-01136-6

Berardy, A., Seager, T., Costello, C., & Wharton, C. (2020). Considering the Role of Life Cycle Analysis in Holistic Food Systems Research Policy and Practice. *Journal of Agriculture, Food Systems, and Community Development*, *9*(4), Article 4. https://doi.org/10.5304/jafscd.2020.094.009

Berg, C., & Raj, M. (2015). A Review of Different Stunning Methods for Poultry—Animal Welfare Aspects (Stunning Methods for Poultry). *Animals*, *5*, 1207–1219. https://doi.org/10.3390/ani5040407

Berners-Lee, M., Hoolohan, C., Cammack, H., & Hewitt, C. N. (2012). The relative greenhouse gas impacts of realistic dietary choices. *Energy Policy*, *43*, 184–190. https://doi.org/10.1016/j.enpol.2011.12.054

Berry, H. L., Hogan, A., Owen, J., Rickwood, D., & Fragar, L. (2011). Climate Change and Farmers' Mental Health: Risks and Responses. *Asia Pacific Journal of Public Health*, *23*(2_suppl), 119S-132S. https://doi.org/10.1177/1010539510392556

Berson, J. (2019). *The Meat Question: Animals, Humans, and the Deep History of Food*. MIT Press.

Bertheau, Y., & Davison, J. (2011). *Soybean in the European Union, Status and Perspective*. https://doi.org/10.5772/18896

Bertola, M., & Mutinelli, F. (2021). A Systematic Review on Viruses in Mass-Reared Edible Insect Species. *Viruses*, *13*(11), 2280. https://doi.org/10.3390/v13112280

Bezos Earth Fund. (2024, June 24). *Bezos Center for Sustainable Protein Launches at Imperial With $30M…*. Bezos Earth Fund. https://www.bezosearthfund.org/news-and-insights/bezos-center-for-sustainable-protein-launches-at-imperial-with-30m-funding

Bianchi, M., Hallström, E., Parker, R. W. R., Mifflin, K., Tyedmers, P., & Ziegler, F. (2022). Assessing seafood nutritional diversity together with climate impacts informs more comprehensive dietary advice. *Communications Earth & Environment*, *3*(1), 1–12. https://doi.org/10.1038/s43247-022-00516-4

Biesbroek, S., Kok, F. J., Tufford, A. R., Bloem, M. W., Darmon, N., Drewnowski, A., Fan, S., Fanzo, J., Gordon, L. J., Hu, F. B., Lähteenmäki, L., Nnam, N., Ridoutt, B. G., Rivera, J., Swinburn, B., & Veer, P. van't. (2023). Toward healthy and sustainable diets for the 21st century: Importance of sociocultural and economic considerations. *Proceedings of the National Academy of Sciences*, *120*(26), e2219272120. https://doi.org/10.1073/pnas.2219272120

Billen, G., Lassaletta, L., & Garnier, J. (2014). A biogeochemical view of the global agro-food system: Nitrogen flows associated with protein production, consumption and trade. *Global Food Security*, *3*(3), 209–219. https://doi.org/10.1016/j.gfs.2014.08.003

Billen, G., Lassaletta, L., & Garnier, J. (2015). A vast range of opportunities for feeding the world in 2050: Trade-off between diet, N contamination and international trade. *Environmental Research Letters*, *10*(2), 025001. https://doi.org/10.1088/1748-9326/10/2/025001

Blandford, D., & Tangermann, S. (2021). *Current Issues In Global Agricultural And Trade Policy: Essays In Honour Of Timothy E. Josling*. World Scientific.

Blaxter, T., Åsbjer, E., & Fraanje, W. (2024). *Animal welfare and ethics in food and agriculture | TABLE Debates*. https://www.tabledebates.org/building-blocks/animal-welfare-and-ethics-food-and-agriculture

Blaxter, T., & Garnett, T. (2023). *Primed for power: A short cultural history of protein*. TABLE Debates. https://tabledebates.org/publication/primed-for-power-section-3

Boakes, E. H., Dalin, C., Etard, A., & Newbold, T. (2024). Impacts of the global food system on terrestrial biodiversity from land use and climate change. *Nature Communications*, *15*(1), 5750. https://doi.org/10.1038/s41467-024-49999-z

Boezeman, D., De Pue, D., Graversgaard, M., & Möckel, S. (2023). Less Livestock in North-western Europe? Discourses and Drivers Behind Livestock Buyout Policies. *EuroChoices*, *22*. https://doi.org/10.1111/1746-692X.12399

Boger, W. H. I. (1984). The United States-European Community Agricultural Export Subsidies Dispute. *Law and Policy in International Business*, *16*(1), 173–238.

Bohnes, F. A., Hauschild, M. Z., Schlundt, J., & Laurent, A. (2019). Life cycle assessments of aquaculture systems: A critical review of reported findings with recommendations for policy and system development. *Reviews in Aquaculture*, *11*(4), 1061–1079. https://doi.org/10.1111/raq.12280

Boissy, A., & Le Neindre, P. (1997). Behavioral, cardiac and cortisol responses to brief peer separation and reunion in cattle. *Physiology & Behavior*, *61*(5), 693–699. https://doi.org/10.1016/s0031-9384(96)00521-5

Boissy, A., Manteuffel, G., Jensen, M. B., Moe, R. O., Spruijt, B., Keeling, L. J., Winckler, C., Forkman, B., Dimitrov, I., Langbein, J., Bakken, M., Veissier, I., & Aubert, A. (2007).

Assessment of positive emotions in animals to improve their welfare. *Physiology & Behavior*, *92*(3), 375–397. https://doi.org/10.1016/j.physbeh.2007.02.003

Bolderdijk, J. W., & Cornelissen, G. (2022). “How do you know someone’s vegan?” They won’t always tell you. An empirical test of the do-gooder’s dilemma. *Appetite*, *168*, 105719. https://doi.org/10.1016/j.appet.2021.105719

Bonfanti, C., Cardoso, C., Afonso, C., Matos, J., Garcia, T., Tanni, S., & Bandarra, N. M. (2018). Potential of microalga *Isochrysis galbana*: Bioactivity and bioaccessibility. *Algal Research*, *29*, 242–248. https://doi.org/10.1016/j.algal.2017.11.035

Borthwick, F., & Garnett, T. (2015). *Policies and actions to shift eating patterns: What works?: A review of the evidence of the effectiveness of interventions aimed at shifting diets in more sustainable and healthy directions*. https://www.research.ed.ac.uk/en/publications/policies-and-actions-to-shift-eating-patterns-what-works-a-review

Bossard, C., Santin, G., & Guseva Canu, I. (2016). Suicide Among Farmers in France: Occupational Factors and Recent Trends. *Journal of Agromedicine*, *21*(4), 310–315. https://doi.org/10.1080/1059924X.2016.1211052

Boutron-Ruault, M.-C., Mesrine, S., & Pierre, F. (2017). 12—Meat Consumption and Health Outcomes. In F. Mariotti (Ed.), *Vegetarian and Plant-Based Diets in Health and Disease Prevention* (pp. 197–214). Academic Press. https://doi.org/10.1016/B978-0-12-803968-7.00012-5

Breen, M., Anders, N., Humborstad, O.-B., Nilsson, J., Tenningen, M., & Vold, A. (2020). Catch Welfare in Commercial Fisheries. In T. S. Kristiansen, A. Fernö, M. A. Pavlidis, & H. van de Vis (Eds.), *The Welfare of Fish* (pp. 401–437). Springer International Publishing. https://doi.org/10.1007/978-3-030-41675-1_17

Brew, B., Inder, K., Allen, J., Thomas, M., & Kelly, B. (2016). The health and wellbeing of Australian farmers: A longitudinal cohort study. *BMC Public Health*, *16*(1), 988. https://doi.org/10.1186/s12889-016-3664-y

Broom, D. M., & Fraser, A. F. (2007a). Handling, transport and humane control of domestic animals. In *Domestic animal behaviour and welfare* (pp. 199–215). https://doi.org/10.1079/9781845932879.0199

Broom, D. M., & Fraser, A. F. (2007b). Welfare assessment. In *Domestic animal behaviour and welfare* (pp. 58–69). https://doi.org/10.1079/9781845932879.0058

Browning, H. (2023). Improving welfare assessment in aquaculture. *Frontiers in Veterinary Science*, *10*. https://doi.org/10.3389/fvets.2023.1060720

Browning, H., Burn, C., Schnell, A. K., Crump, A., & Birch, J. (2025). Animal welfare risks from commercial practices involving cephalopod molluscs and decapod crustaceans. *Animal Welfare*, *34*, e24. https://doi.org/10.1017/awf.2025.25

Bryant, C. (2020). Culture, meat, and cultured meat. *Journal of Animal Science*, *98*(8), skaa172. https://doi.org/10.1093/jas/skaa172

Bryant, C., Couture, A., Ross, E., Clark, A., & Chapman, T. (2024). A Review of Policy Levers to Reduce Meat Production and Consumption. *Appetite*, 107684. https://doi.org/10.1016/j.appet.2024.107684

Bryngelsson, S., Moshtaghian, H., Bianchi, M., & Hallström, E. (2022). Nutritional assessment of plant-based meat analogues on the Swedish market. *International Journal of Food Sciences and Nutrition*, *73*(7), 889–901. https://doi.org/10.1080/09637486.2022.2078286

Buckwell, A., & Nadeu, E. (2018). *What is the Safe Operating Space for EU livestock?* 108.

Bues, A., Preissel, S., Reckling, M., Zander, P., Kuhlman, T., Topp, K., Watson, C., Lindström, K., Stoddard, F. L., & Murphy-Bokern, D. (2013). *The Environmental Role of Protein Crops in the New Common Agricultural Policy*. 119.

Buller, H., Blokhuis, H., Jensen, P., & Keeling, L. (2018). Towards Farm Animal Welfare and Sustainability. *Animals : An Open Access Journal from MDPI*, *8*(6), 81. https://doi.org/10.3390/ani8060081

Camilleri, L., Richard Gill, P., Scarfo, J., & Jago, A. (2023). Resolving the masculinity dilemma: Identifying subtypes of male meat consumers with latent profile analysis. *Food Quality and Preference*, *108*, 104890. https://doi.org/10.1016/j.foodqual.2023.104890

Canfield, M., Anderson, M. D., & McMichael, P. (2021). UN Food Systems Summit 2021: Dismantling Democracy and Resetting Corporate Control of Food Systems. *Frontiers in Sustainable Food Systems*, *5*. https://doi.org/10.3389/fsufs.2021.661552

Capper, J. L. (2020). Opportunities and Challenges in Animal Protein Industry Sustainability: The Battle Between Science and Consumer Perception. *Animal Frontiers*, *10*(4), 7–13. https://doi.org/10.1093/af/vfaa034

Caraher, M. (2011). *Food austerity: A lifestyle choice for whom!* https://www.semanticscholar.org/paper/Food-austerity%3A-A-lifestyle-choice-for-whom!-Caraher/a831b8acd32e56b986141b888f874104cdab976c

Cardinaals, R. P. M., Verly, E. J., Jolliet, O., Van Zanten, H. H. E., & Huppertz, T. (2024). The complementarity of nutrient density and disease burden for Nutritional Life Cycle Assessment. *Frontiers in Sustainable Food Systems*, *8*. https://doi.org/10.3389/fsufs.2024.1304752

Carlsen, M. H., Halvorsen, B. L., Holte, K., Bøhn, S. K., Dragland, S., Sampson, L., Willey, C., Senoo, H., Umezono, Y., Sanada, C., Barikmo, I., Berhe, N., Willett, W. C., Phillips, K. M., Jacobs, D. R., & Blomhoff, R. (2010). The total antioxidant content of more than 3100 foods, beverages, spices, herbs and supplements used worldwide. *Nutrition Journal*, *9*(1), 3. https://doi.org/10.1186/1475-2891-9-3

Carpenter, G., Kleinjans, R., Villasante, S., & O'Leary, B. C. (2016). Landing the blame: The influence of EU Member States on quota setting. *Marine Policy*, *64*, 9–15. https://doi.org/10.1016/j.marpol.2015.11.001

Carpenter, K. J. (1986). The History of Enthusiasm for Protein. *The Journal of Nutrition*, *116*(7), 1364–1370. https://doi.org/10.1093/jn/116.7.1364

Cavalier, H., Trasande, L., & Porta, M. (2023). Exposures to pesticides and risk of cancer: Evaluation of recent epidemiological evidence in humans and paths forward. *International Journal of Cancer*, *152*(5), 879–912. https://doi.org/10.1002/ijc.34300

Cavalli, L., Jeebhay, M. F., Marques, F., Mitchell, R., Neis, B., Ngajilo, D., & Watterson, A. (2019). Scoping Global Aquaculture Occupational Safety and Health. *Journal of Agromedicine*. https://www.tandfonline.com/doi/abs/10.1080/1059924X.2019.1655203

Chalupa-Krebzdak, S., Long, C. J., & Bohrer, B. M. (2018). Nutrient density and nutritional value of milk and plant-based milk alternatives. *International Dairy Journal*, *87*, 84–92. https://doi.org/10.1016/j.idairyj.2018.07.018

Champneys, T., Castaldo, G., Consuegra, S., & Garcia de Leaniz, C. (2018). Density-dependent changes in neophobia and stress-coping styles in the world's oldest farmed fish. *Royal Society Open Science*, *5*(12), 181473. https://doi.org/10.1098/rsos.181473

Chang, J., Havlík, P., Leclère, D., de Vries, W., Valin, H., Deppermann, A., Hasegawa, T., & Obersteiner, M. (2021). Reconciling regional nitrogen boundaries with global food security. *Nature Food*, 1–12. https://doi.org/10.1038/s43016-021-00366-x

Chary, K., van Riel, A.-J., Muscat, A., Wilfart, A., Harchaoui, S., Verdegem, M., Filgueira, R., Troell, M., Henriksson, P. J. G., de Boer, I. J. M., & Wiegertjes, G. F. (2024). Transforming sustainable aquaculture by applying circularity principles. *Reviews in Aquaculture*, *16*(2), 656–673. https://doi.org/10.1111/raq.12860

Chen, G.-C., Lv, D.-B., Pang, Z., & Liu, Q.-F. (2013). Red and processed meat consumption and risk of stroke: A meta-analysis of prospective cohort studies. *European Journal of Clinical Nutrition*, *67*(1), 91–95. https://doi.org/10.1038/ejcn.2012.180

Chen, Z., Franco, O. H., Lamballais, S., Ikram, M. A., Schoufour, J. D., Muka, T., & Voortman, T. (2020). Associations of specific dietary protein with longitudinal insulin resistance, prediabetes and type 2 diabetes: The Rotterdam Study. *Clinical Nutrition*, *39*(1), 242–249. https://doi.org/10.1016/j.clnu.2019.01.021

Cheng, L., Zhang, X., Reis, S., Ren, C., Xu, J., & Gu, B. (2022). A 12% switch from monogastric to ruminant livestock production can reduce emissions and boost crop production for 525 million people. *Nature Food*, *3*(12), Article 12. https://doi.org/10.1038/s43016-022-00661-1

Cherry, K. E., Lyon, B. A., Sampson, L., Galea, S., Nezat, P. F., & Marks, L. D. (2017). Prior Hurricane and Other Lifetime Trauma Predict Coping Style in Older Commercial Fishers After the BP Deepwater Horizon Oil Spill. *Journal of Applied Biobehavioral Research*, *22*(2), e12058. https://doi.org/10.1111/jabr.12058

Chiles, R. M., & Fitzgerald, A. J. (2018). Why is meat so important in Western history and culture? A genealogical critique of biophysical and political-economic explanations. *Agriculture and Human Values*, *35*(1), 1–17. https://doi.org/10.1007/s10460-017-9787-7

Chislock, M., Doster, E., Zitomer, R., & Wilson, A. (2013). *Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems | Learn Science at Scitable*. https://www.nature.com/scitable/knowledge/library/eutrophication-causes-consequences-and-controls-in-aquatic-102364466/

Chriki, S., Ellies-Oury, M.-P., & Hocquette, J.-F. (2022). Is “cultured meat” a viable alternative to slaughtering animals and a good comprise between animal welfare and human expectations? *Animal Frontiers: The Review Magazine of Animal Agriculture*, *12*(1), 35–42. https://doi.org/10.1093/af/vfac002

Chriki, S., & Hocquette, J.-F. (2020). The Myth of Cultured Meat: A Review. *Frontiers in Nutrition*, *7*. https://doi.org/10.3389/fnut.2020.00007

Chungchunlam, S. M. S., & Moughan, P. J. (2023). Comparative bioavailability of vitamins in human foods sourced from animals and plants. *Critical Reviews in Food Science and Nutrition*, *0*(0), 1–36. https://doi.org/10.1080/10408398.2023.2241541

Chungchunlam, S. M. S., & Moughan, P. J. (2024). Diet affordability: A key dimension in the assessment of sustainable food systems and healthy diets. *Frontiers in Nutrition*, *11*. https://doi.org/10.3389/fnut.2024.1399019

Cicek, H., & Tandogan, M. (2016). Estimation of optimum slaughter age in broiler chicks. *Indian Journal of Animal Research*. https://arccjournals.com/journal/indian-journal-of-animal-research/B-350?utm_source=chatgpt.com

Cisternas, F., Sun, C., Contador, C. A., Anders, S., Chu, M., Phan, N., Hu, B., Liu, Z., Lam, H.-M., & Tse, L. A. (2024). Cultural and generational factors shape Asians' sustainable food choices: Insights from choice experiments and information nudges. *Cell Reports Sustainability*, *1*(2), 100020. https://doi.org/10.1016/j.crsus.2024.100020

Clapp, J., & Scrinis, G. (2017). Big Food, Nutritionism, and Corporate Power. *Globalizations*, *14*(4), 578–595. https://doi.org/10.1080/14747731.2016.1239806

Clapp, J., Vriezen, R., Laila, A., Conti, C., Gordon, L., Hicks, C., & Rao, N. (2025). Corporate concentration and power matter for agency in food systems. *Food Policy*, *134*, 102897. https://doi.org/10.1016/j.foodpol.2025.102897

Clare, K., Maani, N., & Milner, J. (2022). Meat, money and messaging: How the environmental and health harms of red and processed meat consumption are framed by the meat industry. *Food Policy*, *109*, 102234. https://doi.org/10.1016/j.foodpol.2022.102234

Clark, M., Domingo, N. G. G., Colgan, K., Thakrar, S. K., Tilman, D., Lynch, J., Azevedo, I. L., & Hill, J. D. (2020). Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets. *Science*, *370*(6517), 705–708. https://doi.org/10.1126/science.aba7357

Clark, M., Springmann, M., Rayner, M., Scarborough, P., Hill, J., Tilman, D., Macdiarmid, J. I., Fanzo, J., Bandy, L., & Harrington, R. A. (2022). Estimating the environmental impacts of 57,000 food products. *Proceedings of the National Academy of Sciences*, *119*(33), e2120584119. https://doi.org/10.1073/pnas.2120584119

Clark, M., & Tilman, D. (2017). Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice. *Environmental Research Letters*, *12*(6), 064016. https://doi.org/10.1088/1748-9326/aa6cd5

Clarke, S. C., Sato, M., Small, C., Sullivan, B. J., Inoue, Y., & Ochi, D. (2014). Bycatch in longline fisheries for tuna and tuna-like species: A global review of status and mitigation measures | Bycatch Management Information System (BMIS). In *Http://www.fao.org/3/a-i4017e.pdf* [Report]. https://www.bmis-bycatch.org/references/n7nq4pf6

Cleaver, C., Johnson, T. R., & Hanes, S. P. (2024). Challenges and opportunities for integrating aquaculture with commercial fishing in Maine. *Marine Policy*, *170*, 106407. https://doi.org/10.1016/j.marpol.2024.106407

Clemente, G. A., Tolini, C., Boscarino, A., Lorenzi, V., Dal Lago, T. L., Benedetti, D., Bellucci, F., Manfrin, A., Trocino, A., & Rota Nodari, S. (2023). Farmed fish welfare during slaughter in Italy: Survey on stunning and killing methods and indicators of unconsciousness. *Frontiers in Veterinary Science*, *10*, 1253151. https://doi.org/10.3389/fvets.2023.1253151

Comerford, K. B., Miller, G. D., Reinhardt Kapsak, W., & Brown, K. A. (2021). The Complementary Roles for Plant-Source and Animal-Source Foods in Sustainable Healthy Diets. *Nutrients*, *13*(10), Article 10. https://doi.org/10.3390/nu13103469

Conant, R. T., Cerri, C. E. P., Osborne, B. B., & Paustian, K. (2017). Grassland management impacts on soil carbon stocks: A new synthesis. *Ecological Applications*, *27*(2), 662–668. https://doi.org/10.1002/eap.1473

Consalez, F., Ahern, M., Andersen, P., & Kjellevold, M. (2022). The Effect of the Meat Factor in Animal-Source Foods on Micronutrient Absorption: A Scoping Review. *Advances in Nutrition*, *13*(6), 2305–2315. https://doi.org/10.1093/advances/nmac089

Cordova, R., Viallon, V., Fontvieille, E., Peruchet-Noray, L., Jansana, A., Wagner, K.-H., Kyrø, C., Tjønneland, A., Katzke, V., Bajracharya, R., Schulze, M. B., Masala, G., Sieri, S., Panico, S., Ricceri, F., Tumino, R., Boer, J. M. A., Verschuren, W. M. M., van der Schouw, Y. T., … Freisling, H. (2023). Consumption of ultra-processed foods and risk of multimorbidity of cancer and cardiometabolic diseases: A multinational cohort study. *The Lancet Regional Health - Europe*, *35*, 100771. https://doi.org/10.1016/j.lanepe.2023.100771

Cornish, A. R., Briley, D., Wilson, B. J., Raubenheimer, D., Schlosberg, D., & McGreevy, P. D. (2020). The price of good welfare: Does informing consumers about what on-package labels mean for animal welfare influence their purchase intentions? *Appetite*, *148*, 104577. https://doi.org/10.1016/j.appet.2019.104577

Costa, C., García-Lestón, J., Costa, S., Coelho, P., Silva, S., Pingarilho, M., Valdiglesias, V., Mattei, F., Dall'Armi, V., Bonassi, S., Laffon, B., Snawder, J., & Teixeira, J. P. (2014). Is organic farming safer to farmers' health? A comparison between organic and traditional farming. *Toxicology Letters*, *230*(2), 166–176. https://doi.org/10.1016/j.toxlet.2014.02.011

Costello, C., Cao, L., Gelcich, S., Cisneros-Mata, M. Á., Free, C. M., Froehlich, H. E., Golden, C. D., Ishimura, G., Maier, J., Macadam-Somer, I., Mangin, T., Melnychuk, M. C., Miyahara, M., de Moor, C. L., Naylor, R., Nøstbakken, L., Ojea, E., O'Reilly, E., Parma, A. M., … Lubchenco, J. (2020). The future of food from the sea. *Nature*, *588*(7836), 95–100. https://doi.org/10.1038/s41586-020-2616-y

Costlow, L., Herforth, A., Sulser, T. B., Cenacchi, N., & Masters, W. A. (2025). Global analysis reveals persistent shortfalls and regional differences in availability of foods needed for health. *Global Food Security*, *44*, 100825. https://doi.org/10.1016/j.gfs.2024.100825

Cottee, S. (2008). *An HSUS Report: The Welfare of Farmed Fish at Slaughter*.

Council Directive 91/676/EEC of 12 December 1991 Concerning the Protection of Waters against Pollution Caused by Nitrates from Agricultural Sources, CONSIL, 375 OJ L (1991). http://data.europa.eu/eli/dir/1991/676/oj/eng

Couturier, C., Charru, M., Doublet, S., & Pointereau, P. (2016). *Afterres 2050—Un scénario soutenable pour l'agriculture et l'utilisation des terres en France à l'hroizon 2050*. Solagro.

Craddock, J. C., Neale, E. P., Probst, Y. C., & Peoples, G. E. (2017). Algal supplementation of vegetarian eating patterns improves plasma and serum docosahexaenoic acid concentrations and omega-3 indices: A systematic literature review. *Journal of Human Nutrition and Dietetics: The Official Journal of the British Dietetic Association*, *30*(6), 693–699. https://doi.org/10.1111/jhn.12474

Craft, R., & Pitt, H. (2024). More than meat? Livestock farmers' views on opportunities to produce for plant-based diets. *Agriculture and Human Values*, *41*(3), 975–988. https://doi.org/10.1007/s10460-023-10533-4

Craig, W. J., Mangels, A. R., Fresán, U., Marsh, K., Miles, F. L., Saunders, A. V., Haddad, E. H., Heskey, C. E., Johnston, P., Larson-Meyer, E., & Orlich, M. (2021). The Safe and Effective Use of Plant-Based Diets with Guidelines for Health Professionals. *Nutrients*, *13*(11), Article 11. https://doi.org/10.3390/nu13114144

Crosland, P., Ananthapavan, J., Davison, J., Lambert, M., & Carter, R. (2019). The economic cost of preventable disease in Australia: A systematic review of estimates and methods. *Australian and New Zealand Journal of Public Health*, *43*(5), 484–495. https://doi.org/10.1111/1753-6405.12925

Cross, A. J., Ferrucci, L. M., Risch, A., Graubard, B. I., Ward, M. H., Park, Y., Hollenbeck, A. R., Schatzkin, A., & Sinha, R. (2010). A Large Prospective Study of Meat Consumption and Colorectal Cancer Risk: An Investigation of Potential Mechanisms Underlying this Association. *Cancer Research*, *70*(6), 2406–2414. https://doi.org/10.1158/0008-5472.CAN-09-3929

Crowe, W., Elliott, C. T., & Green, B. D. (2019). A Review of the In Vivo Evidence Investigating the Role of Nitrite Exposure from Processed Meat Consumption in the Development of Colorectal Cancer. *Nutrients*, *11*(11), 2673. https://doi.org/10.3390/nu11112673

Cusworth, G., Brice, J., Lorimer, J., & Garnett, T. (2023). When you wish upon a (GWP) star: Environmental governance and the reflexive performativity of global warming metrics. *Social Studies of Science*, *53*(1), 3–28. https://doi.org/10.1177/03063127221134275

Dafale, N. A., Srivastava, S., & Purohit, H. J. (2020). Zoonosis: An Emerging Link to Antibiotic Resistance Under "One Health Approach." *Indian Journal of Microbiology*, *60*(2), 139–152. https://doi.org/10.1007/s12088-020-00860-z

Dagevos, H. (2021). Finding flexitarians: Current studies on meat eaters and meat reducers. *Trends in Food Science and Technology*, *114*, 530–539. Scopus. https://doi.org/10.1016/j.tifs.2021.06.021

Daghagh Yazd, S., Wheeler, S. A., & Zuo, A. (2019). Key Risk Factors Affecting Farmers' Mental Health: A Systematic Review. *International Journal of Environmental Research and Public Health*, *16*(23), Article 23. https://doi.org/10.3390/ijerph16234849

Dahdouh, S., Grande, F., Espinosa, S. N., Vincent, A., Gibson, R., Bailey, K., King, J., Rittenschober, D., & Charrondière, U. R. (2019). Development of the FAO/INFOODS/IZINCG Global Food Composition Database for Phytate. *Journal of Food Composition and Analysis*, *78*, 42–48. https://doi.org/10.1016/j.jfca.2019.01.023

Dai, W., Chen, Y., Xiong, W., Li, S., Tan, W.-S., & Zhou, Y. (2024). Development of a serum-free medium for myoblasts long-term expansion and 3D culture for cell-based meat. *Journal of Food Science*, *89*(2), 851–865. https://doi.org/10.1111/1750-3841.16884

Daly, J. (2020). A social practice perspective on meat reduction in Australian households: Rethinking intervention strategies. *Geographical Research*, *58*(3), 240–251. https://doi.org/10.1111/1745-5871.12399

Darmon, N., Briend, A., & Drewnowski, A. (2004). Energy-dense diets are associated with lower diet costs: A community study of French adults. *Public Health Nutrition*, *7*(1), 21–27. https://doi.org/10.1079/PHN2003512

Daugbjerg, C., & Feindt, P. H. (2017). Post-exceptionalism in public policy: Transforming food and agricultural policy. *Journal of European Public Policy*, *24*(11), 1565–1584. https://doi.org/10.1080/13501763.2017.1334081

Daugbjerg, C., & Swinbank, A. (2009). Chapter 1 An Introduction to Agricultural Exceptionalism in EU Farm Policy and the GATT. In C. Daugbjerg & A. Swinbank (Eds.), *Ideas, Institutions, and Trade: The WTO and the Curious Role of EU Farm Policy in Trade Liberalization* (p. 0). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199557752.003.0001

Daugbjerg, C., & Swinbank, A. (2016). Three Decades of Policy Layering and Politically Sustainable Reform in the European Union's Agricultural Policy. *Governance*, *29*(2), 265–280. https://doi.org/10.1111/gove.12171

Dawkins, M. S. (2021). Does Smart Farming Improve or Damage Animal Welfare? Technology and What Animals Want. *Frontiers in Animal Science*, *2*. https://doi.org/10.3389/fanim.2021.736536

Day, L., Cakebread, J. A., & Loveday, S. M. (2022). Food proteins from animals and plants: Differences in the nutritional and functional properties. *Trends in Food Science & Technology*, *119*, 428–442. https://doi.org/10.1016/j.tifs.2021.12.020

de Araújo, P. D., Araújo, W. M. C., Patarata, L., & Fraqueza, M. J. (2022). Understanding the main factors that influence consumer quality perception and attitude towards meat and processed meat products. *Meat Science*, *193*, 108952. https://doi.org/10.1016/j.meatsci.2022.108952

de Boer, J., & Aiking, H. (2019). Strategies towards healthy and sustainable protein consumption: A transition framework at the levels of diets, dishes, and dish ingredients. *Food Quality and Preference*, *73*, 171–181. https://doi.org/10.1016/j.foodqual.2018.11.012

de Boer, J., Helms, M., & Aiking, H. (2006). Protein consumption and sustainability: Diet diversity in EU-15. *Ecological Economics*, *59*(3), 267–274. https://doi.org/10.1016/j.ecolecon.2005.10.011

De Goede, D. M., Erens, J., Kapsomenou, E., & Peters, M. (2013). Large scale insect rearing and animal welfare. In H. Röcklinsberg & P. Sandin (Eds.), *The ethics of consumption: The citizen, the market and the law* (pp. 236–242). Academic Publishers. https://doi.org/10.3920/978-90-8686-784-4_38

de Haas, E. N., Oliemans, E., & van Gerwen, M. A. A. M. (2021). The Need for an Alternative to Culling Day-Old Male Layer Chicks: A Survey on Awareness, Alternatives, and the Willingness to Pay for Alternatives in a Selected Population of Dutch Citizens. *Frontiers in Veterinary Science*, *8*, 662197. https://doi.org/10.3389/fvets.2021.662197

De Pue, D., Roet, D., Lefebvre, W., & Buysse, J. (2017). Mapping impact indicators to link airborne ammonia emissions with nitrogen deposition in Natura 2000 sites. *Atmospheric Environment*, *166*, 120–129. https://doi.org/10.1016/j.atmosenv.2017.07.020

De Schutter, O., Jacobs, N., & Clément, C. (2020). A ‘Common Food Policy’ for Europe: How governance reforms can spark a shift to healthy diets and sustainable food systems. *Food Policy*, *96*, 101849. https://doi.org/10.1016/j.foodpol.2020.101849

De Vries, A., & Marcondes, M. I. (2020). Review: Overview of factors affecting productive lifespan of dairy cows. *Animal*, *14*, s155–s164. https://doi.org/10.1017/S1751731119003264

de Vries, M., van Middelaar, C. E., & de Boer, I. J. M. (2015). Comparing environmental impacts of beef production systems: A review of life cycle assessments. *Livestock Science*, *178*, 279–288. https://doi.org/10.1016/j.livsci.2015.06.020

de Vries, W. (2021). Impacts of nitrogen emissions on ecosystems and human health: A mini review. *Current Opinion in Environmental Science & Health*, *21*, 100249. https://doi.org/10.1016/j.coesh.2021.100249

Dearmond, S., Stallones, L., Chen, P., & Sintek, E. (2006). Depression and Somatic Symptoms within the Farming Community. *Journal of Agricultural Safety and Health*, *12*, 5–15. https://doi.org/10.13031/2013.20195

Degieter, M., Gellynck, X., Goyal, S., Mattelin, M., De Wulf, J., Ott, D., & De Steur, H. (2023). A mixed-methods approach to examine farmers' willingness to adopt protein crops. *Outlook on Agriculture*, 00307270231205924. https://doi.org/10.1177/00307270231205924

del Prado, A., Lynch, J., Liu, S., Ridoutt, B., Pardo, G., & Mitloehner, F. (2023). Animal board invited review: Opportunities and challenges in using GWP* to report the impact of ruminant livestock on global temperature change. *Animal*, *17*(5), 100790. https://doi.org/10.1016/j.animal.2023.100790

Delgado, C. L. (2003). Rising Consumption of Meat and Milk in Developing Countries Has Created a New Food Revolution. *The Journal of Nutrition*, *133*(11), 3907S-3910S. https://doi.org/10.1093/jn/133.11.3907S

Delvendahl, N., Rumpold, B. A., & Langen, N. (2022). Edible Insects as Food–Insect Welfare and Ethical Aspects from a Consumer Perspective. *Insects*, *13*(2), Article 2. https://doi.org/10.3390/insects13020121

Dey, D., Richter, J. K., Ek, P., Gu, B.-J., & Ganjyal, G. M. (2021). Utilization of Food Processing By-products in Extrusion Processing: A Review. *Frontiers in Sustainable Food Systems*, *4*. https://doi.org/10.3389/fsufs.2020.603751

Diana, J. S. (2009). Aquaculture Production and Biodiversity Conservation. *BioScience*, *59*(1), 27–38. https://doi.org/10.1525/bio.2009.59.1.7

Dias, N. F., Tirloni, A. S., dos Reis, D. C., & Moro, A. R. P. (2020). Risk of slaughterhouse workers developing work-related musculoskeletal disorders in different organizational working conditions. *International Journal of Industrial Ergonomics*, *76*, 102929. https://doi.org/10.1016/j.ergon.2020.102929

Dietrich, S., Trefflich, I., Ueland, P. M., Menzel, J., Penczynski, K. J., Abraham, K., & Weikert, C. (2022). Amino acid intake and plasma concentrations and their interplay with gut microbiota in vegans and omnivores in Germany. *European Journal of Nutrition*, *61*(4), 2103–2114. https://doi.org/10.1007/s00394-021-02790-y

Docherty, D., & Jasper, C. (2023). The cheese paradox: How do vegetarians justify consuming non-meat animal products? *Appetite*, *188*, 106976. https://doi.org/10.1016/j.appet.2023.106976

Dogan, K. H. (2012). *Livestock-Handling Related Injuries and Deaths* (pp. 81–116). https://doi.org/10.5772/50834

Domić, J., Grootswagers, P., van Loon, L. J. C., & de Groot, L. C. P. G. M. (2022). Perspective: Vegan Diets for Older Adults? A Perspective On the Potential Impact On Muscle Mass and Strength. *Advances in Nutrition (Bethesda, Md.)*, *13*(3), 712–725. https://doi.org/10.1093/advances/nmac009

Dong, B., Xi, Y., Cui, Y., & Peng, S. (2023). Quantifying Methane Emissions from Aquaculture Ponds in China. *Environmental Science & Technology*, *57*(4), 1576–1583. https://doi.org/10.1021/acs.est.2c05218

Downs, S. M., Ahmed, S., Fanzo, J., & Herforth, A. (2020). Food Environment Typology: Advancing an Expanded Definition, Framework, and Methodological Approach for Improved Characterization of Wild, Cultivated, and Built Food Environments toward Sustainable Diets. *Foods*, *9*(4), 532. https://doi.org/10.3390/foods9040532

Drewnowski, A., Bruins, M. J., & Besselink, J. J. F. (2024). Comparing Nutrient Profiles of Meat and Fish with Plant-Based Alternatives: Analysis of Nutrients, Ingredients, and Fortification Patterns. *Nutrients*, *16*(16), Article 16. https://doi.org/10.3390/nu16162725

Drewnowski, A., & Gomez-Carneros, C. (2000). Bitter taste, phytonutrients, and the consumer: A review123. *The American Journal of Clinical Nutrition*, *72*(6), 1424–1435. https://doi.org/10.1093/ajcn/72.6.1424

Duluins, O., & Baret, P. V. (2024a). A systematic review of the definitions, narratives and paths forwards for a protein transition in high-income countries. *Nature Food*, 1–9. https://doi.org/10.1038/s43016-023-00906-7

Duluins, O., & Baret, P. V. (2024b). The paradoxes of the protein transition maintain existing animal production and consumption systems. *Nature Food*, 1–6. https://doi.org/10.1038/s43016-024-01036-4

Duluins, O., Riera, A., Schuster, M., Baret, P. V., & Van den Broeck, G. (2022). Economic Implications of a Protein Transition: Evidence From Walloon Beef and Dairy Farms. *Frontiers in Sustainable Food Systems*, *6*, 803872. https://doi.org/10.3389/fsufs.2022.803872

Dumont, A., & Baret, P. (2017). Why Working Conditions Are a Key Issue of Sustainability in Agriculture? A Comparison between Agroecological, Organic and Conventional Vegetable Systems. *Journal of Rural Studies*, *57*. https://dial.uclouvain.be/pr/boreal/en/object/boreal%3A187962

Dumont, B., Ryschawy, J., Duru, M., Benoit, M., Chatellier, V., Delaby, L., Donnars, C., Dupraz, P., Lemauviel-Lavenant, S., Méda, B., Vollet, D., & Sabatier, R. (2019). Review: Associations among goods, impacts and ecosystem services provided by livestock farming. *Animal*, *13*(8), 1773–1784. https://doi.org/10.1017/S1751731118002586

Duncan, J., Claeys, P., Rivera-Ferre, M. G., Oteros-Rozas, E., Van Dyck, B., Plank, C., & Desmarais, A. A. (2021). Scholar-activists in an expanding European food sovereignty movement. *The Journal of Peasant Studies*, *48*(4), 875–900. https://doi.org/10.1080/03066150.2019.1675646

Dussiot, A., Fouillet, H., Wang, J., Salomé, M., Huneau, J.-F., Kesse-Guyot, E., & Mariotti, F. (2022). Modeled healthy eating patterns are largely constrained by currently estimated requirements for bioavailable iron and zinc—A diet optimization study in French adults. *The American Journal of Clinical Nutrition*, *115*(3), 958–969. https://doi.org/10.1093/ajcn/nqab373

Duval, J., Cournut, S., & Hostiou, N. (2021). Livestock farmers' working conditions in agroecological farming systems. A review. *Agronomy for Sustainable Development*, *41*(2), 22. https://doi.org/10.1007/s13593-021-00679-y

EFSA. (2012, February 9). *EFSA sets population reference intakes for protein | EFSA*. https://www.efsa.europa.eu/en/press/news/120209

EFSA. (2022, February 2). *Fish welfare | EFSA*. https://www.efsa.europa.eu/en/topics/topic/fish-welfare

EFSA, E. F. S., & ECDE, E. C. for D. P. and C. (ECDC). (2024). The European Union One Health 2023 Zoonoses report. *EFSA Journal*, *22*(12), e9106. https://doi.org/10.2903/j.efsa.2024.9106

EFSA, E. F. S., Vitali, M., Aboagye, G., Ashe, S., Fabris, C., Van de Stede, Y., & Candiani, D. (2023). The use of animal-based measures at slaughter for assessing the welfare of beef cattle on farm: EFSA AHAW Network exercise. *EFSA Supporting Publications*, *20*(11), 8462E. https://doi.org/10.2903/sp.efsa.2023.EN-8462

EFSA Panel on Dietetic Products, Nutrition, and Allergies (NDA). (2010). Scientific Opinion on establishing Food-Based Dietary Guidelines. *EFSA Journal*, *8*(3), 1460. https://doi.org/10.2903/j.efsa.2010.1460

EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA). (2011). Scientific Opinion on the substantiation of health claims related to docosahexaenoic acid (DHA), eicosapentaenoic acid (EPA) and brain, eye and nerve development (ID 501, 513, 540), maintenance of normal brain function (ID 497, 501, 510, 513, 519, 521, 534, 540, 688, 1323, 1360, 4294), maintenance of normal vision (ID 508, 510, 513, 519, 529, 540, 688, 2905, 4294), maintenance of normal cardiac function (ID 510, 688, 1360), "maternal health; pregnancy and nursing" (ID 514), "to fulfil increased omega-3 fatty acids need during pregnancy" (ID 539), "skin and digestive tract epithelial cells maintenance" (ID 525), enhancement of mood (ID 536), "membranes cell structure" (ID 4295), "anti-inflammatory action" (ID 4688) and maintenance of normal blood LDL-cholesterol concentrations (ID 4719) pursuant to Article 13(1) of Regulation (EC) No 1924/2006. *EFSA Journal*, *9*(4), 2078. https://doi.org/10.2903/j.efsa.2011.2078

Elwood, R. W. (2019). Assessing the Potential for Pain in Crustaceans and Other Invertebrates. In C. Carere & J. Mather (Eds.), *The Welfare of Invertebrate Animals* (pp. 147–177). Springer International Publishing. https://doi.org/10.1007/978-3-030-13947-6_7

Embling, R., Neilson, L., Randall, T., Mellor, C., Lee, M., & Wilkinson, L. (2022). 'Edible seaweeds' as an alternative to animal-based proteins in the UK: Identifying product beliefs and consumer traits as drivers of consumer acceptability for macroalgae. *Food Quality and Preference*, *100*, 104613. https://doi.org/10.1016/j.foodqual.2022.104613

Epstein, G., Middelburg, J. J., Hawkins, J. P., Norris, C. R., & Roberts, C. M. (2022). The impact of mobile demersal fishing on carbon storage in seabed sediments. *Global Change Biology*, *28*(9), 2875–2894. https://doi.org/10.1111/gcb.16105

Erickson, M. C., & Doyle, M. P. (2012). PLANT FOOD SAFETY ISSUES: LINKING PRODUCTION AGRICULTURE WITH ONE HEALTH. In *Improving Food Safety Through a One Health Approach: Workshop Summary*. National Academies Press (US). https://www.ncbi.nlm.nih.gov/books/NBK114507/

Eriksen, M. S., Rødbotten, R., Grøndahl, A. M., Friestad, M., Andersen, I. L., & Mejdell, C. M. (2013). Mobile abattoir versus conventional slaughterhouse—Impact on stress parameters and meat quality characteristics in Norwegian lambs. *Applied Animal Behaviour Science*, *149*(1), 21–29. https://doi.org/10.1016/j.applanim.2013.09.007

Etemadi, A., Sinha, R., Ward, M. H., Graubard, B. I., Inoue-Choi, M., Dawsey, S. M., & Abnet, C. C. (2017). Mortality from different causes associated with meat, heme iron, nitrates, and nitrites in the NIH-AARP Diet and Health Study: Population based cohort study. *BMJ (Clinical Research Ed.)*, *357*, j1957. https://doi.org/10.1136/bmj.j1957

EU CAP Network. (2013). *Towards a competitive protein crops production in Europe | EU CAP Network*. https://eu-cap-network.ec.europa.eu/publications/towards-competitive-protein-crops-production-europe_en

EUMOFA. (2024). *The EU market overview*. European Market Observatory for Fisheries and Aquaculture Products. https://eumofa.eu/the-eu-market

European Agency for Safety and Health at Work, Jones, A., Jakob, M., & McNamara, J. (2020). *Review of the future of agriculture and occupational safety and health (OSH): Foresight on new and emerging risks in OSH*. Publications Office of the European Union. https://data.europa.eu/doi/10.2802/769257

European Commission. (2009). *Regulation—1099/2009—EN - EUR-Lex*. https://eur-lex.europa.eu/eli/reg/2009/1099/oj/eng

European Commission. (2018). *Development of plant proteins in the European Union*. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0757&from=EN

European Commission. (2020). *Farm to Fork Strategy. For a Fair, Healthy and Environmentally-Friendly Food System; European Commission: Brussels, Belgium, 2020*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0381

European Commission. (2021a). *EU biodiversity strategy for 2030: Bringing nature back into our lives*. Publications Office of the European Union. https://data.europa.eu/doi/10.2779/677548

European Commission. (2021b). *SUMMARY REPORT on the implementation of direct payments [except greening]* (p. 28). European Commission.

European Commission. (2021c, July 14). *Delivering the European Green Deal—European Commission*. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en

European Commission. (2023). *COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS on a comprehensive approach to mental health*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52023DC0298

European Commission. (2024a). *Access2Markets Barrier: Ban on imports of pigs and pork products from several EU Member States due to African Swine Fever and poultry and poultry products due to Highly pathogenic avian influensa*. https://trade.ec.europa.eu/access-to-markets/en/barriers/details?isSps=true&barrier_id=14402

European Commission. (2024b). *Animal products movements—European Commission*. https://food.ec.europa.eu/animals/animal-products-movements_en

European Commission. (2024c). *Aquaculture policy—European Commission*. https://oceans-and-fisheries.ec.europa.eu/policy/aquaculture-policy_en

European Commission. (2024d). *Dietary Protein—Overview of protein intake in European countries | Knowledge for policy*. https://knowledge4policy.ec.europa.eu/health-promotion-knowledge-gateway/dietary-protein-overview-countries-6_en

European Commission. (2024e). *EU register of health claims—European Commission*. https://food.ec.europa.eu/food-safety/labelling-and-nutrition/nutrition-and-health-claims/eu-register-health-claims_en

European Commission. (2024f). *Food and Feed Information Portal Database | FIP*. https://ec.europa.eu/food/food-feed-portal/screen/health-claims/eu-register

European Commission. (2024g). *Foot-and-mouth disease—European Commission*. https://food.ec.europa.eu/animals/animal-diseases/diseases-and-control-measures/foot-and-mouth-disease_en

European Commission. (2024h). *Health and consumer protection for animal and plant product | Access2Markets*. https://trade.ec.europa.eu/access-to-markets/en/content/health-and-consumer-protection-animal-and-plant-product

European Commission. (2024i, October 8). *Reducing the plant protein deficit of the EU - European Commission*. https://agriculture.ec.europa.eu/farming/crop-productions-and-plant-based-products/cereals/reducing-plan-protein-deficit-eu_en

European Commission. (2024j, December 11). *Crops—European Commission* [2024]. https://agriculture.ec.europa.eu/data-and-analysis/markets/overviews/market-observatories/crops_en

European Commission. (2024k, December 20). *CAP at a glance—European Commission*. https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cap-glance_en

European Commission, Direction générale des affaires maritimes et de la pêche (Commission européenne), Borriello, A., Calvo Santos, A., Codina López, L., Feyen, L., Gaborieau, N., Garaffa, R., Ghiani, M., Guillén, J., Mc Govern, L., Norman, A., Peralta Baptista, A., Petrucco, G., Pistocchi, A., Pleguezuelo Alonso, M., Quatrini, S., Tapoglou, E., Abbagnano Trione, B., … Vousdoukas, M. I. (2024). *The EU blue economy report 2024*. Office des publications de l'Union européenne. https://data.europa.eu/doi/10.2771/186064

European Court of Auditors. (2020, June 11). *Special report no 03/2016: Combating eutrophication in the Baltic Sea: further and more effective action needed*. European Court of Auditors. http://www.eca.europa.eu/en/Pages/Report.aspx?did=35757&TermStoreId=8935807f-8495-4a93-a302-f4b76776d8ea&TermSetId=49e662c4-f172-43ae-8a5e-7276133de92c&TermId=5f6589a2-5a2e-4ae8-8cc6-e05bf544b71f

European Court of Auditors. (2021). *Common agricultural policy and climate: Half of EU climate spending but farm emissions are not decreasing*. Publications Office. https://data.europa.eu/doi/10.2865/390444

European Environment Agency. (2004). *High nature value farmland—Characteristics, trends and policy challenges* [Publication]. https://www.eea.europa.eu/publications/report_2004_1

European Parliament. (2022). *WTO agreement on fisheries subsidies | Think Tank | European Parliament*. https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2021)698842

European Parliament. (2023a). *Procedure File: 2023/2015(INI) European Protein Strategy| Legislative Observatory | European Parliament*.

https://oeil.secure.europarl.europa.eu/oeil/popups/ficheprocedure.do?lang=en&reference=2023/2015(INI)

European Parliament. (2023b). *Religious slaughter: Reconciling animal welfare with freedom of religion or belief | Think Tank | European Parliament*. https://www.europarl.europa.eu/thinktank/en/document/EPRS_IDA(2023)751418

European Parliament. (2024a, March 31). *The common fisheries policy: Origins and development | Fact Sheets on the European Union | European Parliament*. https://www.europarl.europa.eu/factsheets/en/sheet/114/the-common-fisheries-policy-origins-and-development

European Parliament. (2024b, April 17). *Alternative protein sources for food and feed | Think Tank | European Parliament*. https://www.europarl.europa.eu/thinktank/en/document/EPRS_STU(2024)757806

European Trade Union Institute. (2021). *Meat industry: Substandard working conditions of migrant workers | etui*. https://www.etui.org/news/meat-industry-substandard-working-conditions-migrant-workers

Eurostat. (2020). *Agri-environmental indicator—Livestock patterns*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agri-environmental_indicator_-_livestock_patterns

Eurostat. (2022). *Glossary:Livestock unit (LSU)*. Eurostat Statistics Explained. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Livestock_unit_(LSU)

Eurostat. (2023). *Farms and farmland in the European Union—Statistics*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Farms_and_farmland_in_the_European_Union_-_statistics

Eurostat. (2024a). *Accidents at work—Statistics by economic activity—Statistics Explained*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Accidents_at_work_-_statistics_by_economic_activity

Eurostat. (2024b). *Performance of the agricultural sector*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Performance_of_the_agricultural_sector

Eurostat. (2024c). *Statistics | Eurostat*. Crop Production in EU Standard Humidity. https://ec.europa.eu/eurostat/databrowser/view/apro_cpsh1/default/table?lang=en

Eurostat. (2024d, July 31). *EU fisheries remained ahead of aquaculture in 2022*. https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20240731-1

Eurostat. (2025a). *Aquaculture statistics*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Aquaculture_statistics

Eurostat. (2025b). *Glossary:Livestock unit (LSU)*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Livestock_unit_(LSU)

FADN Public Database SO. (2024). https://agridata.ec.europa.eu/extensions/FADNPublicDatabase/FADNPublicDatabase.html

Fageria, N. K. (2007). Green Manuring in Crop Production. *Journal of Plant Nutrition*, *30*(5), 691–719. https://doi.org/10.1080/01904160701289529

Fairbairn, M., & Reisman, E. (2024). The incumbent advantage: Corporate power in agri-food tech. *The Journal of Peasant Studies*, *0*(0), 1–24. https://doi.org/10.1080/03066150.2024.2310146

Fang, X., Zhao, J., Wu, S., Yu, K., Huang, J., Ding, Y., Hu, T., Xiao, S., Liu, S., & Zou, J. (2022). A two-year measurement of methane and nitrous oxide emissions from freshwater aquaculture ponds: Affected by aquaculture species, stocking and water management. *The Science of the Total Environment*, *813*, 151863. https://doi.org/10.1016/j.scitotenv.2021.151863

FAO. (2011). *Impact of animal nutrition on animal welfare*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.fao.org/4/i3148e/i3148e00.pdf

FAO. (2022). *The State of World Fisheries and Aquaculture 2022*. FAO. https://openknowledge.fao.org/handle/20.500.14283/cc0461en

FAO. (2024a). *FAOSTAT*. https://www.fao.org/faostat/en/#data

FAO. (2024b). *The State of Food Security and Nutrition in the World*. https://doi.org/10.4060/cd1254en

FAO. (2024c). *The State of World Fisheries and Aquaculture*. Publications. https://doi.org/10.4060/cd0683en

FAO, WHO, UNU, & University, U. N. (2007). *Protein and amino acid requirements in human nutrition: Report of a joint FAO/WHO/UNU expert consultation*. World Health Organization. https://iris.who.int/handle/10665/43411

FAOSTAT. (2024a). https://www.fao.org/faostat/en/#data

FAOSTAT. (2024b). *Stocks—Live animals*. https://www.fao.org/faostat/en/#data/QCL

Fardet, A. (2015). Complex foods versus functional foods, nutraceuticals and dietary supplements: Differential health impact (Part 1). *Agro Food Industry Hi Tech*, *26*.

Fardet, A., & Boirie, Y. (2014). Associations between food and beverage groups and major diet-related chronic diseases: An exhaustive review of pooled/meta-analyses and systematic reviews. *Nutrition Reviews*, *72*(12), 741–762. https://doi.org/10.1111/nure.12153

Farmery, A. K., Gardner, C., Jennings, S., Green, B. S., & Watson, R. A. (2017). Assessing the inclusion of seafood in the sustainable diet literature. *Fish and Fisheries*, *18*(3), 607–618. https://doi.org/10.1111/faf.12205

Farouk, M. M., Al-Mazeedi, H. M., Sabow, A. B., Bekhit, A. E. D., Adeyemi, K. D., Sazili, A. Q., & Ghani, A. (2014). Halal and kosher slaughter methods and meat quality: A review. *Meat Science*, *98*(3), 505–519. https://doi.org/10.1016/j.meatsci.2014.05.021

Farvid, M. S., Cho, E., Chen, W. Y., Eliassen, A. H., & Willett, W. C. (2015). Adolescent meat intake and breast cancer risk. *International Journal of Cancer*, *136*(8), 1909–1920. https://doi.org/10.1002/ijc.29218

Fasani, F., & Mazza, J. (2023). Being on the Frontline? Immigrant Workers in Europe and the COVID-19 Pandemic. *Industrial & Labor Relations Review*, 00197939231173676. https://doi.org/10.1177/00197939231173676

Feindt, P. H. (2010). Policy-Learning and Environmental Policy Integration in the Common Agricultural Policy, 1973–2003. *Public Administration*, *88*(2), 296–314. https://doi.org/10.1111/j.1467-9299.2010.01833.x

Fernqvist, F., Spendrup, S., & Tellström, R. (2024). Understanding food choice: A systematic review of reviews. *Heliyon*, *10*(12). https://doi.org/10.1016/j.heliyon.2024.e32492

Feskens, E. J. M., Sluik, D., & van Woudenbergh, G. J. (2013). Meat consumption, diabetes, and its complications. *Current Diabetes Reports*, *13*(2), 298–306. https://doi.org/10.1007/s11892-013-0365-0

Fielding, R. A., & Parkington, J. (2002). What Are the Dietary Protein Requirements of Physically Active Individuals? New Evidence on the Effects of Exercise on Protein Utilization During Post-Exercise Recovery. *Nutrition in Clinical Care*, *5*(4), 191–196. https://doi.org/10.1046/j.1523-5408.2002.00606.x

Filazzola, A., Brown, C., Dettlaff, M. A., Batbaatar, A., Grenke, J., Bao, T., Peetoom Heida, I., & Cahill, J. F. (2020). The effects of livestock grazing on biodiversity are multi-trophic: A meta-analysis. *Ecology Letters*, *23*(8), 1298–1309. https://doi.org/10.1111/ele.13527

Finnveden, G., & Potting, J. (2014). Life Cycle Assessment. In P. Wexler (Ed.), *Encyclopedia of Toxicology (Third Edition)* (pp. 74–77). Academic Press. https://doi.org/10.1016/B978-0-12-386454-3.00627-8

Fitzgerald, A. (2010). A Social History of the Slaughterhouse: From Inception to Contemporary Implications. *Human Ecology Review*, *17*, 58–69.

Flower, F. C., & Weary, D. M. (2003). The Effects of Early Separation on the Dairy Cow and Calf. *Animal Welfare*, *12*(3), 339–348. https://doi.org/10.1017/S0962728600025847

Fontana, L., Partridge, L., & Longo, V. D. (2010). Extending Healthy Life Span—From Yeast to Humans. *Science*, *328*(5976), 321–326. https://doi.org/10.1126/science.1172539

Food and Feed Information Portal Database | FIP. (n.d.). Retrieved November 21, 2024, from https://ec.europa.eu/food/food-feed-portal/screen/health-claims/eu-register

Foote, N. (2019, November 13). *EFSA suggests ways to avoid mass suffering of unwanted male chicks*. Euractiv. https://www.euractiv.com/section/agriculture-food/news/efsa-suggests-ways-to-avoid-mass-suffering-of-unwanted-male-chicks/

Fraeye, I., Kratka, M., Vandenburgh, H., & Thorrez, L. (2020). Sensorial and Nutritional Aspects of Cultured Meat in Comparison to Traditional Meat: Much to Be Inferred. *Frontiers in Nutrition*, *7*, 35. https://doi.org/10.3389/fnut.2020.00035

Francione, G. L. (2020). *Why Veganism Matters: The Moral Value of Animals*. Columbia University Press. https://doi.org/10.7312/fran19960

Franks, B., Ewell, C., & Jacquet, J. (2021). Animal welfare risks of global aquaculture. *Science Advances*, *7*(14), eabg0677. https://doi.org/10.1126/sciadv.abg0677

Fraser, D. (2008a). Animal Welfare and the Intensification of Animal Production. In P. B. Thompson (Ed.), *The Ethics of Intensification: Agricultural Development and Cultural Change* (pp. 167–189). Springer Netherlands. https://doi.org/10.1007/978-1-4020-8722-6_12

Fraser, D. (2008b). Understanding animal welfare. *Acta Veterinaria Scandinavica*, *50*(1), S1. https://doi.org/10.1186/1751-0147-50-S1-S1

Freidberg, S. (2015). It's Complicated: Corporate Sustainability and the Uneasiness of Life Cycle Assessment. *Science as Culture*, *24*(2), 157–182. https://doi.org/10.1080/09505431.2014.942622

French, S. A., Jeffery, R. W., Story, M., Breitlow, K. K., Baxter, J. S., Hannan, P., & Snyder, M. P. (2001). Pricing and promotion effects on low-fat vending snack purchases: The CHIPS Study. *American Journal of Public Health*, *91*(1), 112–117.

Freund, F., Soisontes, S., Laquai, V., & Banse, M. (2025). Global land-use implications of preference shifts towards regional feed and sustainable diets in Germany and the European Union. *Ecological Economics*, *228*, 108455. https://doi.org/10.1016/j.ecolecon.2024.108455

Friedmann, H. (1993). *The political economy of food: A global crisis*. *197*, 29–57.

Friedrich, M., Schiffer, K., Retz, S., Stehling, C., Seuss-Baum, I., & Hensel, O. (2015). The Effect of On-Farm Slaughter via Gunshot and Conventional Slaughter on Sensory and Objective

Measures of Beef Quality Parameters. *Journal of Food Research; Vol. 4, No. 2; 2015*, *4*. https://doi.org/10.5539/jfr.v4n2p

Fuchs, D., & Kalfagianni, A. (2010). The Causes and Consequences of Private Food Governance. *Business and Politics*, *12*(3), 1–34. https://doi.org/10.2202/1469-3569.1319

Fulton, E. A., Punt, A. E., Dichmont, C. M., Harvey, C. J., & Gorton, R. (2019). Ecosystems say good management pays off. *Fish and Fisheries*, *20*(1), 66–96. https://doi.org/10.1111/faf.12324

Fuseini, A., Miele, M., & Lever, J. (2023). Poultry Welfare at Slaughter. *Poultry*, *2*. https://doi.org/10.3390/poultry2010010

Gałęcki, R., & Sokół, R. (2019). A parasitological evaluation of edible insects and their role in the transmission of parasitic diseases to humans and animals. *PLoS ONE*, *14*(7), e0219303. https://doi.org/10.1371/journal.pone.0219303

Gamborg, C., Röcklinsberg, H., & Gjerris, M. (2018). Sustainable Proteins? Values Related to Insects in Food Systems. In A. Halloran, R. Flore, P. Vantomme, & N. Roos (Eds.), *Edible Insects in Sustainable Food Systems* (pp. 199–211). Springer International Publishing. https://doi.org/10.1007/978-3-319-74011-9_13

Gander, P., van den Berg, M., & Signal, L. (2008). Sleep and sleepiness of fishermen on rotating schedules. *Chronobiology International*, *25*(2), 389–398. https://doi.org/10.1080/07420520802106728

García-Gusano, D., Martín-Gamboa, M., Iribarren, D., & Dufour, J. (2016). Prospective Analysis of Life-Cycle Indicators through Endogenous Integration into a National Power Generation Model. *Resources*, *5*(4), Article 4. https://doi.org/10.3390/resources5040039

Gastaldello, A., Giampieri, F., De Giuseppe, R., Grosso, G., Baroni, L., & Battino, M. (2022). The rise of processed meat alternatives: A narrative review of the manufacturing, composition, nutritional profile and health effects of newer sources of protein, and their place in healthier diets. *Trends in Food Science & Technology*, *127*, 263–271. https://doi.org/10.1016/j.tifs.2022.07.005

Gatto, A., Kuiper, M., & van Meijl, H. (2023). Economic, social and environmental spillovers decrease the benefits of a global dietary shift. *Nature Food*, *4*(6), 496–507. https://doi.org/10.1038/s43016-023-00769-y

Gehring, J., Touvier, M., Baudry, J., Julia, C., Buscail, C., Srour, B., Hercberg, S., Péneau, S., Kesse-Guyot, E., & Allès, B. (2021). Consumption of Ultra-Processed Foods by Pesco-Vegetarians, Vegetarians, and Vegans: Associations with Duration and Age at Diet Initiation. *The Journal of Nutrition*, *151*(1), 120–131. https://doi.org/10.1093/jn/nxaa196

Geibel, I., & Freund, F. (2023). The effects of dietary changes in Europe on greenhouse gas emissions and agricultural incomes in Ireland and Denmark. *Environmental Research Letters*, *18*(12), 124026. https://doi.org/10.1088/1748-9326/ad0681

Gephart, J. A., Henriksson, P. J. G., Parker, R. W. R., Shepon, A., Gorospe, K. D., Bergman, K., Eshel, G., Golden, C. D., Halpern, B. S., Hornborg, S., Jonell, M., Metian, M., Mifflin, K., Newton, R., Tyedmers, P., Zhang, W., Ziegler, F., & Troell, M. (2021). Environmental performance of blue foods. *Nature*, *597*(7876), 360–365. https://doi.org/10.1038/s41586-021-03889-2

Gerber, P. J., Hristov, A. N., Henderson, B., Makkar, H., Oh, J., Lee, C., Meinen, R., Montes, F., Ott, T., Firkins, J., Rotz, A., Dell, C., Adesogan, A. T., Yang, W. Z., Tricarico, J. M., Kebreab, E., Waghorn, G., Dijkstra, J., & Oosting, S. (2013). Technical options for the mitigation of direct methane and nitrous oxide emissions from livestock: A review. *Animal*, *7*(s2), 220–234. https://doi.org/10.1017/S1751731113000876

Gerber, P. J., Uwizeye, A., Schulte, R., Opio, C., & de Boer, I. (2014). Nutrient use efficiency: A valuable approach to benchmark the sustainability of nutrient use in global livestock production? *Current Opinion in Environmental Sustainability*, *9–10*, 122–130. https://doi.org/10.1016/j.cosust.2014.09.007

Gheewala, S. H., Jungbluth, N., Notarnicola, B., Ridoutt, B., & van der Werf, H. (2020). No simple menu for sustainable food production and consumption. *The International Journal of Life Cycle Assessment*, *25*(7), 1175–1182. https://doi.org/10.1007/s11367-020-01783-z

Gil, M., Rudy, M., Duma-Kocan, P., Stanisławczyk, R., Krajewska, A., Dziki, D., & Hassoon, W. H. (2024). Sustainability of Alternatives to Animal Protein Sources, a Comprehensive Review. *Sustainability*, *16*(17), Article 17. https://doi.org/10.3390/su16177701

Gille, D., & Schmid, A. (2015). Vitamin B12 in meat and dairy products. *Nutrition Reviews*, *73*(2), 106–115. https://doi.org/10.1093/nutrit/nuu011

GLEAM v3. (2023). *Tableau de bord | Global Livestock Environmental Assessment Model (GLEAM) | Organisation des Nations Unies pour l'alimentation et l'agriculture*. https://www.fao.org/gleam/dashboard/fr/

Godfray, H. C. J., Aveyard, P., Garnett, T., Hall, J., Key, T., Lorimer, J., Pierrehumbert, R., Scarborough, P., Springmann, M., & Jebb, S. (2018). Meat consumption, health, and the environment. *Science*, *361*(6399), eaam5324. https://doi.org/10.1126/science.aam5324

Golden, C. D., Koehn, J. Z., Shepon, A., Passarelli, S., Free, C. M., Viana, D. F., Matthey, H., Eurich, J. G., Gephart, J. A., Fluet-Chouinard, E., Nyboer, E. A., Lynch, A. J., Kjellevold, M., Bromage, S., Charlebois, P., Barange, M., Vannuccini, S., Cao, L., Kleisner, K. M., … Thilsted, S. H. (2021). Aquatic foods to nourish nations. *Nature*, *598*(7880), 315–320. https://doi.org/10.1038/s41586-021-03917-1

Good Food Institute. (2021, March 18). *Record $3.1 billion invested in alt proteins in 2020 signals growing market momentum for sustainable proteins*. https://gfi.org/blog/2020-state-of-the-industry-highlights/

Good Food Institute. (2022, July 12). *Defining alternative proteins | GFI*. https://gfi.org/defining-alternative-protein/

Good Food Institute. (2023a). *Italy ban on cultivated meat cuts itself off from innovation and blocks sustainable development—GFI Europe*. https://gfieurope.org/blog/italy-ban-on-cultivated-meat-cuts-itself-off-from-innovation-and-blocks-sustainable-development/

Good Food Institute. (2023b, February 16). *Investment in sustainable protein up 24% in Europe for 2022 despite global economic turbulence*. https://gfieurope.org/blog/2022-sustainable-protein-investment/

Good Food Institute. (2024a). *Investment resources (2024) | Alternative protein startups | GFI*. https://gfi.org/investment/

Good Food Institute. (2024b, July 2). *European consumer insights on the alternative protein sector—GFI Europe*. https://gfieurope.org/industry/european-consumer-insights-on-the-alternative-protein-sector/

Good Food Institute. (2024c, August 5). *European investment figures point to an evolving alternative protein sector—GFI Europe*. https://gfieurope.org/blog/european-investment-figures-point-to-an-evolving-alternative-protein-sector/

Gorton, M., Yeh, C.-H., Chatzopoulou, E., White, J., Tocco, B., Hubbard, C., & Hallam, F. (2023). Consumers' willingness to pay for an animal welfare food label. *Ecological Economics*, *209*, 107852. https://doi.org/10.1016/j.ecolecon.2023.107852

Gosby, A. K., Conigrave, A. D., Lau, N. S., Iglesias, M. A., Hall, R. M., Jebb, S. A., Brand-Miller, J., Caterson, I. D., Raubenheimer, D., & Simpson, S. J. (2011). Testing protein leverage in lean humans: A randomised controlled experimental study. *PloS One*, *6*(10), e25929. https://doi.org/10.1371/journal.pone.0025929

Gosby, A. K., Conigrave, A. D., Raubenheimer, D., & Simpson, S. J. (2014). Protein leverage and energy intake. *Obesity Reviews: An Official Journal of the International Association for the Study of Obesity*, *15*(3), 183–191. https://doi.org/10.1111/obr.12131

Gouel, C., & Guimbard, H. (2019). Nutrition Transition and the Structure of Global Food Demand. *American Journal of Agricultural Economics*, *101*(2), 383–403. https://doi.org/10.1093/ajae/aay030

Govzman, S., Looby, S., Wang, X., Butler, F., Gibney, E. R., & Timon, C. M. (2021). A systematic review of the determinants of seafood consumption. *The British Journal of Nutrition*, *126*(1), 66–80. https://doi.org/10.1017/S0007114520003773

Graça, J., Campos, L., Guedes, D., Roque, L., Brazão, V., Truninger, M., & Godinho, C. (2023). How to enable healthier and more sustainable food practices in collective meal contexts: A scoping review. *Appetite*, *187*, 106597. https://doi.org/10.1016/j.appet.2023.106597

Graça, J., Godinho, C. A., & Truninger, M. (2019). Reducing meat consumption and following plant-based diets: Current evidence and future directions to inform integrated transitions. *Trends in Food Science & Technology*, *91*, 380–390. https://doi.org/10.1016/j.tifs.2019.07.046

Graça, J., Truninger, M., Junqueira, L., & Schmidt, L. (2019). Consumption orientations may support (or hinder) transitions to more plant-based diets. *Appetite*, *140*, 19–26. https://doi.org/10.1016/j.appet.2019.04.027

Grandin, T. (2010). Auditing animal welfare at slaughter plants. *Meat Science*, *86*(1), 56–65. https://doi.org/10.1016/j.meatsci.2010.04.022

Gregory, N. G., Fielding, H. R., von Wenzlawowicz, M., & von Holleben, K. (2010). Time to collapse following slaughter without stunning in cattle. *Meat Science*, *85*(1), 66–69. https://doi.org/10.1016/j.meatsci.2009.12.005

Grundy, E. A. C., Slattery, P., Saeri, A. K., Watkins, K., Houlden, T., Farr, N., Askin, H., Lee, J., Mintoft-Jones, A., Cyna, S., Dziegielewski, A., Gelber, R., Rowe, A., Mathur, M. B., Timmons, S., Zhao, K., Wilks, M., Peacock, J. R., Harris, J., … Zorker, M. (2022). Interventions that influence animal-product consumption: A meta-review. *Future Foods*, *5*, 100111. https://doi.org/10.1016/j.fufo.2021.100111

Gu, B. (2022). Recoupling livestock and crops. *Nature Food*, *3*(2), Article 2. https://doi.org/10.1038/s43016-022-00466-2

Guarnido-López, P., Resconi, V. C., Campo, M. del M., Guerrero, A., María, G. A., & Olleta, J. L. (2022). Slaughtering of heifers in a local or an industrial abattoir: Animal welfare and meat quality consequences. *Livestock Science*, *259*, 104904. https://doi.org/10.1016/j.livsci.2022.104904

Gudding, R., & Van Muiswinkel, W. B. (2013). A history of fish vaccination: Science-based disease prevention in aquaculture. *Fish & Shellfish Immunology*, *35*(6), 1683–1688. https://doi.org/10.1016/j.fsi.2013.09.031

Guillin, F. M., Gaudichon, C., Guérin-Deremaux, L., Lefranc-Millot, C., Azzout-Marniche, D., Khodorova, N., & Calvez, J. (2021). Multi-criteria assessment of pea protein quality in rats: A comparison between casein, gluten and pea protein alone or supplemented with methionine. *British Journal of Nutrition*, *125*(4), 389–397. https://doi.org/10.1017/S0007114520002883

Guo, K., Yang, J., Yu, N., Luo, L., & Wang, E. (2022). Biological nitrogen fixation in cereal crops: Progress, strategies, and perspectives. *Plant Communications*, *4*(2), 100499. https://doi.org/10.1016/j.xplc.2022.100499

Guthman, J., & Biltekoff, C. (2021). Magical disruption? Alternative protein and the promise of de-materialization. *Environment and Planning E: Nature and Space*, *4*(4), 1583–1600. https://doi.org/10.1177/2514848620963125

Guthman, J., & Biltekoff, C. (2023). Agri-food tech's building block: Narrating protein, agnostic of source, in the face of crisis. *BioSocieties*, *18*(3), 656–678. https://doi.org/10.1057/s41292-022-00287-3

Guthman, J., Butler, M., Martin, S. J., Mather, C., & Biltekoff, C. (2022). In the name of protein. *Nature Food*, 1–3. https://doi.org/10.1038/s43016-022-00532-9

Guyomard, H., Bouamra-Mechemache, Z., Chatellier, V., Delaby, L., Détang-Dessendre, C., Peyraud, J.-L., & Réquillart, V. (2021). Review: Why and how to regulate animal production and consumption: The case of the European Union. *Animal*, *15*, 100283. https://doi.org/10.1016/j.animal.2021.100283

Gwenzi, W., Chaukura, N., Muisa-Zikali, N., Teta, C., Musvuugwa, T., Rzymski, P., & Abia, A. L. K. (2021). Insects, Rodents, and Pets as Reservoirs, Vectors, and Sentinels of Antimicrobial Resistance. *Antibiotics*, *10*(1), 68. https://doi.org/10.3390/antibiotics10010068

Hagen, B. N. M., Albright, A., Sargeant, J., Winder, C. B., Harper, S. L., O'Sullivan, T. L., & Jones-Bitton, A. (2019). Research trends in farmers' mental health: A scoping review of mental health outcomes and interventions among farming populations worldwide. *PLOS ONE*, *14*(12), e0225661. https://doi.org/10.1371/journal.pone.0225661

Hagevoort, G. R., Douphrate ,David I., & and Reynolds, S. J. (2013). A Review of Health and Safety Leadership and Managerial Practices on Modern Dairy Farms. *Journal of Agromedicine*, *18*(3), 265–273. https://doi.org/10.1080/1059924X.2013.796905

Hald-Mortensen, C. (2023). *The Main Drivers of Biodiversity Loss: A Brief Overview* (SSRN Scholarly Paper No. 4579821). Social Science Research Network. https://papers.ssrn.com/abstract=4579821

Halkjaer, J., Olsen, A., Bjerregaard, L. J., Deharveng, G., Tjønneland, A., Welch, A. A., Crowe, F. L., Wirfält, E., Hellstrom, V., Niravong, M., Touvier, M., Linseisen, J., Steffen, A., Ocké, M. C., Peeters, P. H. M., Chirlaque, M. D., Larrañaga, N., Ferrari, P., Contiero, P., … Bingham, S. (2009). Intake of total, animal and plant proteins, and their food sources in 10 countries in the European Prospective Investigation into Cancer and Nutrition. *European Journal of Clinical Nutrition*, *63 Suppl 4*, S16-36. https://doi.org/10.1038/ejcn.2009.73

Händel, M. N., Rohde, J. F., Jacobsen, R., & Heitmann, B. L. (2021). Processed Meat Consumption and the Risk of Cancer: A Critical Evaluation of the Constraints of Current Evidence from Epidemiological Studies. *Nutrients*, *13*(10), 3601. https://doi.org/10.3390/nu13103601

Harfeld, J. L., Cornou, C., Kornum, A., & Gjerris, M. (2016). Seeing the Animal: On the Ethical Implications of De-animalization in Intensive Animal Production Systems. *Journal of Agricultural and Environmental Ethics*, *29*(3), 407–423. https://doi.org/10.1007/s10806-016-9611-1

Harris, F., Moss, C., Joy, E. J. M., Quinn, R., Scheelbeek, P. F. D., Dangour, A. D., & Green, R. (2020). The Water Footprint of Diets: A Global Systematic Review and Meta-analysis. *Advances in Nutrition*, *11*(2), 375–386. https://doi.org/10.1093/advances/nmz091

Hashem, N. M., González-Bulnes, A., & Rodriguez-Morales, A. J. (2020). Animal Welfare and Livestock Supply Chain Sustainability Under the COVID-19 Outbreak: An Overview. *Frontiers in Veterinary Science*, *7*. https://doi.org/10.3389/fvets.2020.582528

Hassanein, N. (2008). Locating Food Democracy: Theoretical and Practical Ingredients. *Journal of Hunger & Environmental Nutrition*, *3*(2–3), 286–308. https://doi.org/10.1080/19320240802244215

Hattersley, L., Thiebaud, A., Silver, L. D., & Mandeville, K. (2020). *Taxes on Sugar-Sweetened Beverages - Summary of International Evidence and Experiences (Vol. 1 of 2): International Evidence and Experiences* [Text/HTML]. World Bank. https://documents.banquemondiale.org/fr/publication/documents-reports/documentdetail/en/456591592449998717

Hayes, M. (2023). Challenges Regarding Protein Provision for the Growing Global Population: Improving the Environmental Impact of Traditional Protein Supply Chains and Maximising use of Coproducts and Alternative, New Resources. *Global Challenges*, *7*(5), 2300059. https://doi.org/10.1002/gch2.202300059

Hebert, J. R., Clemow, L., Pbert, L., Ockene, I. S., & Ockene, J. K. (1995). Social desirability bias in dietary self-report may compromise the validity of dietary intake measures. *International Journal of Epidemiology*, *24*(2), 389–398. https://doi.org/10.1093/ije/24.2.389

Hedberg, R. C. (2023). Bad animals, techno-fixes, and the environmental narratives of alternative protein. *Frontiers in Sustainable Food Systems*, *7*. https://www.frontiersin.org/articles/10.3389/fsufs.2023.1160458

Heinola, K., Kauppinen, T., Niemi, J. K., Wallenius, E., & Raussi, S. (2021). Comparison of 12 Different Animal Welfare Labeling Schemes in the Pig Sector. *Animals*, *11*(8), Article 8. https://doi.org/10.3390/ani11082430

Hellberg, R. S., DeWitt, C. A. M., & Morrissey, M. T. (2012). Risk-Benefit Analysis of Seafood Consumption: A Review. *Comprehensive Reviews in Food Science and Food Safety*, *11*(5), 490–517. https://doi.org/10.1111/j.1541-4337.2012.00200.x

Henderson, B. B., Gerber, P. J., Hilinski, T. E., Falcucci, A., Ojima, D. S., Salvatore, M., & Conant, R. T. (2015). Greenhouse gas mitigation potential of the world's grazing lands: Modeling soil carbon and nitrogen fluxes of mitigation practices. *Agriculture, Ecosystems & Environment*, *207*, 91–100. https://doi.org/10.1016/j.agee.2015.03.029

Henderson, B., & Verma, M. (2021). *Global assessment of the carbon leakage implications of carbon taxes on agricultural emissions*. OECD. https://doi.org/10.1787/fc304fad-en

Hendrickson, M., Howard, P. H., & Constance, D. (2017). *Power, Food and Agriculture: Implications for Farmers, Consumers and Communities* (SSRN Scholarly Paper No. 3066005). Social Science Research Network. https://doi.org/10.2139/ssrn.3066005

Hengeveld, L. M., Boer, J. M. A., Gaudreau, P., Harris, T. B., Jagger, C., Mendonça, N., Ocké, M. C., Presse, N., Sette, S., Tapanainen, H., Turrini, A., Virtanen, S. M., Wijnhoven, H. a. H., & Visser, M. (2018). Prevalence of low protein intake in older persons: A multi-cohort approach. *Clinical Nutrition*, *37,* S24. https://doi.org/10.1016/j.clnu.2018.06.2099

Henn, K., Goddyn, H., Olsen, S. B., & Bredie, W. L. P. (2022). Identifying behavioral and attitudinal barriers and drivers to promote consumption of pulses: A quantitative survey across five European countries. *Food Quality and Preference*, *98*, 104455. https://doi.org/10.1016/j.foodqual.2021.104455

Hennessy, D. P., Shalloo, L., Zanten, H. H. E., Schop, M., & Boer, I. J. M. D. (2021). The net contribution of livestock to the supply of human edible protein: The case of Ireland. *The Journal of Agricultural Science*, 1–9. https://doi.org/10.1017/S0021859621000642

Henriksson, P. JG., Cucurachi, S., Guinée, J. B., Heijungs, R., Troell, M., & Ziegler, F. (2021). A rapid review of meta-analyses and systematic reviews of environmental footprints of food commodities and diets. *Global Food Security*, *28*, 100508. https://doi.org/10.1016/j.gfs.2021.100508

Herforth, A., Arimond, M., Álvarez-Sánchez, C., Coates, J., Christianson, K., & Muehlhoff, E. (2019). A Global Review of Food-Based Dietary Guidelines. *Advances in Nutrition*, *10*(4), 590–605. https://doi.org/10.1093/advances/nmy130

Hermann, M. (2009). The impact of the European Novel Food Regulation on trade and food innovation based on traditional plant foods from developing countries. *Food Policy*, *34*, 499–507. https://doi.org/10.1016/j.foodpol.2009.08.005

Hernandez-Mendo, O., von Keyserlingk, M. A. G., Veira, D. M., & Weary, D. M. (2007). Effects of Pasture on Lameness in Dairy Cows. *Journal of Dairy Science*, *90*(3), 1209–1214. https://doi.org/10.3168/jds.S0022-0302(07)71608-9

Herzon, I., Raatikainen, K., Wehn, S., Rūsiņa, S., Helm, A., Cousins, S., & Rašomavičius, V. (2021). Semi-natural habitats in boreal Europe: A rise of a social-ecological research agenda. *Ecology and Society*, *26*(2). https://doi.org/10.5751/ES-12313-260213

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. https://doi.org/10.1016/S2214-109X(19)30447-4

HLPE-FSN. (2019). *Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition* (No. 14). https://openknowledge.fao.org/home

Hoffman, J. R., & Falvo, M. J. (2004). Protein – Which is Best? *Journal of Sports Science & Medicine*, *3*(3), 118.

Hohoff, E., Zahn, H., Weder, S., Fischer, M., Längler, A., Michalsen, A., Keller, M., & Alexy, U. (2022). Food Costs of Children and Adolescents Consuming Vegetarian, Vegan or Omnivore Diets: Results of the Cross-Sectional VeChi Youth Study. *Nutrients*, *14*(19), Article 19. https://doi.org/10.3390/nu14194010

Holen, S., & Holmen, I. M. (2025). Occupational Injuries and Fatalities in Norwegian Fish Farming. *Journal of Agromedicine*. https://www.tandfonline.com/doi/abs/10.1080/1059924X.2025.2453060

Holland, C., Ryden, P., Edwards, C. H., & Grundy, M. M.-L. (2020). Plant Cell Walls: Impact on Nutrient Bioaccessibility and Digestibility. *Foods*, *9*(2), Article 2. https://doi.org/10.3390/foods9020201

Howard, P. H. (2022). Cellular agriculture will reinforce power asymmetries in food systems. *Nature Food*, *3*(10), 798–800. https://doi.org/10.1038/s43016-022-00609-5

Howard, P. H., Ajena, F., Yamaoka, M., & Clarke, A. (2021). "Protein" Industry Convergence and Its Implications for Resilient and Equitable Food Systems. *Frontiers in Sustainable Food Systems*, *5*, 284. https://doi.org/10.3389/fsufs.2021.684181

Hu, Z., Lee, J. W., Chandran, K., Kim, S., & Khanal, S. K. (2012). Nitrous Oxide (N2O) Emission from Aquaculture: A Review. *Environmental Science & Technology*, *46*(12), 6470–6480. https://doi.org/10.1021/es300110x

Hultgren, J., Schiffer, K. J., Babol, J., & Berg, C. (2022). Animal Welfare and Food Safety When Slaughtering Cattle Using the Gunshot Method. *Animals*, *12*(4), Article 4. https://doi.org/10.3390/ani12040492

Hundscheid, L., Voigt, C., Bergthaler, D., Plank, C., Wurzinger, M., & Melcher, A. H. (2024). Policy mix for the sustainable protein transition in Austria—Addressing repercussions of regime shifts as a prerequisite for acceleration. *Environmental Innovation and Societal Transitions*, *51*, 100819. https://doi.org/10.1016/j.eist.2024.100819

IEEP. (2022). Just transition in the EU agriculture and land use sector. *IEEP AISBL*. https://ieep.eu/publications/just-transition-in-the-eu-agriculture-and-land-use-sector/

ILVO. (2024). *Methane from ruminants and climate impact: A difference between GWP and GWP star calculation - ILVO Vlaanderen*. ILVO (English). https://ilvo.vlaanderen.be/en/news/methane-from-ruminants-and-climate-impact-a-difference-between-gwp-and-gwp-star-calculation

IPBES. (2018). *The IPBES assessment report on land degradation and restoration*. Zenodo. https://doi.org/10.5281/zenodo.3237393

iPES Food. (2023). *Who's tipping the scales? The growing influence of corporations on the governance of food systems, and how to counter it*. https://www. ipes-food.org/_img/upload/files/tippingthescales.pdf

Isbrandt, R., Wiegard, M., Meemken, D., & Langkabel, N. (2022). Impact of Procedures and Human-Animal Interactions during Transport and Slaughter on Animal Welfare of Pigs: A Systematic Literature Review. *Animals*, *12*(23), Article 23. https://doi.org/10.3390/ani12233391

Ivanovich, C. C., Sun, T., Gordon, D. R., & Ocko, I. B. (2023). Future warming from global food consumption. *Nature Climate Change*, *13*(3), 297–302. https://doi.org/10.1038/s41558-023-01605-8

Jackson, P., Candel, J., Davies, A., de Vries, H., Derani, C., Dragović-Uzelac, V., Hoel, A. H., Holm, L., Morone, P., Penker, M., Guadalupe Rivera-Ferre, M., Śpiewak, R., Termeer, K., Thøgersen, J., & Mathijs, E. (2020). *A Sustainable Food System for the European Union*. SAPEA.

Jahn, S., Furchheim, P., & Strässner, A.-M. (2021). Plant-Based Meat Alternatives: Motivational Adoption Barriers and Solutions. *Sustainability*, *13*(23), Article 23. https://doi.org/10.3390/su132313271

Jakob, M. C., Santa, D., Holte, K. A., Sikkeland, I. J., Hilt, B., & Lundqvist, P. (2021). Occupational health and safety in agriculture – a brief report on organization, legislation and support in selected European countries. *Annals of Agricultural and Environmental Medicine*, *28*(3), 452–457. https://doi.org/10.26444/aaem/140197

Jallinoja, P., Niva, M., & Latvala, T. (2016). Future of sustainable eating? Examining the potential for expanding bean eating in a meat-eating culture. *Futures*, *83*, 4–14. https://doi.org/10.1016/j.futures.2016.03.006

Jangir, C. K., Thakur, A., Bijani, H., Thakur, P., Kumar, S., Meena, R. S., Bedwal, S., Rani, K., Shukla, U. N., Meena, A. K., & Dev, P. (2022). Chapter 7—Residual nitrogen for succeeding crops in legume-based cropping system. In R. S. Meena & S. Kumar (Eds.), *Advances in Legumes for Sustainable Intensification* (pp. 113–132). Academic Press. https://doi.org/10.1016/B978-0-323-85797-0.00024-0

Janin, P., Fofiri Nzossié, E.-J., & Racaud, S. (2023). Governance challenges for sustainable food systems: The return of politics and territories. *Current Opinion in Environmental Sustainability*, *65*, 101382. https://doi.org/10.1016/j.cosust.2023.101382

Jansson, T., Nordin, I., Wilhelmsson, F., Witzke, P., Manevska-Tasevska, G., Weiss, F., & Gocht, A. (2021). Coupled Agricultural Subsidies in the EU Undermine Climate Efforts. *Applied Economic Perspectives and Policy*, *43*(4), 1503–1519. Scopus. https://doi.org/10.1002/aepp.13092

Järviö, N., Maljanen, N.-L., Kobayashi, Y., Ryynänen, T., & Tuomisto, H. L. (2021). An attributional life cycle assessment of microbial protein production: A case study on using hydrogen-oxidizing bacteria. *Science of The Total Environment*, *776*, 145764. https://doi.org/10.1016/j.scitotenv.2021.145764

Jaureguiberry, P., Titeux, N., Wiemers, M., Bowler, D. E., Coscieme, L., Golden, A. S., Guerra, C. A., Jacob, U., Takahashi, Y., Settele, J., Díaz, S., Molnár, Z., & Purvis, A. (2022). The direct drivers of recent global anthropogenic biodiversity loss. *Science Advances*, *8*(45), eabm9982. https://doi.org/10.1126/sciadv.abm9982

Jayedi, A., & Shab-Bidar, S. (2020). Fish Consumption and the Risk of Chronic Disease: An Umbrella Review of Meta-Analyses of Prospective Cohort Studies. *Advances in Nutrition*, *11*(5), 1123–1133. https://doi.org/10.1093/advances/nmaa029

Jensen, O. C. C., Petursdottir, G., Holmen, I. M., Abrahamsen, A., & Lincoln, J. (2014). A review of fatal accident incidence rate trends in fishing. *International Maritime Health*, *65*(2), 47–52. https://doi.org/10.5603/IMH.2014.0011

Johnston, B., De Smet, S., Leroy, F., Mente, A., & Stanton, A. (2023). Non-communicable disease risk associated with red and processed meat consumption—Magnitude, certainty, and contextuality of risk? *Animal Frontiers*, *13*(2), 19–27. https://doi.org/10.1093/af/vfac095

Jordon, M. W., Buffet, J.-C., Dungait, J. A. J., Galdos, M. V., Garnett, T., Lee, M. R. F., Lynch, J., Röös, E., Searchinger, T. D., Smith, P., & Godfray, H. C. J. (2024). A restatement of the natural science evidence base concerning grassland management, grazing livestock and soil carbon storage. *Proceedings of the Royal Society B: Biological Sciences*, *291*(2015), 20232669. https://doi.org/10.1098/rspb.2023.2669

JRC. (2024). *Scientific, Technical and Economic Committee for Fisheries (STECF)—The 2024 Annual Economic Report on the EU Fishing Fleet (STECF 24-03 & 24-07)*. JRC Publications Repository. https://doi.org/10.2760/5037826

JRC, Scientific, Technical and Economic Committee for Fisheries (European Commission), Guillen, J., Virtanen, J., & Nielsen, R. (2023). *Economic report on the EU aquaculture (STECF-22-17)*. Publications Office of the European Union. https://data.europa.eu/doi/10.2760/51391

Kamenik, J., Paral, V., Pyszko, M., & Voslarova, E. (2019). Cattle stunning with a penetrative captive bolt device: A review. *Animal Science Journal*, *90*(3), 307–316. https://doi.org/10.1111/asj.13168

Karlsson, J., Parodi, A., Zanten, H., Hansson, P.-A., & Röös, E. (2021). Halting European Union soybean feed imports favours ruminants over pigs and poultry. *Nature Food*, *2*, 1–9. https://doi.org/10.1038/s43016-020-00203-7

Karlsson Potter, H., Lundmark, L., & Röös, E. (2020). Environmental impact of plant-based foods – data collection for the development of a consumer guide for plant-based foods. *Rapport (Institutionen För Energi Och Teknik, SLU)*, *112*. https://res.slu.se/id/publ/107935

Kårlund, A., Gómez-Gallego, C., Turpeinen, A. M., Palo-oja, O.-M., El-Nezami, H., & Kolehmainen, M. (2019). Protein Supplements and Their Relation with Nutrition, Microbiota Composition and Health: Is More Protein Always Better for Sportspeople? *Nutrients*, *11*(4), Article 4. https://doi.org/10.3390/nu11040829

Katz-Rosene, R., Heffernan, A., & Arora, A. (2023). Protein pluralism and food systems transition: A review of sustainable protein meta-narratives. *World Development*, *161*, 106121. https://doi.org/10.1016/j.worlddev.2022.106121

Kennedy, A. J., Maple, M. J., McKay, K., & Brumby, S. A. (2014). Suicide and accidental death in Australia's rural farming communities: A review of the literature. *Rural and Remote Health*, *14*(1), 2517.

Kestin, S. C., Gordon, S., Su, G., & Sørensen, P. (2001). Relationships in broiler chickens between lameness, liveweight, growth rate and age. *Veterinary Record*, *148*(7), 195–197. https://doi.org/10.1136/vr.148.7.195

Key, T. J., Appleby, P. N., Crowe, F. L., Bradbury, K. E., Schmidt, J. A., & Travis, R. C. (2014). Cancer in British vegetarians: Updated analyses of 4998 incident cancers in a cohort of 32,491 meat eaters, 8612 fish eaters, 18,298 vegetarians, and 2246 vegans1234. *The American Journal of Clinical Nutrition*, *100*, 378S-385S. https://doi.org/10.3945/ajcn.113.071266

Keyzer, W. D., Caneghem, S. V., Heath, A.-L. M., Vanaelst, B., Verschraegen, M., Henauw, S. D., & Huybrechts, I. (2012). Nutritional quality and acceptability of a weekly vegetarian lunch in primary-school canteens in Ghent, Belgium: 'Thursday Veggie Day.' *Public Health Nutrition*, *15*(12), 2326–2330. https://doi.org/10.1017/S1368980012000870

Khan, K. M., Baidya, R., Aryal, A., Farmer, J. R., & Valliant, J. (2018). Neurological and mental health outcomes among conventional and organic farmers in Indiana, USA. *Annals of Agricultural and Environmental Medicine: AAEM*, *25*(2), 244–249. https://doi.org/10.26444/aaem/75113

King, T. J., Turner, R., Versace, V., Abernethy, K., Kilpatrick, S., & Brumby, S. (2021). Mental health in the commercial fishing industry: Modern uncertainties and traditional risks. *Fish and Fisheries*, *22*(5), 1136–1149. https://doi.org/10.1111/faf.12572

Kitada, M., Ogura, Y., Monno, I., & Koya, D. (2019). The impact of dietary protein intake on longevity and metabolic health. *eBioMedicine*, *43*, 632–640. https://doi.org/10.1016/j.ebiom.2019.04.005

Klapp, A.-L., Feil, N., & Risius, A. (2022). A Global Analysis of National Dietary Guidelines on Plant-Based Diets and Substitutions for Animal-Based Foods. *Current Developments in Nutrition*, *6*(11), nzac144. https://doi.org/10.1093/cdn/nzac144

Klingelschmidt, J., Milner, A., Khireddine-Medouni, I., Witt, K., Alexopoulos, E. C., Toivanen, S., LaMontagne, A. D., Chastang, J.-F., & Niedhammer, I. (2018). Suicide among agricultural, forestry, and fishery workers: A systematic literature review and meta-analysis. *Scandinavian Journal of Work, Environment & Health*, *44*(1), 3–15. https://doi.org/10.5271/sjweh.3682

Ko, H.-L., Temple, D., Hales, J., Manteca, X., & Llonch, P. (2022). Welfare and Performance of Post-Weaning Sows and Piglets Previously Housed in Farrowing Pens with Temporary Crating on a Spanish Commercial Farm: A Pilot Study. *Animals : An Open Access Journal from MDPI*, *12*(6), 724. https://doi.org/10.3390/ani12060724

Koehn, J. Z., Allison, E. H., Golden, C. D., & Hilborn, R. (2022). The role of seafood in sustainable diets. *Environmental Research Letters*, *17*(3), 035003. https://doi.org/10.1088/1748-9326/ac3954

Koole, B. (2022). Veganism and plant-based protein crops: Contentious visioning almost obstructing a transition. *Environmental Innovation and Societal Transitions*, *42*, 88–98. https://doi.org/10.1016/j.eist.2021.12.003

Kouimintzis, D., Chatzis, C., & Linos, A. (2007). Health effects of livestock farming in Europe. *Journal of Public Health*, *15*(4), 245–254. https://doi.org/10.1007/s10389-007-0130-4

Kozicka, M., Havlík, P., Valin, H., Wollenberg, E., Deppermann, A., Leclère, D., Lauri, P., Moses, R., Boere, E., Frank, S., Davis, C., Park, E., & Gurwick, N. (2023). Feeding climate and biodiversity goals with novel plant-based meat and milk alternatives. *Nature Communications*, *14*(1), Article 1. https://doi.org/10.1038/s41467-023-40899-2

Kristensen, N. B., Madsen, M. L., Hansen, T. H., Allin, K. H., Hoppe, C., Fagt, S., Lausten, M. S., Gøbel, R. J., Vestergaard, H., Hansen, T., & Pedersen, O. (2015). Intake of macro- and micronutrients in Danish vegans. *Nutrition Journal*, *14*(1), 115. https://doi.org/10.1186/s12937-015-0103-3

Krystallis, A., de Barcellos, M. D., Kügler, J. O., Verbeke, W., & Grunert, K. G. (2009). Attitudes of European citizens towards pig production systems. *Livestock Science*, *126*(1), 46–56. https://doi.org/10.1016/j.livsci.2009.05.016

Kunutsor, S. K., Apekey, T. A., Walley, J., & Kain, K. (2013). Ferritin levels and risk of type 2 diabetes mellitus: An updated systematic review and meta-analysis of prospective evidence. *Diabetes/Metabolism Research and Reviews*, *29*(4), 308–318. https://doi.org/10.1002/dmrr.2394

Kuruc, K., & McFadden, J. (2023). Animal welfare in economic analyses of food production. *Nature Food*, 1–2. https://doi.org/10.1038/s43016-023-00759-0

Kwasny, T., Dobernig, K., & Riefler, P. (2022). Towards reduced meat consumption: A systematic literature review of intervention effectiveness, 2001–2019. *Appetite*, *168*, 105739. https://doi.org/10.1016/j.appet.2021.105739

Kyttä, V., Hyvönen, T., & Saarinen, M. (2023). Land-use-driven biodiversity impacts of diets—A comparison of two assessment methods in a Finnish case study. *The International Journal of Life Cycle Assessment*, *28*(9), 1104–1116. https://doi.org/10.1007/s11367-023-02201-w

Laestadius, L. I. (2015). Public Perceptions of the Ethics of In-vitro Meat: Determining an Appropriate Course of Action. *Journal of Agricultural and Environmental Ethics*, *28*(5), 991–1009. https://doi.org/10.1007/s10806-015-9573-8

Lähteenmäki-Uutela, A., Rahikainen, M., Lonkila, A., & Yang, B. (2021). Alternative proteins and EU food law. *Food Control*, *130*, 108336. https://doi.org/10.1016/j.foodcont.2021.108336

Lambooij, E. (2024). Animal Stress and Welfare During Transport and Slaughtering: An Outline for Future Policies. *Animals*, *14*(21), Article 21. https://doi.org/10.3390/ani14213064

Lanzoni, L., Whatford, L., Atzori, A. S., Chincarini, M., Giammarco, M., Fusaro, I., & Vignola, G. (2023). Review: The challenge to integrate animal welfare indicators into the Life Cycle Assessment. *Animal*, *17*(5), 100794. https://doi.org/10.1016/j.animal.2023.100794

Laratte, B., Guillaume, B., Kim, J., & Birregah, B. (2014). Modeling cumulative effects in life cycle assessment: The case of fertilizer in wheat production contributing to the global warming potential. *Science of The Total Environment*, *481*, 588–595. https://doi.org/10.1016/j.scitotenv.2014.02.020

Larson, N., & Story, M. (2009). A Review of Environmental Influences on Food Choices. *Annals of Behavioral Medicine*, *38*(suppl_1), s56–s73. https://doi.org/10.1007/s12160-009-9120-9

Lassaletta, L., Billen, G., Garnier, J., Bouwman, L., Velazquez, E., Mueller, N. D., & Gerber, J. S. (2016). Nitrogen use in the global food system: Past trends and future trajectories of agronomic performance, pollution, trade, and dietary demand. *Environmental Research Letters*, *11*(9), 095007. https://doi.org/10.1088/1748-9326/11/9/095007

Lassaletta, L., Billen, G., Romero, E., Garnier, J., & Aguilera, E. (2014). How changes in diet and trade patterns have shaped the N cycle at the national scale: Spain (1961–2009). *Regional Environmental Change*, *14*(2), 785–797. https://doi.org/10.1007/s10113-013-0536-1

Latunde-Dada, G. O., Yang, W., & Vera Aviles, M. (2016). In Vitro Iron Availability from Insects and Sirloin Beef. *Journal of Agricultural and Food Chemistry*, *64*(44), 8420–8424. https://doi.org/10.1021/acs.jafc.6b03286

Lauber, K., Rippin, H., Wickramasinghe, K., & Gilmore, A. B. (2022). Corporate political activity in the context of sugar-sweetened beverage tax policy in the WHO European Region. *European Journal of Public Health*, *32*(5), 786–793. https://doi.org/10.1093/eurpub/ckac117

Laursen, D. C., Silva, P. I. M., Larsen, B. K., & Höglund, E. (2013). High oxygen consumption rates and scale loss indicate elevated aggressive behaviour at low rearing density, while elevated brain serotonergic activity suggests chronic stress at high rearing densities in farmed rainbow trout. *Physiology & Behavior*, *122*, 147–154. https://doi.org/10.1016/j.physbeh.2013.08.026

Lawrence, A. B., Vigors, B., & Sandøe, P. (2019). What Is so Positive about Positive Animal Welfare?—A Critical Review of the Literature. *Animals*, *9*(10), Article 10. https://doi.org/10.3390/ani9100783

Layman, D. K. (2009). Dietary Guidelines should reflect new understandings about adult protein needs. *Nutrition & Metabolism*, *6*(1), 12. https://doi.org/10.1186/1743-7075-6-12

Layrisse, M., Martínez-torres, C., & Roche, M. (1968). Effect of Interaction of Various Foods on Iron Absorption1234. *The American Journal of Clinical Nutrition*, *21*(10), 1175–1183. https://doi.org/10.1093/ajcn/21.10.1175

Le Noë, J., Billen, G., & Garnier, J. (2017). How the structure of agro-food systems shapes nitrogen, phosphorus, and carbon fluxes: The generalized representation of agro-food system applied at the regional scale in France. *Science of The Total Environment*, *586*, 42–55. https://doi.org/10.1016/j.scitotenv.2017.02.040

Lee, D. Y., Lee, S. Y., Jo, C., Yoon, Y., Jeong, J. Y., & Hur, S. J. (2021). Effect on health from consumption of meat and meat products. *Journal of Animal Science and Technology*, *63*(5), 955–976. https://doi.org/10.5187/jast.2021.e101

Lehmann, J., Trübner, M., Patzina, A., Jeitler, M., Hoffmann, R., & Kessler, C. S. (2024). The willingness to transition to a more plant-based diet among omnivores: Determinants and socioeconomic differences. *Appetite*, 107765. https://doi.org/10.1016/j.appet.2024.107765

Leialohilani, A., & de Boer, A. (2020). EU food legislation impacts innovation in the area of plant-based dairy alternatives. *Trends in Food Science & Technology*, *104*, 262–267. https://doi.org/10.1016/j.tifs.2020.07.021

Leidy, H. J., Clifton, P. M., Astrup, A., Wycherley, T. P., Westerterp-Plantenga, M. S., Luscombe-Marsh, N. D., Woods, S. C., & Mattes, R. D. (2015). The role of protein in weight loss and maintenance. *The American Journal of Clinical Nutrition*, *101*(6), 1320S-1329S. https://doi.org/10.3945/ajcn.114.084038

Leni, G., Caligiani, A., & Sforza, S. (2021). Chapter 40 - Bioconversion of agri-food waste and by-products through insects: A new valorization opportunity. In R. Bhat (Ed.), *Valorization of Agri-Food Wastes and By-Products* (pp. 809–828). Academic Press. https://doi.org/10.1016/B978-0-12-824044-1.00013-1

Leonard, U. M., & Kiely, M. E. (2024). Can micronutrient requirements be met by diets from sustainable sources: Outcomes of dietary modelling studies using diet optimization. *Annals of Medicine*, *56*(1), 2389295. https://doi.org/10.1080/07853890.2024.2389295

Lepore, W., & Cunningham, J. B. (2024). Making choices in addressing sustainability problems: A link to framing effects and protected values. *Public Management Review*, *26*(8), 2169–2193. https://doi.org/10.1080/14719037.2023.2180656

Levitt, T. (2021, December 15). Netherlands announces €25bn plan to radically reduce livestock numbers. *The Guardian*. https://www.theguardian.com/environment/2021/dec/15/netherlands-announces-25bn-plan-to-radically-reduce-livestock-numbers

Liao, X., Gerichhausen, M. J. W., Bengoa, X., Rigarlsford, G., Beverloo, R. H., Bruggeman, Y., & Rossi, V. (2020). Large-scale regionalised LCA shows that plant-based fat spreads have a lower climate, land occupation and water scarcity impact than dairy butter. *The International Journal of Life Cycle Assessment*, *25*(6), 1043–1058. https://doi.org/10.1007/s11367-019-01703-w

Lichtenstein, A. H., Erkkilä, A. T., Lamarche, B., Schwab, U. S., Jalbert, S. M., & Ausman, L. M. (2003). Influence of hydrogenated fat and butter on CVD risk factors: Remnant-like particles, glucose and insulin, blood pressure and C-reactive protein. *Atherosclerosis*, *171*(1), 97–107. https://doi.org/10.1016/j.atherosclerosis.2003.07.005

Lin, Y., Mouratidou, T., Vereecken, C., Kersting, M., Bolca, S., de Moraes, A. C. F., Cuenca-García, M., Moreno, L. A., González-Gross, M., Valtueña, J., Labayen, I., Grammatikaki, E., Hallstrom, L., Leclercq, C., Ferrari, M., Gottrand, F., Beghin, L., Manios, Y., Ottevaere, C., … On behalf of the HELENA study group. (2015). Dietary animal and plant protein intakes and their associations with obesity and cardio-metabolic indicators in European adolescents: The HELENA cross-sectional study. *Nutrition Journal*, *14*(1), 10. https://doi.org/10.1186/1475-2891-14-10

Lindberg, L., McCann, R. R., Smyth, B., Woodside, J. V., & Nugent, A. P. (2024). The environmental impact, ingredient composition, nutritional and health impact of meat alternatives: A systematic review. *Trends in Food Science & Technology*, *149*, 104483. https://doi.org/10.1016/j.tifs.2024.104483

Lines, J., & Spence, J. (2012). Safeguarding the welfare of farmed fish at harvest. *Fish Physiology and Biochemistry*, *38*, 153–162. https://doi.org/10.1007/s10695-011-9561-5

Liu, Q., Rossouw, J. E., Roberts, M. B., Liu, S., Johnson, K. C., Shikany, J. M., Manson, J. E., Tinker, L. F., & Eaton, C. B. (2017). Theoretical Effects of Substituting Butter with Margarine on Risk of Cardiovascular Disease. *Epidemiology (Cambridge, Mass.)*, *28*(1), 145–156. https://doi.org/10.1097/EDE.0000000000000557

Livingstone, M. B. E., & Black, A. E. (2003). Markers of the validity of reported energy intake. *The Journal of Nutrition*, *133 Suppl 3*, 895S-920S. https://doi.org/10.1093/jn/133.3.895S

Lloyd, S. M., & Ries, R. (2007). Characterizing, Propagating, and Analyzing Uncertainty in Life-Cycle Assessment: A Survey of Quantitative Approaches. *Journal of Industrial Ecology*, *11*(1), 161–179. https://doi.org/10.1162/jiec.2007.1136

Lo, W.-C., Hu, T.-H., Shih, C.-Y., Lin, H.-H., & Hwang, J.-S. (2024). Impact of Healthy Lifestyle Factors on Life Expectancy and Lifetime Health Care Expenditure: Nationwide Cohort Study. *JMIR Public Health and Surveillance*, *10*, e57045. https://doi.org/10.2196/57045

Lofstedt, A., de Roos, B., & Fernandes, P. G. (2021). Less than half of the European dietary recommendations for fish consumption are satisfied by national seafood supplies. *European Journal of Nutrition*, *60*(8), 4219–4228. https://doi.org/10.1007/s00394-021-02580-6

Lombardini, C., & Lankoski, L. (2013). Forced Choice Restriction in Promoting Sustainable Food Consumption: Intended and Unintended Effects of the Mandatory Vegetarian Day in

Helsinki Schools. *Journal of Consumer Policy*, *36*(2), 159–178. https://doi.org/10.1007/s10603-013-9221-5

Lordan, S., Ross, R. P., & Stanton, C. (2011). Marine Bioactives as Functional Food Ingredients: Potential to Reduce the Incidence of Chronic Diseases. *Marine Drugs*, *9*(6), Article 6. https://doi.org/10.3390/md9061056

Loughnan, S., Bastian, B., & Haslam, N. (2014a). The Psychology of Eating Animals. *Current Directions in Psychological Science*, *23*(2), 104–108. https://doi.org/10.1177/0963721414525781

Loughnan, S., Bastian, B., & Haslam, N. (2014b). The Psychology of Eating Animals. *Current Directions in Psychological Science*, *23*(2), 104–108. https://doi.org/10.1177/0963721414525781

Lucas, E., Guo, M., & Guillén-Gosálbez, G. (2023). Low-carbon diets can reduce global ecological and health costs. *Nature Food*, *4*(5), 394–406. https://doi.org/10.1038/s43016-023-00749-2

Lumsden, C. L., Jägermeyr, J., Ziska, L., & Fanzo, J. (2024). Critical overview of the implications of a global protein transition in the face of climate change: Key unknowns and research imperatives. *One Earth*, *7*(7), 1187–1201. https://doi.org/10.1016/j.oneear.2024.06.013

Lurie-Luke, E. (2024). Alternative protein sources: Science powered startups to fuel food innovation. *Nature Communications*, *15*(1), 4425. https://doi.org/10.1038/s41467-024-47091-0

Lusk, J. L., & Norwood, F. B. (2016). Some vegetarians spend less money on food, others don't. *Ecological Economics*, *130*, 232–242. https://doi.org/10.1016/j.ecolecon.2016.07.005

Lynch, J. (2019). Availability of disaggregated greenhouse gas emissions from beef cattle production: A systematic review. *Environmental Impact Assessment Review*, *76*, 69–78. https://doi.org/10.1016/j.eiar.2019.02.003

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. https://doi.org/10.1016/j.scitotenv.2015.07.022

MacLeod, M. J., Hasan, M. R., Robb, D. H. F., & Mamun-Ur-Rashid, M. (2020). Quantifying greenhouse gas emissions from global aquaculture. *Scientific Reports*, *10*(1), 11679. https://doi.org/10.1038/s41598-020-68231-8

Magrini, M.-B., Anton, M., Cholez, C., Corre-Hellou, G., Duc, G., Jeuffroy, M.-H., Meynard, J.-M., Pelzer, E., Voisin, A.-S., & Walrand, S. (2016). Why are grain-legumes rarely present in cropping systems despite their environmental and nutritional benefits? Analyzing lock-in in the French agrifood system. *Ecological Economics*, *126*, 152–162. https://doi.org/10.1016/j.ecolecon.2016.03.024

Major-Smith, D., Morgan, J., Emmett, P., Golding, J., & Northstone, K. (2022). Associations between religious/spiritual beliefs and behaviours and dietary patterns: Analysis of the parental generation in a prospective cohort study (ALSPAC) in Southwest England. *Public Health Nutrition*, *26*(12), 2895–2911. https://doi.org/10.1017/S1368980023001866

Malézieux, E., Verger, E. O., Avallone, S., Alpha, A., Ngigi, P. B., Lourme-Ruiz, A., Bazile, D., Bricas, N., Ehret, I., Martin-Prevel, Y., & Amiot, M. J. (2024). Biofortification versus diversification to fight micronutrient deficiencies: An interdisciplinary review. *Food Security*, *16*(1), 261–275. https://doi.org/10.1007/s12571-023-01422-z

Malila, Y., Owolabi, I. O., Chotanaphuti, T., Sakdibhornssup, N., Elliott, C. T., Visessanguan, W., Karoonuthaisiri, N., & Petchkongkaew, A. (2024a). Current challenges of alternative proteins as future foods. *Npj Science of Food*, *8*(1), 53. https://doi.org/10.1038/s41538-024-00291-w

Malila, Y., Owolabi, I. O., Chotanaphuti, T., Sakdibhornssup, N., Elliott, C. T., Visessanguan, W., Karoonuthaisiri, N., & Petchkongkaew, A. (2024b). Current challenges of alternative proteins as future foods. *Npj Science of Food*, *8*(1), 53. https://doi.org/10.1038/s41538-024-00291-w

Mambro, A. D. (2024, January 19). *Austria, France and Italy lead charge against lab-grown meat*. Www.Euractiv.Com. https://www.euractiv.com/section/agriculture-food/news/austria-france-and-italy-lead-charge-against-lab-grown-meat/

Marino, L., & Allen, K. (2017). The Psychology of Cows. *Animal Behavior and Cognition*, *4*, 474–498. https://doi.org/10.26451/abc.04.04.06.2017

Marino, L., & Colvin, C. M. (2015). Thinking Pigs: A Comparative Review of Cognition, Emotion, and Personality in Sus domesticus. *International Journal of Comparative Psychology*, *28*(1). https://doi.org/10.46867/ijcp.2015.28.00.04

Mariotti, F., & Gardner, C. D. (2019). Dietary Protein and Amino Acids in Vegetarian Diets—A Review. *Nutrients*, *11*(11), Article 11. https://doi.org/10.3390/nu11112661

Markowski, K. L., & Roxburgh, S. (2019). “If I became a vegan, my family and friends would hate me:” Anticipating vegan stigma as a barrier to plant-based diets. *Appetite*, *135*, 1–9. https://doi.org/10.1016/j.appet.2018.12.040

Martens, E. A., Lemmens, S. G., & Westerterp-Plantenga, M. S. (2013). Protein leverage affects energy intake of high-protein diets in humans. *The American Journal of Clinical Nutrition*, *97*(1), 86–93. https://doi.org/10.3945/ajcn.112.046540

Martínez Steele, E., Raubenheimer, D., Simpson, S. J., Baraldi, L. G., & Monteiro, C. A. (2018). Ultra-processed foods, protein leverage and energy intake in the USA. *Public Health Nutrition*, *21*(1), 114–124. https://doi.org/10.1017/S1368980017001574

Mason, G., Clubb, R., Latham, N., & Vickery, S. (2007). Why and how should we use environmental enrichment to tackle stereotypic behaviour? *Applied Animal Behaviour Science*, *102*(3), 163–188. https://doi.org/10.1016/j.applanim.2006.05.041

Mather, J. A. (2008). Cephalopod consciousness: Behavioural evidence. *Consciousness and Cognition*, *17*(1), 37–48. https://doi.org/10.1016/j.concog.2006.11.006

Mather, J. A. (2023). Ethics and Invertebrates: The Problem Is Us. *Animals*, *13*(18), Article 18. https://doi.org/10.3390/ani13182827

Mathijs, E. (2015). Exploring future patterns of meat consumption. *Meat Science*, *109*, 112–116. https://doi.org/10.1016/j.meatsci.2015.05.007

Matich, E. K., Laryea, J. A., Seely, K. A., Stahr, S., Su, L. J., & Hsu, P.-C. (2021). Association between pesticide exposure and colorectal cancer risk and incidence: A systematic review. *Ecotoxicology and Environmental Safety*, *219*, 112327. https://doi.org/10.1016/j.ecoenv.2021.112327

Matthews, A. (2020, February 24). *The protective effect of EU agricultural tariffs | CAP Reform*. http://capreform.eu/the-protective-effect-of-eu-agricultural-tariffs/

Matthews, A. (2024). *Farmer Protests and the 2024 European Parliament Elections*. *2024*(2), 83–87.

Matthews, A., Candel, J., de Mûelenaere, N., & Scheelbeek, P. (2023). The Political Economy of Food System Transformation in the European Union. In *The Political Economy of Food System Transformation: Pathways to Progress in a Polarized World*. Oxford University Press.

Mawois, M., Vidal, A., Revoyron, E., Casagrande, M., Jeuffroy, M.-H., & Le Bail, M. (2019). Transition to legume-based farming systems requires stable outlets, learning, and peer-networking. *Agronomy for Sustainable Development*, *39*(1), 14. https://doi.org/10.1007/s13593-019-0559-1

Mazac, R., Meinilä, J., Korkalo, L., Järviö, N., Jalava, M., & Tuomisto, H. L. (2022). Incorporation of novel foods in European diets can reduce global warming potential, water use and land use by over 80%. *Nature Food*, *3*(4), Article 4. https://doi.org/10.1038/s43016-022-00489-9

Mazac, R., Sahlin, K. R., Hyypiä, I., Keränen, F., Niva, M., Berglund, N., & Herzon, I. (2025). Does “better” mean “less”? Sustainable meat consumption in the context of natural pasture-raised beef. *Agriculture and Human Values*. https://doi.org/10.1007/s10460-025-10707-2

McAllister, T. A., & Topp, E. (2012). Role of livestock in microbiological contamination of water: Commonly the blame, but not always the source. *Animal Frontiers*, *2*(2), 17–27. https://doi.org/10.2527/af.2012-0039

McCullough, E. B., Lu, M., Nouve, Y., Arsenault, J., & Zhen, C. (2024). Nutrient adequacy for poor households in Africa would improve with higher income but not necessarily with lower food prices. *Nature Food*, *5*(2), 171–181. https://doi.org/10.1038/s43016-024-00927-w

McIlhone, A. E., Beausoleil, N. J., Kells, N. J., Mellor, D. J., & Johnson, C. B. (2018). Effects of noxious stimuli on the electroencephalogram of anaesthetised chickens (Gallus gallus domesticus). *PLoS ONE*, *13*(4), e0196454. https://doi.org/10.1371/journal.pone.0196454

Mclaren, D. (1974). THE GREAT PROTEIN FIASCO. *The Lancet*, *304*(7872), 93–96. https://doi.org/10.1016/S0140-6736(74)91649-3

McLaren, S., Berardy, A., Henderson, A., Holden, N., Huppertz, T., Jolliet, O., De Camillis, C., Renouf, M., Rugani, B., Saarinen, M., van der Pols, J., Vázquez-Rowe, I., Antón Vallejo, A., Bianchi, M., Chaudhary, A., Chen, C., Cooreman-Algoed, M., Dong, H., Grant, T., … Van Zanten, H. (2021). *Integration of environment and nutrition in life cycle assessment of food Items: Opportunities and challenges*. FAO. https://doi.org/10.4060/cb8054en

Meagher, R. K., Beaver, A., Weary, D. M., & von Keyserlingk, M. A. G. (2019). Invited review: A systematic review of the effects of prolonged cow-calf contact on behavior, welfare, and productivity. *Journal of Dairy Science*, *102*(7), 5765–5783. https://doi.org/10.3168/jds.2018-16021

Meehan, C. L., & Mench, J. A. (2007). The challenge of challenge: Can problem solving opportunities enhance animal welfare? *Applied Animal Behaviour Science*, *102*(3), 246–261. https://doi.org/10.1016/j.applanim.2006.05.031

Mehrabi, Z., Gill, M., Wijk, M. van, Herrero, M., & Ramankutty, N. (2020). Livestock policy for sustainable development. *Nature Food*, *1*(3), Article 3. https://doi.org/10.1038/s43016-020-0042-9

Meier, M. S., Stoessel, F., Jungbluth, N., Juraske, R., Schader, C., & Stolze, M. (2015). Environmental impacts of organic and conventional agricultural products – Are the differences captured by life cycle assessment? *Journal of Environmental Management*, *149*, 193–208. https://doi.org/10.1016/j.jenvman.2014.10.006

Mekonnen, M., & Hoekstra, A. (2012). A Global Assessment of the Water Footprint of Farm Animal Products. *Ecosystems*, *15*. https://doi.org/10.1007/s10021-011-9517-8

Mekonnen, M., & Hoekstra, A. Y. (2011). The green, blue and grey water footprint of crops and derived crop products. *Hydrology and Earth System Sciences*, *15*(5), 1577–1600. https://doi.org/10.5194/hess-15-1577-2011

Menzel, J., Abraham, K., Stangl, G. I., Ueland, P. M., Obeid, R., Schulze, M. B., Herter-Aeberli, I., Schwerdtle, T., & Weikert, C. (2021). Vegan Diet and Bone Health—Results from the Cross-Sectional RBVD Study. *Nutrients*, *13*(2), 685. https://doi.org/10.3390/nu13020685

Merisalu, E., Leppälä, J., Jakob, M., & Rautiainen, R. H. (2019). *Variation in Eurostat and national statistics of accidents in agriculture*. http://hdl.handle.net/10492/5436

Metera, E., Sakowski, T., Sloniewski, K., & Romanowicz, B. (2010). Grazing as a tool to maintain biodiversity of grassland—A review. *Animal Science Papers and Reports*, *28*, 315–334.

Meybeck, A., Cederberg, C., Gustavsson, J., van Otterdijk, R., & Sonesson, U. (2011). *Global food losses and food waste*. FAO. https://openknowledge.fao.org/items/4a463cff-586d-433f-9124-af4b99246f91

Michel, F., Hartmann, C., & Siegrist, M. (2021). Consumers' associations, perceptions and acceptance of meat and plant-based meat alternatives. *Food Quality and Preference*, *87*, 104063. https://doi.org/10.1016/j.foodqual.2020.104063

Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science*, *6*(1), 42. https://doi.org/10.1186/1748-5908-6-42

Miele, M., Bock, B., & Horlings, L. (2015). *Chapter 15: Animal welfare: The challenges of implementing a common legislation in Europe*. https://www.elgaronline.com/edcollchap/edcoll/9781782548256/9781782548256.00023.xml

Milford, A. B., Le Mouël, C., Bodirsky, B. L., & Rolinski, S. (2019). Drivers of meat consumption. *Appetite*, *141*, 104313. https://doi.org/10.1016/j.appet.2019.06.005

Miller, V., Reedy, J., Cudhea, F., Zhang, J., Shi, P., Erndt-Marino, J., Coates, J., Micha, R., Webb, P., Mozaffarian, D., Abbott, P., Abdollahi, M., Abedi, P., Abumweis, S., Adair, L., Nsour, M. A., Al-Daghri, N., Al-Hamad, N., Al-Hooti, S., … Zohoori, F. V. (2022). Global, regional, and national consumption of animal-source foods between 1990 and 2018: Findings from the Global Dietary Database. *The Lancet Planetary Health*, *6*(3), e243–e256. https://doi.org/10.1016/S2542-5196(21)00352-1

Milner, A., Spittal, M. J., Pirkis, J., & LaMontagne, A. D. (2013). Suicide by occupation: Systematic review and meta-analysis. *The British Journal of Psychiatry*, *203*(6), 409–416. https://doi.org/10.1192/bjp.bp.113.128405

Mirmiran, P., Yuzbashian, E., Aghayan, M., Mahdavi, M., Asghari, G., & Azizi, F. (2020). A Prospective Study of Dietary Meat Intake and Risk of Incident Chronic Kidney Disease. *Journal of Renal Nutrition*, *30*(2), 111–118. https://doi.org/10.1053/j.jrn.2019.06.008

Mitloehner, F., Kebreab, E., & Boccadoro, M. (2020, September 2). *Methane, Cows, and Climate Change: California Dairy's Path to Climate Neutrality | CLEAR Center*. https://clear.ucdavis.edu/news/methane-cows-and-climate-change-california-dairys-path-climate-neutrality

Mittendorfer, B., Klein, S., & Fontana, L. (2020). A word of caution against excessive protein intake. *Nature Reviews. Endocrinology*, *16*(1), 59–66. https://doi.org/10.1038/s41574-019-0274-7

Moberg, E., Karlsson Potter, H., Wood, A., Hansson, P.-A., & Röös, E. (2020). Benchmarking the Swedish Diet Relative to Global and National Environmental Targets—Identification of Indicator Limitations and Data Gaps. *Sustainability*, *12*(4), Article 4. https://doi.org/10.3390/su12041407

Modlinska, K., & Pisula, W. (2018). Selected Psychological Aspects of Meat Consumption—A Short Review. *Nutrients*, *10*(9), 1301. https://doi.org/10.3390/nu10091301

Molina, P., & Ríos-Osorio, L. (2020). Occupational health and safety in agriculture. A systematic review. *Revista de La Facultad de Medicina*, *68*. https://doi.org/10.15446/revfacmed.v68n4.76519

Monteiro, C. A., Cannon, G., Levy, R. B., Moubarac, J.-C., Louzada, M. L., Rauber, F., Khandpur, N., Cediel, G., Neri, D., Martinez-Steele, E., Baraldi, L. G., & Jaime, P. C. (2019). Ultra-processed foods: What they are and how to identify them. *Public Health Nutrition*, *22*(5), 936–941. https://doi.org/10.1017/S1368980018003762

Moreau, D. T. R., & Neis, B. (2009). Occupational health and safety hazards in Atlantic Canadian aquaculture: Laying the groundwork for prevention. *Marine Policy*, *33*(2), 401–411. https://doi.org/10.1016/j.marpol.2008.09.001

Mottet, A., de Haan, C., Falcucci, A., Tempio, G., Opio, C., & Gerber, P. J. (2017). Livestock: On our plates or eating at our table? A new analysis of the feed/food debate. *Global Food Security*, *14*, 1–8. https://doi.org/10.1016/j.gfs.2017.01.001

Moughan, P. J., Fulgoni, V. L., & Wolfe, R. R. (2024). The Importance of Dietary Protein Quality in Mid- to High-Income Countries. *The Journal of Nutrition*, *154*(3), 804–814. https://doi.org/10.1016/j.tjnut.2024.01.020

Mozaffarian, D. (2016). Dietary and Policy Priorities for Cardiovascular Disease, Diabetes, and Obesity – A Comprehensive Review. *Circulation*, *133*(2), 187–225. https://doi.org/10.1161/CIRCULATIONAHA.115.018585

Muñoz, M., Reul, A., Guijarro, B., & Hidalgo, M. (2023). Carbon footprint, economic benefits and sustainable fishing: Lessons for the future from the Western Mediterranean. *Science of The Total Environment*, *865*, 160783. https://doi.org/10.1016/j.scitotenv.2022.160783

Muñoz-Ulecia, E., Bernués, A., Casasús, I., Olaizola, A. M., Lobón, S., & Martín-Collado, D. (2021). Drivers of change in mountain agriculture: A thirty-year analysis of trajectories of evolution of cattle farming systems in the Spanish Pyrenees. *Agricultural Systems*, *186*, 102983. https://doi.org/10.1016/j.agsy.2020.102983

Murray, C. J. L. (2022). The Global Burden of Disease Study at 30 years. *Nature Medicine*, *28*(10), 2019–2026. https://doi.org/10.1038/s41591-022-01990-1

Murray, C. J. L., Ikuta, K. S., Sharara, F., Swetschinski, L., Aguilar, G. R., Gray, A., Han, C., Bisignano, C., Rao, P., Wool, E., Johnson, S. C., Browne, A. J., Chipeta, M. G., Fell, F., Hackett, S., Haines-Woodhouse, G., Hamadani, B. H. K., Kumaran, E. A. P., McManigal, B., … Naghavi, M. (2022). Global burden of bacterial antimicrobial resistance in 2019: A systematic analysis. *The Lancet*, *399*(10325), 629–655. https://doi.org/10.1016/S0140-6736(21)02724-0

Myers, M. L. (2010). Review of occupational hazards associated with aquaculture. *Journal of Agromedicine*, *15*(4), 412–426. https://doi.org/10.1080/1059924X.2010.512854

Nagata, C. (2021). Soy intake and chronic disease risk: Findings from prospective cohort studies in Japan. *European Journal of Clinical Nutrition*, *75*(6), 890–901. https://doi.org/10.1038/s41430-020-00744-x

Nájera Espinosa, S., Hadida, G., Jelmar Sietsma, A., Alae-Carew, C., Turner, G., Green, R., Pastorino, S., Picetti, R., & Scheelbeek, P. (2024). Mapping the evidence of novel plant-based foods: A systematic review of nutritional, health, and environmental impacts in high-income countries. *Nutrition Reviews*, nuae031. https://doi.org/10.1093/nutrit/nuae031

Näsholm, T., Kielland, K., & Ganeteg, U. (2009). Uptake of organic nitrogen by plants. *New Phytologist*, *182*(1), 31–48. https://doi.org/10.1111/j.1469-8137.2008.02751.x

Ngajilo, D., & Jeebhay, M. F. (2019). Occupational injuries and diseases in aquaculture – A review of literature. *Aquaculture*, *507*, 40–55. https://doi.org/10.1016/j.aquaculture.2019.03.053

Nicholson, F. A., Smith, S. R., Alloway, B. J., Carlton-Smith, C., & Chambers, B. J. (2003). An inventory of heavy metals inputs to agricultural soils in England and Wales. *Science of The Total Environment*, *311*(1), 205–219. https://doi.org/10.1016/S0048-9697(03)00139-6

Nicolaisen, S., Langkabel, N., Thoene-Reineke, C., & Wiegard, M. (2023). Animal Welfare during Transport and Slaughter of Cattle: A Systematic Review of Studies in the European Legal Framework. *Animals*, *13*(12), Article 12. https://doi.org/10.3390/ani13121974

Nisa, C. F., Bélanger, J. J., Schumpe, B. M., & Faller, D. G. (2019). Meta-analysis of randomised controlled trials testing behavioural interventions to promote household action on climate change. *Nature Communications*, *10*(1), 4545. https://doi.org/10.1038/s41467-019-12457-2

Nouri-Majd, S., Salari-Moghaddam, A., Aminianfar, A., Larijani, B., & Esmaillzadeh, A. (2022). Association Between Red and Processed Meat Consumption and Risk of Prostate Cancer: A Systematic Review and Meta-Analysis. *Frontiers in Nutrition*, *9*, 801722. https://doi.org/10.3389/fnut.2022.801722

Nowakowski, A. C., Miller, A. C., Miller, M. E., Xiao, H., & Wu, X. (2022). Potential health benefits of edible insects. *Critical Reviews in Food Science and Nutrition*, *62*(13), 3499–3508. https://doi.org/10.1080/10408398.2020.1867053

Nowson, C., & O'Connell, S. (2015). Protein Requirements and Recommendations for Older People: A Review. *Nutrients*, *7*(8), Article 8. https://doi.org/10.3390/nu7085311

Nygaard Sorensen, J., & Thorup-Kristensen, K. (2011). Plant-based fertilizers for organic vegetable production. *Journal of Plant Nutrition and Soil Science*, *174*(2), 321–332. https://doi.org/10.1002/jpln.200900321

OECD. (2023). *Agricultural financial support*. OECD. https://www.oecd.org/en/data/indicators/agricultural-financial-support.html

Oenema, O., & Tamminga, S. (2005). Nitrogen in global animal production and management options for improving nitrogen use efficiency. *Science in China. Series C, Life Sciences*, *48 Suppl 2*, 871–887. https://doi.org/10.1007/BF03187126

Offermanns, L., Tiemeyer, B., Dettmann, U., Rüffer, J., Düvel, D., Vogel, I., & Brümmer, C. (2023). High greenhouse gas emissions after grassland renewal on bog peat soil. *Agricultural and Forest Meteorology*, *331*, 109309. https://doi.org/10.1016/j.agrformet.2023.109309

Onwezen, M. C., Bouwman, E. P., Reinders, M. J., & Dagevos, H. (2021). Edible Insects as a Protein Source: A Review of Public Perception, Processing Technology, and Research Trends. *Appetite*, *159*, 105058. https://doi.org/10.1016/j.appet.2020.105058

Orach, K., Schlüter, M., & Österblom, H. (2017). Tracing a pathway to success: How competing interest groups influenced the 2013 EU Common Fisheries Policy reform. *Environmental Science & Policy*, *76*, 90–102. https://doi.org/10.1016/j.envsci.2017.06.010

Orlich, M. J., Jaceldo-Siegl, K., Sabaté, J., Fan, J., Singh, P. N., & Fraser, G. E. (2014). Patterns of food consumption among vegetarians and non-vegetarians. *British Journal of Nutrition*, *112*(10), 1644–1653. https://doi.org/10.1017/S000711451400261X

Ortega, R. M., Arribas-López, N., Salas-González, M. D., Aparicio, A., González-Rodríguez, L. G., Bermejo, L. M., Lozano-Estevan, M. D. C., Cuadrado-Soto, E., López-Sobaler, A. M., & Loria-Kohen, V. (2024). High-Protein Processed Foods: Impact on Diet, Nutritional Status, and Possible Effects on Health. *Nutrients*, *16*(11), 1697. https://doi.org/10.3390/nu16111697

Osimani, A., Milanović, V., Cardinali, F., Garofalo, C., Clementi, F., Ruschioni, S., Riolo, P., Isidoro, N., Loreto, N., Galarini, R., Moretti, S., Petruzzelli, A., Micci, E., Tonucci, F., & Aquilanti, L. (2018). Distribution of Transferable Antibiotic Resistance Genes in Laboratory-Reared Edible Mealworms (Tenebrio molitor L.). *Frontiers in Microbiology*, *9*. https://doi.org/10.3389/fmicb.2018.02702

Österblom, H., Jouffray, J.-B., Folke, C., Crona, B., Troell, M., Merrie, A., & Rockström, J. (2015). Transnational Corporations as 'Keystone Actors' in Marine Ecosystems. *PLOS ONE*, *10*(5), e0127533. https://doi.org/10.1371/journal.pone.0127533

Our World in Data. (2021). *Daily per capita protein supply*. Our World in Data. https://ourworldindata.org/grapher/daily-per-capita-protein-supply

Pais, D. F., Marques, A. C., & Fuinhas, J. A. (2020). Reducing Meat Consumption to Mitigate Climate Change and Promote Health: But Is It Good for the Economy? *Environmental Modeling & Assessment*, *25*(6), 793–807. https://doi.org/10.1007/s10666-020-09710-0

Pais, D. F., Marques, A. C., & Fuinhas, J. A. (2022). The cost of healthier and more sustainable food choices: Do plant-based consumers spend more on food? *Agricultural and Food Economics*, *10*(1), 18. https://doi.org/10.1186/s40100-022-00224-9

Pakseresht, A., Ahmadi Kaliji, S., & Canavari, M. (2022). Review of factors affecting consumer acceptance of cultured meat. *Appetite*, *170*, 105829. https://doi.org/10.1016/j.appet.2021.105829

Pan, A., Sun, Q., Bernstein, A. M., Schulze, M. B., Manson, J. E., Stampfer, M. J., Willett, W. C., & Hu, F. B. (2012). Red meat consumption and mortality: Results from 2 prospective cohort studies. *Archives of Internal Medicine*, *172*(7), 555–563. https://doi.org/10.1001/archinternmed.2011.2287

Pandey, R., Asche, F., Misund, B., Nygaard, R., Adewumi, O. M., Straume, H.-M., & Zhang, D. (2023). Production growth, company size, and concentration: The case of salmon. *Aquaculture*, *577*, 739972. https://doi.org/10.1016/j.aquaculture.2023.739972

Papangelou, A., & Mathijs, E. (2021). Assessing agro-food system circularity using nutrient flows and budgets. *Journal of Environmental Management*, *288*, 112383. https://doi.org/10.1016/j.jenvman.2021.112383

Parker, R., Blanchard, J., Gardner, C., Green, B., Hartmann, K., Tyedmers, P., & Watson, R. (2018). Fuel use and greenhouse gas emissions of world fisheries. *Nature Climate Change*, *8*, 333–337. https://doi.org/10.1038/s41558-018-0117-x

Parodi, A., Leip, A., De Boer, I. J. M., Slegers, P. M., Ziegler, F., Temme, E. H. M., Herrero, M., Tuomisto, H., Valin, H., Van Middelaar, C. E., Van Loon, J. J. A., & van Zanten, H. H. E. (2018). The potential of future foods for sustainable and healthy diets. *Nature Sustainability*, *1*(12), Article 12. https://doi.org/10.1038/s41893-018-0189-7

Parry, J. (2010). Gender and slaughter in popular gastronomy. *Feminism & Psychology*, *20*(3), 381–396. https://doi.org/10.1177/0959353510368129

Pathak, M., Slade, R., Pichs-Madruga, R., Ürge-Vorsatz, D., Shukla, R., & Skea, J. (2022). *Climate change 2022 mitigation of climate change: Technical summary*. https://www.ipcc.ch/report/ar6/wg2/chapter/technical-summary/

Pauly, D., Hilborn, R., & Branch, T. A. (2013). Fisheries: Does catch reflect abundance? *Nature*, *494*(7437), 303–306. https://doi.org/10.1038/494303a

Pedersen, A. N., Kondrup, J., & Børsheim, E. (2013). Health effects of protein intake in healthy adults: A systematic literature review. *Food & Nutrition Research*. https://doi.org/10.3402/fnr.v57i0.21245

Pedrazzani, A. S., Cozer, N., Quintiliano, M. H., & Ostrensky, A. (2024). Insights into Decapod Sentience: Applying the General Welfare Index (GWI) for Whiteleg Shrimp (Penaeus vannamei—Boone, 1931) Reared in Aquaculture Grow-Out Ponds. *Fishes*, *9*(11), Article 11. https://doi.org/10.3390/fishes9110440

Pencharz, P. B., Elango, R., & Wolfe, R. R. (2016). Recent developments in understanding protein needs – How much and what kind should we eat? *Applied Physiology, Nutrition, and Metabolism*, *41*(5), 577–580. https://doi.org/10.1139/apnm-2015-0549

Peyraud, J.-L., & MacLeod, M. (2020). *Future of EU livestock: How to contribute to a sustainable agricultural sector ? : final report*. Publications Office of the European Union. https://data.europa.eu/doi/10.2762/3440

Pierce, J. (2019). Putting the "Free" Back in Freedom: The failure and future of animal welfare science. In *Why We Love and Exploit Animals*. Routledge.

Pinckaers, P. J. M., Trommelen, J., Snijders, T., & van Loon, L. J. C. (2021). The Anabolic Response to Plant-Based Protein Ingestion. *Sports Medicine (Auckland, N.z.)*, *51*(Suppl 1), 59–74. https://doi.org/10.1007/s40279-021-01540-8

Platel, K., & Srinivasan, K. (2016). Bioavailability of Micronutrients from Plant Foods: An Update. *Critical Reviews in Food Science and Nutrition*, *56*(10), 1608–1619. https://doi.org/10.1080/10408398.2013.781011

Plush, K., Lines, D., Staveley, L., D'Souza, D., & van Barneveld, R. (2024). A five domains assessment of sow welfare in a novel free farrowing system. *Frontiers in Veterinary Science*, *11*. https://doi.org/10.3389/fvets.2024.1339947

Ponte, G., Chiandetti, C., Edelman, D. B., Imperadore, P., Pieroni, E. M., & Fiorito, G. (2022). Cephalopod Behavior: From Neural Plasticity to Consciousness. *Frontiers in Systems Neuroscience*, *15*. https://doi.org/10.3389/fnsys.2021.787139

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, *360*(6392), 987–992. https://doi.org/10.1126/science.aaq0216

Popkin, B. M. (1993). Nutritional Patterns and Transitions. *Population and Development Review*, *19*(1), 138–157. https://doi.org/10.2307/2938388

Popkin, B. M. (2006). Global nutrition dynamics: The world is shifting rapidly toward a diet linked with noncommunicable diseases. *The American Journal of Clinical Nutrition*, *84*(2), 289–298. https://doi.org/10.1093/ajcn/84.2.289

Portz, D., Woodley, C., & Cech, J. (2006). Stress-associated impacts of short-term holding on fishes. *Reviews in Fish Biology and Fisheries*, *16*, 125–170. https://doi.org/10.1007/s11160-006-9012-z

Post, M. J., Levenberg, S., Kaplan, D. L., Genovese, N., Fu, J., Bryant, C., Negowetti, N., Verzijden, K., & Moutsatsou, P. (2020). Scientific, sustainability and regulatory challenges of cultured meat. *Nature Food*, *1*(7), 403–415. https://doi.org/10.1038/s43016-020-0112-z

Potter, H., Lundmark, L., & Röös, E. (2020). *Environmental impact of plant-based foods – data collection for the development of a consumer guide for plant-based foods*. https://www.semanticscholar.org/paper/Environmental-impact-of-plant-based-foods-%E2%80%93-data-of-Potter-Lundmark/1a4201fd47cff92e1c5ff610ea31c850be4c0d2c

Poux, X., & Aubert, P.-M. (2018). *An agroecological Europe in 2050: Multifunctional agriculture for healthy eating. Findings from the Ten Years For Agroecology (TYFA) modelling exercice*. IDDRI.

Previti, A., Biondi, V., Bruno, F., Castelli, G., Pugliese, M., Vitale, F., Padalino, B., & Passantino, A. (2025). Text mining and topic modeling insights on fish welfare and antimicrobial use in aquaculture. *BMC Veterinary Research*, *21*, 225. https://doi.org/10.1186/s12917-025-04544-y

Prochazka, P., Soukupova, J., Abrham, J., Mullen, K. J., Tomsik, K., Cechura, L., Cabelkova, I., & Smutka, L. (2024). Protein consumption in Europe: Sustainability, tradition, and policy implications. *Sustainable Development*, *n/a*(n/a). https://doi.org/10.1002/sd.3171

Protz, A. (2025, April 3). Nijmegen Becomes Third Dutch City To Ban Meat Ads. *Plant Based News*. https://plantbasednews.org/lifestyle/nijmegen-ban-meat-ads-embraces-plant-based-treaty/

ProVeg International. (2024, November 28). *Nutritional assessment of plant-based meat alternatives*. ProVeg International. https://proveg.org/fsd-article/nutritional-assessment-of-plant-based-meat-alternatives/

Pryshlakivsky, J., & Searcy, C. (2021). Life Cycle Assessment as a decision-making tool: Practitioner and managerial considerations. *Journal of Cleaner Production*, *309*, 127344. https://doi.org/10.1016/j.jclepro.2021.127344

Pulungan, M. A., Suzuki, S., Gavina, M. K. A., Tubay, J. M., Ito, H., Nii, M., Ichinose, G., Okabe, T., Ishida, A., Shiyomi, M., Togashi, T., Yoshimura, J., & Morita, S. (2019). Grazing enhances species diversity in grassland communities. *Scientific Reports*, *9*(1), 11201. https://doi.org/10.1038/s41598-019-47635-1

Qaim, M., Barrangou, R., & Ronald, P. C. (2024). Sustainability of animal-sourced foods and plant-based alternatives. *Proceedings of the National Academy of Sciences*, *121*(50), e2400495121. https://doi.org/10.1073/pnas.2400495121

Qian, F., Riddle, M. C., Wylie-Rosett, J., & Hu, F. B. (2020). Red and Processed Meats and Health Risks: How Strong Is the Evidence? *Diabetes Care*, *43*(2), 265–271. https://doi.org/10.2337/dci19-0063

Raj, A. B., Johnson, S. P., Wotton, S. B., & McInstry, J. L. (1997). Welfare implications of gas stunning pigs: 3. The time to loss of somatosensory evoked potentials and spontaneous electrocorticogram of pigs during exposure to gases. *Veterinary Journal (London, England: 1997)*, *153*(3), 329–339. https://doi.org/10.1016/s1090-0233(97)80067-6

Rand, W. M., Pellett, P. L., & Young, V. R. (2003). Meta-analysis of nitrogen balance studies for estimating protein requirements in healthy adults123. *The American Journal of Clinical Nutrition*, *77*(1), 109–127. https://doi.org/10.1093/ajcn/77.1.109

Ranganathan, J., Vennard, D., Waite, R., Lipinski, B., Searchinger, T., Dumas, P., Forslund, A., Guyomard, H., Manceron, S., Marajo Petitzon, E., Mouël, C., Havlík, P., Herrero, M., Zhang, X., Wirsenius, S., Ramos, F., Yan, X., Phillips, M., & Mungkung, R. (2016). *Shifting Diets for a Sustainable Food Future*. https://doi.org/10.13140/RG.2.1.3808.2961

Razmaitė, V., Šiukščius, A., Sveistiene, R., Bliznikas, S., & Jatkauskienė, V. (2020). Relationships Between Fat and Cholesterol Contents and Fatty Acid Composition in Different Meat-Producing Animal Species. *Acta Veterinaria*, *70*. https://doi.org/10.2478/acve-2020-0028

Reedy, J., Cudhea, F., Shi, P., Zhang, J., Onopa, J., Miller, V., Singh, G., Micha, R., & Mozaffarian, D. (2019). Global Intakes of Total Protein and Sub-types; Findings from the 2015 Global Dietary Database (P10-050-19). *Current Developments in Nutrition*, *3*, nzz034.P10-050-19. https://doi.org/10.1093/cdn/nzz034.P10-050-19

Refsgaard, J. C., van der Sluijs, J. P., Højberg, A. L., & Vanrolleghem, P. A. (2007). Uncertainty in the environmental modelling process – A framework and guidance. *Environmental Modelling & Software*, *22*(11), 1543–1556. https://doi.org/10.1016/j.envsoft.2007.02.004

Regulation (EU) 2015/2283 of the European Parliament and of the Council of 25 November 2015 on Novel Foods, Amending Regulation (EU) No 1169/2011 of the European Parliament and of the Council and Repealing Regulation (EC) No 258/97 of the European Parliament and of the Council and Commission Regulation (EC) No 1852/2001, 327 OJ L (2015). http://data.europa.eu/eli/reg/2015/2283/oj/eng

Reimert, I., Webb, L. E., van Marwijk, M. A., & Bolhuis, J. E. (2023). Review: Towards an integrated concept of animal welfare. *Animal*, *17*, 100838. https://doi.org/10.1016/j.animal.2023.100838

Reis, D. C. dos, Ramos, E., Reis, P. F., Hembecker, P. K., Gontijo, L. A., & Moro, A. R. P. (2015). Assessment of Risk Factors of Upper-limb Musculoskeletal Disorders in Poultry Slaughterhouse. *Procedia Manufacturing*, *3*, 4309–4314. https://doi.org/10.1016/j.promfg.2015.07.423

Resare Sahlin, K. (2024). *"Less but Better" Meat: Pathways for Food Systems Sustainability?* [Stockholm University, Faculty of Science, Stockholm Resilience Centre.]. https://urn.kb.se/resolve?urn=urn:nbn:se:su:diva-234541

Resare Sahlin, K., Gordon, L. J., Lindborg, R., Piipponen, J., Van Rysselberge, P., Rouet-Leduc, J., & Röös, E. (2024). An exploration of biodiversity limits to grazing ruminant milk and meat production. *Nature Sustainability*, 1–11. https://doi.org/10.1038/s41893-024-01398-4

Riaz, M. N., Irshad, F., Riaz, N. M., & Regenstein, J. M. (2021). Pros and cons of different stunning methods from a Halal perspective: A review. *Translational Animal Science*, *5*(4), txab154. https://doi.org/10.1093/tas/txab154

Riber, A. B., van de Weerd, H. A., de Jong, I. C., & Steenfeldt, S. (2018). Review of environmental enrichment for broiler chickens. *Poultry Science*, *97*(2), 378–396. https://doi.org/10.3382/ps/pex344

Rice, K. C., & Herman, J. S. (2012). Acidification of Earth: An assessment across mechanisms and scales. *Applied Geochemistry*, *27*(1), 1–14. https://doi.org/10.1016/j.apgeochem.2011.09.001

Richardson, J. R., Fitsanakis, V., Westerink, R. H. S., & Kanthasamy, A. G. (2019). Neurotoxicity of pesticides. *Acta Neuropathologica*, *138*(3), 343–362. https://doi.org/10.1007/s00401-019-02033-9

Richthofen, J.-S., Pahl, H., Bouttet, D., Casta, P., Cartrysse, C., Charles, R., & Lafarga, A. (2006). What do European farmers think about grain legumes? *Grain Legumes*, *45*, 14–15.

Rickerby, A., & Green, R. (2024). Barriers to Adopting a Plant-Based Diet in High-Income Countries: A Systematic Review. *Nutrients*, *16*(6), Article 6. https://doi.org/10.3390/nu16060823

Ridoutt, B. G., Sanguansri, P., Nolan, M., & Marks, N. (2012). Meat consumption and water scarcity: Beware of generalizations. *Journal of Cleaner Production*, *28*, 127–133. https://doi.org/10.1016/j.jclepro.2011.10.027

Rieger, J., Freund, F., Offermann, F., Geibel, I., & Gocht, A. (2023). From fork to farm: Impacts of more sustainable diets in the EU-27 on the agricultural sector. *Journal of Agricultural Economics*, *74*(3), 764–784. https://doi.org/10.1111/1477-9552.12530

Riera, A., Duluins, O., Schuster, M., & Baret, P. V. (2023). Accounting for diversity while assessing sustainability: Insights from the Walloon bovine sectors. *Agronomy for Sustainable Development*, *43*(2), 30. https://doi.org/10.1007/s13593-023-00882-z

Rincker, L. E. D., VandeHaar, M. J., Wolf, C. A., Liesman, J. S., Chapin, L. T., & Nielsen, M. S. W. (2011). Effect of intensified feeding of heifer calves on growth, pubertal age, calving age, milk yield, and economics. *Journal of Dairy Science*, *94*(7), 3554–3567. https://doi.org/10.3168/jds.2010-3923

Ritchie, H., Rosado, P., & Roser, M. (2023). Animal Welfare. *Our World in Data*. https://ourworldindata.org/animal-welfare

Ritchie, H., & Roser, M. (2021). Forests and Deforestation. *Our World in Data*. https://ourworldindata.org/soy

Roberts, C., Béné, C., Bennett, N., Boon, J. S., Cheung, W. W. L., Cury, P., Defeo, O., De Jong Cleyndert, G., Froese, R., Gascuel, D., Golden, C. D., Hawkins, J., Hobday, A. J., Jacquet, J., Kemp, P., Lam, M. E., Le Manach, F., Meeuwig, J. J., Micheli, F., … O'Leary, B. C. (2024). Rethinking sustainability of marine fisheries for a fast-changing planet. *Npj Ocean Sustainability*, *3*(1), 1–11. https://doi.org/10.1038/s44183-024-00078-2

Robinson, E., & Jones, A. (2024). Causality or confounding? Applying E values to examine associations between ultra-processed food consumption and risk of weight gain. *International Journal of Obesity*, *48*(9), 1342–1346. https://doi.org/10.1038/s41366-024-01566-8

Röcklinsberg, H., Gräns, A., Kornum, A., & Gjerris, M. (2019). *37. Ethical aspects of farming of wild fish*. Brill. https://doi.org/10.3920/978-90-8686-892-6_37

Rodríguez-Ortega, T., Oteros-Rozas, E., Ripoll-Bosch, R., Tichit, M., Martín-López, B., & Bernués, A. (2014). Applying the ecosystem services framework to pasture-based livestock farming systems in Europe. *Animal*, *8*(8), 1361–1372. https://doi.org/10.1017/S1751731114000421

Rogers, R. A. (2008). Beasts, Burgers, and Hummers: Meat and the Crisis of Masculinity in Contemporary Television Advertisements. *Environmental Communication*, *2*(3), 281–301. https://doi.org/10.1080/17524030802390250

Rojas Conzuelo, Z., Bez, N. S., Theobald, S., & Kopf-Bolanz, K. A. (2022). Protein Quality Changes of Vegan Day Menus with Different Plant Protein Source Compositions. *Nutrients*, *14*(5), 1088. https://doi.org/10.3390/nu14051088

Ronchi, B., & Ramanzin, M. (2024). Ecosystem Services and Livestock Systems in Mountain Areas. In G. Antonelli, T. Qin, M. V. Ferroni, & A. Erwin (Eds.), *Biodiversity Laws, Policies and Science in Europe, the United States and China* (pp. 125–149). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-56218-1_7

Röös, E., Bajželj, B., Smith, P., Patel, M., Little, D., & Garnett, T. (2017). Protein futures for Western Europe: Potential land use and climate impacts in 2050. *Regional Environmental Change*, *17*(2), 367–377. https://doi.org/10.1007/s10113-016-1013-4

Röös, E., Karlsson, H., Witthöft, C., & Sundberg, C. (2015). Evaluating the sustainability of diets–combining environmental and nutritional aspects. *Environmental Science & Policy*, *47*, 157–166. https://doi.org/10.1016/j.envsci.2014.12.001

Rosentreter, J. A., Borges, A., Deemer, B. R., Holgerson, M. A., Liu, S., Song, C., Melack, J., Raymond, P. A., Duarte, C. M., Allen, G. H., Olefeldt, D., Poulter, B., Battin, T. I., & Eyre, B. D. (2021). Half of global methane emissions come from highly variable aquatic ecosystem sources. *Nature Geoscience*, *14*(0). https://doi.org/10.1038/s41561-021-00715-2

Rouhani, M. H., Salehi-Abargouei, A., Surkan, P. J., & Azadbakht, L. (2014). Is there a relationship between red or processed meat intake and obesity? A systematic review and meta-analysis of observational studies. *Obesity Reviews*, *15*(9), 740–748. https://doi.org/10.1111/obr.12172

Rowe, E., Norton, L., McVittie, A., Watson, C., Wagner, M., Waterton, C., & Smith, L. (2025). Using fuzzy cognitive mapping to assess the sustainability impacts of transitioning to pasture-fed production in the UK beef sector. *Renewable Agriculture and Food Systems*, *40*, e1. https://doi.org/10.1017/S1742170524000206

Rubiales, D., Annicchiarico, P., Vaz Patto, M. C., & Julier, B. (2021). Legume Breeding for the Agroecological Transition of Global Agri-Food Systems: A European Perspective. *Frontiers in Plant Science*, *12*. https://doi.org/10.3389/fpls.2021.782574

Rui, Y., Murphy, D. V., Wang, X., & Hoyle, F. C. (2016). Microbial respiration, but not biomass, responded linearly to increasing light fraction organic matter input: Consequences for carbon sequestration. *Scientific Reports*, *6*(1), Article 1. https://doi.org/10.1038/srep35496

Runge, T., Latacz-Lohmann, U., Schaller, L., Todorova, K., Daugbjerg, C., Termansen, M., Liira, J., Le Gloux, F., Dupraz, P., Leppanen, J., Fogarasi, J., Vigh, E. Z., Bradfield, T., Hennessy, T., Targetti, S., Viaggi, D., Berzina, I., Schulp, C., Majewski, E., … Velazquez, F. J. B. (2022). Implementation of Eco-schemes in Fifteen European Union Member States. *EuroChoices*, *21*(2), 19–27. https://doi.org/10.1111/1746-692X.12352

Rutherford, M. C., & Powrie, L. W. (2013). Impacts of heavy grazing on plant species richness: A comparison across rangeland biomes of South Africa. *South African Journal of Botany*, *87*, 146–156. https://doi.org/10.1016/j.sajb.2013.03.020

Sakellariou, N. (2018). A historical perspective on the engineering ideologies of sustainability: The case of SLCA. *The International Journal of Life Cycle Assessment*, *23*(3), 445–455. https://doi.org/10.1007/s11367-016-1167-9

Sala, E., Mayorga, J., Bradley, D., Cabral, R. B., Atwood, T. B., Auber, A., Cheung, W., Costello, C., Ferretti, F., Friedlander, A. M., Gaines, S. D., Garilao, C., Goodell, W., Halpern, B. S., Hinson, A., Kaschner, K., Kesner-Reyes, K., Leprieur, F., McGowan, J., … Lubchenco, J. (2021). Protecting the global ocean for biodiversity, food and climate. *Nature*, *592*(7854), 397–402. https://doi.org/10.1038/s41586-021-03371-z

Säll, S., & Gren, I.-M. (2015). Effects of an environmental tax on meat and dairy consumption in Sweden. *Food Policy*, *55*, 41–53. https://doi.org/10.1016/j.foodpol.2015.05.008

Saner, C., Tassoni, D., Harcourt, B. E., Kao, K.-T., Alexander, E. J., McCallum, Z., Olds, T., Rowlands, A. V., Burgner, D. P., Simpson, S. J., Raubenheimer, D., Senior, A. M., Juonala, M., & Sabin, M. A. (2020). Evidence for Protein Leverage in Children and Adolescents with Obesity. *Obesity (Silver Spring, Md.)*, *28*(4), 822–829. https://doi.org/10.1002/oby.22755

Sans, P., & Combris, P. (2015). World meat consumption patterns: An overview of the last fifty years (1961–2011). *Meat Science*, *109*, 106–111. https://doi.org/10.1016/j.meatsci.2015.05.012

Santo, R. E., Kim, B. F., Goldman, S. E., Dutkiewicz, J., Biehl, E. M. B., Bloem, M. W., Neff, R. A., & Nachman, K. E. (2020). Considering Plant-Based Meat Substitutes and Cell-Based Meats: A Public Health and Food Systems Perspective. *Frontiers in Sustainable Food Systems*, *0*. https://doi.org/10.3389/fsufs.2020.00134

SAPEA. (2023). *Towards sustainable food consumption – Scientific Advice Mechanism*. https://scientificadvice.eu/advice/towards-sustainable-food-consumption/

Saraiva, S., Esteves, A., Oliveira, I., Mitchell, M., & Stilwell, G. (2020). Impact of pre-slaughter factors on welfare of broilers. *Veterinary and Animal Science*, *10*, 100146. https://doi.org/10.1016/j.vas.2020.100146

Satija, A., Bhupathiraju, S. N., Rimm, E. B., Spiegelman, D., Chiuve, S. E., Borgi, L., Willett, W. C., Manson, J. E., Sun, Q., & Hu, F. B. (2016). Plant-Based Dietary Patterns and Incidence of Type 2 Diabetes in US Men and Women: Results from Three Prospective Cohort Studies. *PLoS Medicine*, *13*(6), e1002039. https://doi.org/10.1371/journal.pmed.1002039

Scarborough, P., Bhatnagar, P., Wickramasinghe, K. K., Allender, S., Foster, C., & Rayner, M. (2011). The economic burden of ill health due to diet, physical inactivity, smoking, alcohol and obesity in the UK: An update to 2006-07 NHS costs. *Journal of Public Health (Oxford, England)*, *33*(4), 527–535. https://doi.org/10.1093/pubmed/fdr033

Schebesta, H., & Candel, J. (2020). Game-changing potential of the EU's Farm to Fork Strategy. *Nature Food*, *1*(10), Article 10. https://doi.org/10.1038/s43016-020-00166-9

Scheelbeek, P., Green, R., Papier, K., Knuppel, A., Alae-Carew, C., Balkwill, A., Key, T. J., Beral, V., & Dangour, A. D. (2020). Health impacts and environmental footprints of diets that meet the Eatwell Guide recommendations: Analyses of multiple UK studies. *BMJ Open*, *10*(8), e037554. https://doi.org/10.1136/bmjopen-2020-037554

Scherer, L., Tomasik, B., Rueda, O., & Pfister, S. (2018). Framework for integrating animal welfare into life cycle sustainability assessment. *The International Journal of Life Cycle Assessment*, *23*(7), 1476–1490. https://doi.org/10.1007/s11367-017-1420-x

Schiavo, M., Le Mouël, C., Poux, X., & Aubert, P.-M. (2023). The land use, trade, and global food security impacts of an agroecological transition in the EU. *Frontiers in Sustainable Food Systems*, *7*. https://doi.org/10.3389/fsufs.2023.1189952

Schillings, J., Bennett, R., & Rose, D. C. (2021). Exploring the Potential of Precision Livestock Farming Technologies to Help Address Farm Animal Welfare. *Frontiers in Animal Science*, *2*. https://doi.org/10.3389/fanim.2021.639678

Schlegel, L., Kleine, A. S., Doherr, M. G., & Fischer-Tenhagen, C. (2024). How to see stress in chickens: On the way to a Stressed Chicken Scale. *Poultry Science*, *103*(8), 103875. https://doi.org/10.1016/j.psj.2024.103875

Schmidt, K. (2011). Concepts of Animal Welfare in Relation to Positions in Animal Ethics. *Acta Biotheoretica*, *59*(2), 153–171. https://doi.org/10.1007/s10441-011-9128-y

Schuck-Paim, C., & Alonso, W. J. (2022). Productivity of mother pigs is lower, and mortality greater, in countries that still confine them in gestation crates. *F1000Research*, *11*, 564. https://doi.org/10.12688/f1000research.122042.2

Schüpbach, R., Wegmüller, R., Berguerand, C., Bui, M., & Herter-Aeberli, I. (2017). Micronutrient status and intake in omnivores, vegetarians and vegans in Switzerland. *European Journal of Nutrition*, *56*(1), 283–293. https://doi.org/10.1007/s00394-015-1079-7

Schutter, O. D. (2019). The Political Economy Approach to Food Systems Reform. *IDS Bulletin*, *50*(2), Article 2. https://doi.org/10.19088/1968-2019.115

Searchinger, T., Herrero, M., Yan, X., Wang, J., Beauchemin, K., & Kebreab, E. (2021). Opportunities to reduce methane emissions from global agriculture. *Faculty of Cornell University: Ithaca, NY, USA*. https://searchinger.princeton.edu/sites/g/files/toruqf4701/files/methane_discussion_paper_nov_2021.pdf

Sellami, M. H., Pulvento, C., Aria, M., Stellacci, A. M., & Lavini, A. (2019). A Systematic Review of Field Trials to Synthesize Existing Knowledge and Agronomic Practices on Protein Crops in Europe. *Agronomy*, *9*(6), Article 6. https://doi.org/10.3390/agronomy9060292

Semenchuk, P., Plutzar, C., Kastner, T., Matej, S., Bidoglio, G., Erb, K.-H., Essl, F., Haberl, H., Wessely, J., Krausmann, F., & Dullinger, S. (2022). Relative effects of land conversion and land-use intensity on terrestrial vertebrate diversity. *Nature Communications*, *13*(1), 615. https://doi.org/10.1038/s41467-022-28245-4

Sevenster, M., Luo, Z., Eady, S., & Grant, T. (2020). Including long-term soil organic carbon changes in life cycle assessment of agricultural products. *The International Journal of Life Cycle Assessment*, *25*(7), 1231–1241. https://doi.org/10.1007/s11367-019-01660-4

Sexton, A. E., Garnett, T., & Lorimer, J. (2019). Framing the future of food: The contested promises of alternative proteins. *Environment and Planning E: Nature and Space*, *2*, 251484861982700. https://doi.org/10.1177/2514848619827009

Shahid, M., Shah, P., Mach, K., Rodgers-Hunt, B., Finnigan, T., Frost, G., Neal, B., & Hadjikakou, M. (2024). The environmental impact of mycoprotein-based meat alternatives compared to plant-based meat alternatives: A systematic review. *Future Foods*, *10*, 100410. https://doi.org/10.1016/j.fufo.2024.100410

Shalloo, L., O' Donovan, M., Leso, L., Werner, J., Ruelle, E., Geoghegan, A., Delaby, L., & O'Leary, N. (2018). Review: Grass-based dairy systems, data and precision technologies. *Animal*, *12*, s262–s271. https://doi.org/10.1017/S175173111800246X

Shan, D. (2022). Enforcement of fishing Occupational Health and Safety (OHS) standards: Challenges in Atlantic Canada. *Marine Policy*, *145*, 105282. https://doi.org/10.1016/j.marpol.2022.105282

Shang, X., Scott, D., Hodge, A. M., English, D. R., Giles, G. G., Ebeling, P. R., & Sanders, K. M. (2016). Dietary protein intake and risk of type 2 diabetes: Results from the Melbourne Collaborative Cohort Study and a meta-analysis of prospective studies12. *The American Journal of Clinical Nutrition*, *104*(5), 1352–1365. https://doi.org/10.3945/ajcn.116.140954

Shanmugam, K., Bryngelsson, S., Östergren, K., & Hallström, E. (2023). Climate Impact of Plant-based Meat Analogues: A Review of Life Cycle Assessments. *Sustainable Production and Consumption*, *36*, 328–337. https://doi.org/10.1016/j.spc.2023.01.014

Shepon, A., Wu, T., Kremen, C., Dayan, T., Perfecto, I., Fanzo, J., Eshel, G., & Golden, C. D. (2023). Exploring scenarios for the food system–zoonotic risk interface. *The Lancet Planetary Health*, *7*(4), e329–e335. https://doi.org/10.1016/S2542-5196(23)00007-4

Sherrington, R., Carlile, C., & Healy, H. (2023, December 9). Big meat and dairy lobbyists turn out in record numbers at Cop28. *The Guardian*. https://www.theguardian.com/environment/2023/dec/09/big-meat-dairy-lobbyists-turn-out-record-numbers-cop28

Shkembi, B., & Huppertz, T. (2022). Calcium Absorption from Food Products: Food Matrix Effects. *Nutrients*, *14*(1), Article 1. https://doi.org/10.3390/nu14010180

Sholar, A. (2025). *“The Meat of the Future” Risks Capture by Today’s Monopolists*. Food & Power. https://www.foodandpower.net/latest/cellular-meat-funding-consolidation-potential

Siddique, M. R. H., Hossain, M., & Rashid, A. Z. M. M. (2023). The dilemma of prioritizing conservation over livelihoods: Assessing the impact of fishing restriction to the fishermen of the Sundarbans. *Trees, Forests and People*, *11*, 100366. https://doi.org/10.1016/j.tfp.2022.100366

Siddiqui, S. A., Pleissner, D., Pentjuss, A., Gołaszewski, J., Karwowska, A., Dace, E., Pahmeyer, M., Van Miert, S., Frooninckx, L., Broeckx, L., Heinz, V., & Smetana, S. (2023). Biological nitrogen recirculation to food protein – A review. *Cleaner and Circular Bioeconomy*, 100056. https://doi.org/10.1016/j.clcb.2023.100056

Siegrist, A., Green, A., Michel, F., & Mathys, A. (2024). Comparing the nutritional value and prices of meat and milk substitutes with their animal-based benchmarks across six European countries. *Food Research International*, *197*, 115213. https://doi.org/10.1016/j.foodres.2024.115213

Siegrist, M., Michel, F., & Hartmann, C. (2024). The shift from meat to plant-based proteins: Consumers and public policy. *Current Opinion in Food Science*, 101182. https://doi.org/10.1016/j.cofs.2024.101182

Sievert, K., Lawrence, M., Parker, C., & Baker, P. (2024). How power in corporate-industrial meat supply chains enables negative externalities: Three case studies from Brazil, the US, and Australia. *One Earth*, *7*. https://doi.org/10.1016/j.oneear.2024.07.004

Sigsgaard, T., Basinas, I., Doekes, G., de Blay, F., Folletti, I., Heederik, D., Lipinska-Ojrzanowska, A., Nowak, D., Olivieri, M., Quirce, S., Raulf, M., Sastre, J., Schlünssen, V., Walusiak-Skorupa, J., & Siracusa, A. (2020). Respiratory diseases and allergy in farmers working with livestock: A EAACI position paper. *Clinical and Translational Allergy*, *10*(1), 29. https://doi.org/10.1186/s13601-020-00334-x

Simitzis, P., Tzanidakis, C., Tzamaloukas, O., & Sossidou, E. (2022). Contribution of Precision Livestock Farming Systems to the Improvement of Welfare Status and Productivity of Dairy Animals. *Dairy*, *3*(1), Article 1. https://doi.org/10.3390/dairy3010002

Simon, W. J., Hijbeek, R., Frehner, A., Cardinaals, R., Talsma, E. F., & van Zanten, H. H. E. (2024). Circular food system approaches can support current European protein intake levels while reducing land use and greenhouse gas emissions. *Nature Food*, *5*(5), 402–412. https://doi.org/10.1038/s43016-024-00975-2

Simpson, S. J., & Raubenheimer, D. (2005). Obesity: The protein leverage hypothesis. *Obesity Reviews*, *6*(2), 133–142. https://doi.org/10.1111/j.1467-789X.2005.00178.x

Sinha, R., Cross, A. J., Graubard, B. I., Leitzmann, M. F., & Schatzkin, A. (2009). Meat Intake and Mortality: A Prospective Study of Over Half a Million People. *Archives of Internal Medicine*, *169*(6), 562–571. https://doi.org/10.1001/archinternmed.2009.6

Sinke, P., Swartz, E., Sanctorum, H., van der Giesen, C., & Odegard, I. (2023). Ex-ante life cycle assessment of commercial-scale cultivated meat production in 2030. *The International Journal of Life Cycle Assessment*, *28*(3), 234–254. https://doi.org/10.1007/s11367-022-02128-8

Skerritt, D. J., Arthur, R., Ebrahim, N., Le Brenne, V., Le Manach, F., Schuhbauer, A., Villasante, S., & Sumaila, U. R. (2020). A 20-year retrospective on the provision of fisheries subsidies in the European Union. *ICES Journal of Marine Science*, *77*(7–8), 2741–2752. https://doi.org/10.1093/icesjms/fsaa142

Skogstad, G. (1998). Ideas, Paradigms and Institutions: Agricultural Exceptionalism in the European Union and the United States. *Governance*, *11*(4), 463–490. https://doi.org/10.1111/0952-1895.00082

Slade, J., & Alleyne, E. (2023). The Psychological Impact of Slaughterhouse Employment: A Systematic Literature Review. *Trauma, Violence, & Abuse*, *24*(2), 429–440. https://doi.org/10.1177/15248380211030243

Sluijs, I., Beulens, J. W. J., van der A, D. L., Spijkerman, A. M. W., Grobbee, D. E., & van der Schouw, Y. T. (2010). Dietary intake of total, animal, and vegetable protein and risk of type 2 diabetes in the European Prospective Investigation into Cancer and Nutrition (EPIC)-NL study. *Diabetes Care*, *33*(1), 43–48. https://doi.org/10.2337/dc09-1321

Smetana, S., Mathys, A., Knoch, A., & Heinz, V. (2015). Meat alternatives: Life cycle assessment of most known meat substitutes. *The International Journal of Life Cycle Assessment*, *20*(9), 1254–1267. https://doi.org/10.1007/s11367-015-0931-6

Smetana, S., Ristic, D., Pleissner, D., Tuomisto, H. L., Parniakov, O., & Heinz, V. (2023). Meat substitutes: Resource demands and environmental footprints. *Resources, Conservation and Recycling*, *190*, 106831. https://doi.org/10.1016/j.resconrec.2022.106831

Smith, A. (2007). Seafarer Fatigue: The Cardiff Research Programme. *Seaways*.

Smith, A. G., Croft, M. T., Moulin, M., & Webb, M. E. (2007). Plants need their vitamins too. *Current Opinion in Plant Biology*, *10*(3), 266–275. https://doi.org/10.1016/j.pbi.2007.04.009

Smith, K. G., Scheelbeek, P., Balmford, A., Alexander, P., & Garnett, E. E. (2021). Discrepancies between two long-term dietary datasets in the United Kingdom (UK). *Wellcome Open Research*, *6*, 350. https://doi.org/10.12688/wellcomeopenres.17245.3

Smith, K., Watson, A. W., Lonnie, M., Peeters, W. M., Oonincx, D., Tsoutsoura, N., Simon-Miquel, G., Szepe, K., Cochetel, N., Pearson, A. G., Witard, O. C., Salter, A. M., Bennett, M., & Corfe, B. M. (2024). Meeting the global protein supply requirements of a growing and ageing population. *European Journal of Nutrition*, *63*(5), 1425–1433. https://doi.org/10.1007/s00394-024-03358-2

Sneddon, L. U., Elwood, R. W., Adamo, S. A., & Leach, M. C. (2014). Defining and assessing animal pain. *Animal Behaviour*, *97*, 201–212. https://doi.org/10.1016/j.anbehav.2014.09.007

Soedamah-Muthu, S. S., & de Goede, J. (2018). Dairy Consumption and Cardiometabolic Diseases: Systematic Review and Updated Meta-Analyses of Prospective Cohort Studies. *Current Nutrition Reports*, *7*(4), 171–182. https://doi.org/10.1007/s13668-018-0253-y

Soto Mas, F., Handal ,Alexis J., Rohrer ,Rose E., & and Tomalá Viteri, E. (2018). Health and Safety in Organic Farming: A Qualitative Study. *Journal of Agromedicine*, *23*(1), 92–104. https://doi.org/10.1080/1059924X.2017.1382409

Spendrup, S., & Hovmalm, H. P. (2022). Consumer attitudes and beliefs towards plant-based food in different degrees of processing – The case of Sweden. *Food Quality and Preference*, *102*, 104673. https://doi.org/10.1016/j.foodqual.2022.104673

Springmann, M. (2024). A multicriteria analysis of meat and milk alternatives from nutritional, health, environmental, and cost perspectives. *Proceedings of the National Academy of Sciences*, *121*(50), e2319010121. https://doi.org/10.1073/pnas.2319010121

Springmann, M., Clark, M. A., Rayner, M., Scarborough, P., & Webb, P. (2021). The global and regional costs of healthy and sustainable dietary patterns: A modelling study. *The Lancet Planetary Health*, *5*(11), e797–e807. https://doi.org/10.1016/S2542-5196(21)00251-5

Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B. L., Lassaletta, L., de Vries, W., Vermeulen, S. J., Herrero, M., Carlson, K. M., Jonell, M., Troell, M., DeClerck, F., Gordon, L. J., Zurayk, R., Scarborough, P., Rayner, M., Loken, B., Fanzo, J., … Willett, W.

(2018). Options for keeping the food system within environmental limits. *Nature*, *562*(7728), Article 7728. https://doi.org/10.1038/s41586-018-0594-0

Stehfest, E., Vuuren, D., Kram, T., Bouwman, A., Alkemade, R., Bakkenes, M., Biemans, H., Bouwman, A., Elzen, M., Janse, J., Lucas, P., van Minnen, J., Müller, M., & Prins, A. (2014). *Integrated Assessment of Global Environmental Change with IMAGE 3.0. Model description and policy applications*.

Stěhulová, I., Lidfors, L., & Spinka, M. (2008). Response of dairy cows and calves to the early separation: Effect of calves' age and visual/auditory contact after separation. *Applied Animal Behaviour Science*, *110*, 144–165. https://doi.org/10.1016/j.applanim.2007.03.028

Steinfeld, H., Gerber, P. J., Wassenaar, T., Castel, V., Rosales, M., & Haan, C. de. (2006). *Livestock's long shadow: Environmental issues and options*. FAO. http://www.fao.org/publications/card/fr/c/9655af93-7f88-58fc-84e8-d70a9a4d8bec/

Stephens, N., Di Silvio, L., Dunsford, I., Ellis, M., Glencross, A., & Sexton, A. E. (2018). Bringing cultured meat to market: Technical, socio-political, and regulatory challenges in cellular agriculture. *Trends in Food Science & Technology*, *78*, 155–166. https://doi.org/10.1016/j.tifs.2018.04.010

Stephens, T. V., Payne, M., Ball, R. O., Pencharz, P. B., & Elango, R. (2015). Protein Requirements of Healthy Pregnant Women during Early and Late Gestation Are Higher than Current Recommendations1, 2, 3, 4. *The Journal of Nutrition*, *145*(1), 73–78. https://doi.org/10.3945/jn.114.198622

Stull, V. j. (2021). Impacts of insect consumption on human health. *Journal of Insects as Food and Feed*, *7*(5), 695–713. https://doi.org/10.3920/JIFF2020.0115

Su, W., Zhang, Y. Y., & Sheng, J. (2024). Consumers' willingness to pay for alternative protein food products: Taste preference, health, and environmental concerns. *Applied Economics*, *0*(0), 1–17. https://doi.org/10.1080/00036846.2024.2408035

Subar, A. F., Freedman, L. S., Tooze, J. A., Kirkpatrick, S. I., Boushey, C., Neuhouser, M. L., Thompson, F. E., Potischman, N., Guenther, P. M., Tarasuk, V., Reedy, J., & Krebs-Smith, S. M. (2015). Addressing Current Criticism Regarding the Value of Self-Report Dietary Data. *The Journal of Nutrition*, *145*(12), 2639–2645. https://doi.org/10.3945/jn.115.219634

Sutherland, M. A. (2015). Welfare implications of invasive piglet husbandry procedures, methods of alleviation and alternatives: A review. *New Zealand Veterinary Journal*. https://www.tandfonline.com/doi/abs/10.1080/00480169.2014.961990

Sutherland, M. A., Ballou, M. A., Davis, B. L., & Brooks, T. A. (2013). Effect of castration and dehorning singularly or combined on the behavior and physiology of Holstein calves1. *Journal of Animal Science*, *91*(2), 935–942. https://doi.org/10.2527/jas.2012-5190

Swedish Food Agency. (2021). *Food for you who are pregnant*. https://www.livsmedelsverket.se/en/food-habits-health-and-environment/dietary-guidelines/food-for-you-who-are-pregnant

Swing, C., Thompson, T., Guimaraes, O., Geornaras, I., Engle, T., Belk, K., Gifford, C., & N. Nair, M. (2021). Nutritional Composition of Novel Plant-Based Meat Alternatives and Traditional Animal-Based Meats. *Food Science and Nutrition*, *7*. https://doi.org/10.24966/FSN-1076/100109

TABLE Debates. (2020). *GWP*: Methane, metrics and confounding science and policy | TABLE Debates*. https://tabledebates.org/essay/gwp-methane-metrics-and-confounding-science-and-policy

TABLE Debates. (2024). *Nitrogen in the Food System | TABLE Debates*. https://tabledebates.org/building-blocks/nitrogen-food-system

Tahamtani, F. M., Pedersen, I. J., & Riber, A. B. (2019). Effects of environmental complexity on welfare indicators of fast-growing broiler chickens. *Poultry Science*, *99*(1), 21–29. https://doi.org/10.3382/ps/pez510

Takenaka, S., Sugiyama, S., Ebara, S., Miyamoto, E., Abe, K., Tamura, Y., Watanabe, F., Tsuyama, S., & Nakano, Y. (2001). Feeding dried purple laver (nori) to vitamin B12-deficient rats significantly improves vitamin B12 status. *The British Journal of Nutrition*, *85*(6), 699–703. https://doi.org/10.1079/bjn2001352

Temple, D., & Manteca, X. (2020). Animal Welfare in Extensive Production Systems Is Still an Area of Concern. *Frontiers in Sustainable Food Systems*, *4*. https://www.frontiersin.org/articles/10.3389/fsufs.2020.545902

Thoma, G., Blackstone, N., Nemecek, T., & Jolliet, O. (2022). *Life cycle assessment of food systems and diets* (pp. 37–62). https://doi.org/10.1016/B978-0-12-822112-9.00004-7

Thomassen, M. A., Dalgaard, R., Heijungs, R., & de Boer, I. (2008). Attributional and consequential LCA of milk production. *The International Journal of Life Cycle Assessment*, *13*(4), 339–349. https://doi.org/10.1007/s11367-008-0007-y

Thomsen, S. T., Pires, S. M., Devleesschauwer, B., Poulsen, M., Fagt, S., Ygil, K. H., & Andersen, R. (2018). Investigating the risk-benefit balance of substituting red and processed meat with fish in a Danish diet. *Food and Chemical Toxicology*, *120*, 50–63. https://doi.org/10.1016/j.fct.2018.06.063

Thorvaldsen, T., Kongsvik, T., Holmen, I. M., Størkersen, K., Salomonsen, C., Sandsund, M., & Bjelland, H. V. (2020). Occupational health, safety and work environments in Norwegian fish farming—Employee perspective. *Aquaculture*, *524*, 735238. https://doi.org/10.1016/j.aquaculture.2020.735238

Thorvaldsen, T., Sønvisen, S. A., & Holmen, I. M. (2022). The impact of fisheries management on fishers' health and safety: A case study from Norway. *Marine Policy*, *140*, 105066. https://doi.org/10.1016/j.marpol.2022.105066

Thurstan, R. H., & Roberts, C. M. (2014). The past and future of fish consumption: Can supplies meet healthy eating recommendations? *Marine Pollution Bulletin*, *89*(1–2), 5–11. https://doi.org/10.1016/j.marpolbul.2014.09.016

Tiano, J., De Borger, E., Paradis, S., Bradshaw, C., Morys, C., Pusceddu, A., Ennas, C., Soetaert, K., Puig, P., Masqué, P., & Sciberras, M. (2024). Global meta-analysis of demersal fishing impacts on organic carbon and associated biogeochemistry. *Fish and Fisheries*, *25*(6), 936–950. https://doi.org/10.1111/faf.12855

Tijhuis, M., Ezendam, J., Westenbrink, S., van Rossum, C., & Temme, L. (2011). *Replacement of meat and dairy by more sustainable protein sources in the Netherlands Quality of the diet*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.rivm.nl/bibliotheek/rapporten/350123001.pdf

Tlusty, M. F., Tyedmers, P., Bailey, M., Ziegler, F., Henriksson, P. J. G., Béné, C., Bush, S., Newton, R., Asche, F., Little, D. C., Troell, M., & Jonell, M. (2019). Reframing the sustainable seafood narrative. *Global Environmental Change*, *59*, 101991. https://doi.org/10.1016/j.gloenvcha.2019.101991

Toh, D. W. K., Srv, A., & Henry, C. J. (2022). Unknown impacts of plant-based meat alternatives on long-term health. *Nature Food*, *3*(2), 90–91. https://doi.org/10.1038/s43016-022-00463-5

Tomás, M., Behrens, J. W., Nielsen, D. B., Sparrevohn, C. R., Gesto, M., McEvoy, F., & Gräns, A. (2024). Investigating the effects of pelagic trawling on the welfare of Atlantic herring (Clupea harengus). *Scientific Reports*, *14*, 17530. https://doi.org/10.1038/s41598-024-68629-8

Tonstad, S., Butler, T., Yan, R., & Fraser, G. E. (2009). Type of Vegetarian Diet, Body Weight, and Prevalence of Type 2 Diabetes. *Diabetes Care*, *32*(5), 791–796. https://doi.org/10.2337/dc08-1886

Tonstad, S., Stewart, K., Oda, K., Batech, M., Herring, R. P., & Fraser, G. E. (2013). Vegetarian diets and incidence of diabetes in the Adventist Health Study-2. *Nutrition, Metabolism and Cardiovascular Diseases*, *23*(4), 292–299. https://doi.org/10.1016/j.numecd.2011.07.004

Torpman, O., & Röcklinsberg, H. (2021). Reinterpreting the SDGs: Taking Animals into Direct Consideration. *Sustainability*, *13*(2), Article 2. https://doi.org/10.3390/su13020843

Toutirais, L., Vaysse, C., Gueugneau, M., & Walrand, S. (n.d.). Plant proteins: Are they a good alternative to animal proteins in older people? *Current Opinion in Clinical Nutrition & Metabolic Care*, 10.1097/MCO.0000000000001026. https://doi.org/10.1097/MCO.0000000000001026

Traylor, D. A., Gorissen, S. H. M., & Phillips, S. M. (2018). Perspective: Protein Requirements and Optimal Intakes in Aging: Are We Ready to Recommend More Than the Recommended Daily Allowance? *Advances in Nutrition*, *9*(3), 171–182. https://doi.org/10.1093/advances/nmy003

Trewern, J., Chenoweth, J., Christie, I., Keller, E., & Halevy, S. (2021). Are UK retailers well placed to deliver 'less and better' meat and dairy to consumers? *Sustainable Production and Consumption*, *28*, 154–163. https://doi.org/10.1016/j.spc.2021.03.037

Trigo, J. P., Palmnäs-Bédard, M., Juanola, M. V.-L., & Undeland, I. (2023). Effects of whole seaweed consumption on humans: Current evidence from randomized-controlled intervention trials, knowledge gaps, and limitations. *Frontiers in Nutrition*, *10*, 1226168. https://doi.org/10.3389/fnut.2023.1226168

Trinomics, Bognar, J., Lam, L., Forestier, O., Finesso, A., Bolscher, H., Springer, K., Nesbit, M., Nadeu, E., Hiller, N., Dijk, R. van, Jakob, M., Tarpey, J., McDonald, H., Zakkour, P., Heller, C., Görlach, B., Scheid, A., & Tremblay, L.-L. (2023). *Pricing agricultural emissions and rewarding climate action in the agri-food value chain*. Publications Office of the European Union. https://data.europa.eu/doi/10.2834/200

Tripolskaja, L., Kazlauskaite-Jadzevice, A., & Razukas, A. (2023). Organic Carbon, Nitrogen Accumulation and Nitrogen Leaching as Affected by Legume Crop Residues on Sandy Loam in the Eastern Baltic Region. *Plants*, *12*(13), 2478. https://doi.org/10.3390/plants12132478

Troell, M., Naylor, R. L., Metian, M., Beveridge, M., Tyedmers, P. H., Folke, C., Arrow, K. J., Barrett, S., Crépin, A.-S., Ehrlich, P. R., Gren, A., Kautsky, N., Levin, S. A., Nyborg, K., Österblom, H., Polasky, S., Scheffer, M., Walker, B. H., Xepapadeas, T., & de Zeeuw, A. (2014). Does aquaculture add resilience to the global food system? *Proceedings of the National Academy of Sciences of the United States of America*, *111*(37), 13257–13263. https://doi.org/10.1073/pnas.1404067111

Truchot, D., & Andela, M. (2018). Burnout and hopelessness among farmers: The Farmers Stressors Inventory. *Social Psychiatry and Psychiatric Epidemiology*, *53*(8), 859–867. https://doi.org/10.1007/s00127-018-1528-8

Tso, R., Lim, A. J., & Forde, C. G. (2021). A Critical Appraisal of the Evidence Supporting Consumer Motivations for Alternative Proteins. *Foods*, *10*(1), Article 1. https://doi.org/10.3390/foods10010024

Tubay, J. M., Suzuki, K., Uehara, T., Kakishima, S., Ito, H., Ishida, A., Yoshida, K., Mori, S., Rabajante, J. F., Morita, S., Yokozawa, M., & Yoshimura, J. (2015). Microhabitat locality allows multi-species coexistence in terrestrial plant communities. *Scientific Reports*, *5*(1), 15376. https://doi.org/10.1038/srep15376

Tufford, A. R., Brennan, L., van Trijp, H., D'Auria, S., Feskens, E., Finglas, P., Kok, F., Kolesárová, A., Poppe, K., Zimmermann, K., & van 't Veer, P. (2023). A scientific transition to support the 21st century dietary transition. *Trends in Food Science & Technology*, *131*, 139–150. https://doi.org/10.1016/j.tifs.2022.11.021

Tukker, A. (2000). Philosophy of science, policy sciences and the basis of decision support with LCA Based on the toxicity controversy in Sweden and the Netherlands. *The International Journal of Life Cycle Assessment*, *5*(3), 177–186. https://doi.org/10.1007/BF02978621

Tullis, P. (2023, November 16). Nitrogen wars: The Dutch farmers' revolt that turned a nation upside-down. *The Guardian*. https://www.theguardian.com/environment/2023/nov/16/nitrogen-wars-the-dutch-farmers-revolt-that-turned-a-nation-upside-down

Tuomisto, H. L., Allan, S. J., & Ellis, M. J. (2022a). Prospective life cycle assessment of a bioprocess design for cultured meat production in hollow fiber bioreactors. *Science of The Total Environment*, *851*, 158051. https://doi.org/10.1016/j.scitotenv.2022.158051

Tuomisto, H. L., Allan, S. J., & Ellis, M. J. (2022b). Prospective life cycle assessment of a bioprocess design for cultured meat production in hollow fiber bioreactors. *Science of The Total Environment*, *851*, 158051. https://doi.org/10.1016/j.scitotenv.2022.158051

Turnhout, E., Neves, K., & de Lijster, E. (2014). 'Measurementality' in Biodiversity Governance: Knowledge, Transparency, and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (Ipbes). *Environment and Planning A: Economy and Space*, *46*(3), 581–597. https://doi.org/10.1068/a4629

Ulmann, L., & Benros, R. (2017). *Blue Growth Strategy* (No. 47; The European Files, p. 44).

UNFCCC. (2023). *COP 28: What Was Achieved and What Happens Next? | UNFCCC*. https://unfccc.int/cop28/5-key-takeaways

Upcraft, T., Tu, W.-C., Johnson, R., Finnigan, T., Hung, N. V., Hallett, J., & Guo, M. (2021). Protein from renewable resources: Mycoprotein production from agricultural residues. *Green Chemistry*, *23*(14), 5150–5165. https://doi.org/10.1039/D1GC01021B

USDA. (n.d.). *USDA FoodData Central*. Retrieved October 2, 2024, from https://fdc.nal.usda.gov/fdc-app.html#/food-search?query=seaweed&type=SR%20Legacy

Uzunca, B., & Li, S.-C. (2018). How sustainable innovations win in the fish industry: Theorizing incumbent-entrant dynamics across aquaculture and fisheries. In *Handbook of Knowledge Management for Sustainable Water Systems* (pp. 133–156). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781119271659.ch6

Vallone, S., & Lambin, E. F. (2023). Public policies and vested interests preserve the animal farming status quo at the expense of animal product analogs. *One Earth*, *6*(9), 1213–1226. https://doi.org/10.1016/j.oneear.2023.07.013

Van Boeckel, T. P., Brower, C., Gilbert, M., Grenfell, B. T., Levin, S. A., Robinson, T. P., Teillant, A., & Laxminarayan, R. (2015). Global trends in antimicrobial use in food animals. *Proceedings of the National Academy of Sciences*, *112*(18), 5649–5654. https://doi.org/10.1073/pnas.1503141112

van de Vis, H., Kolarevic, J., Stien, L. H., Kristiansen, T. S., Gerritzen, M., van de Braak, K., Abbink, W., Sæther, B.-S., & Noble, C. (2020). Welfare of Farmed Fish in Different Production Systems and Operations. In T. S. Kristiansen, A. Fernö, M. A. Pavlidis, & H. van de Vis (Eds.), *The Welfare of Fish* (pp. 323–361). Springer International Publishing. https://doi.org/10.1007/978-3-030-41675-1_14

van der Giessen, J., Isken, L., & Tiemersma, E. (2004). *Zoonoses in Europe: A Risk to Public Health*.

van der Schatte Olivier, A., Jones, L., Vay, L. L., Christie, M., Wilson, J., & Malham, S. K. (2020). A global review of the ecosystem services provided by bivalve aquaculture. *Reviews in Aquaculture*, *12*(1), 3–25. https://doi.org/10.1111/raq.12301

van Selm, B., Frehner, A., de Boer, I. J. M., van Hal, O., Hijbeek, R., van Ittersum, M. K., Talsma, E. F., Lesschen, J. P., Hendriks, C. M. J., Herrero, M., & van Zanten, H. H. E. (2022). Circularity in animal production requires a change in the EAT-Lancet diet in Europe. *Nature Food*, 1–8. https://doi.org/10.1038/s43016-021-00425-3

van Selm, B., Hijbeek, R., van Ittersum, M. K., van Hal, O., van Middelaar, C. E., & de Boer, I. J. M. (2023). Recoupling livestock and feed production in the Netherlands to reduce environmental impacts. *Science of The Total Environment*, 165540. https://doi.org/10.1016/j.scitotenv.2023.165540

van Zanten, H. H. E., Herrero, M., Hal, O. V., Röös, E., Muller, A., Garnett, T., Gerber, P. J., Schader, C., & Boer, I. J. M. D. (2018). Defining a land boundary for sustainable livestock consumption. *Global Change Biology*, *24*(9), 4185–4194. https://doi.org/10.1111/gcb.14321

Vanham, D., Comero, S., Gawlik, B. M., & Bidoglio, G. (2018). The water footprint of different diets within European sub-national geographical entities. *Nature Sustainability*, *1*(9), 518–525. https://doi.org/10.1038/s41893-018-0133-x

Varghese, J. V., Sebastian, E. M., Iqbal, T., & Tom, A. A. (2021). Pesticide applicators and cancer: A systematic review. *Reviews on Environmental Health*, *36*(4), 467–476. https://doi.org/10.1515/reveh-2020-0121

Veit, W., & Browning, H. (2020). Perspectival pluralism for animal welfare. *European Journal for Philosophy of Science*, *11*(1), 9. https://doi.org/10.1007/s13194-020-00322-9

Velarde, A., & Dalmau, A. (2012). Animal welfare assessment at slaughter in Europe: Moving from inputs to outputs. *Meat Science*, *92*(3), 244–251. https://doi.org/10.1016/j.meatsci.2012.04.009

Veldhuizen, L. J. L., Berentsen, P. B. M., Boer, I. J. M. de, Vis, J. W. van de, & Bokkers, E. a. M. (2018). Fish welfare in capture fisheries: A review of injuries and mortality. *Fisheries Research*, *204*, 41–48. https://doi.org/10.1016/j.fishres.2018.02.001

Vellinga, R. E., Eykelenboom, M., Olthof, M. R., Steenhuis, I. H. M., de Jonge, R., & Temme, E. H. M. (2022). Less meat in the shopping basket. The effect on meat purchases of higher prices, an information nudge and the combination: A randomised controlled trial. *BMC Public Health*, *22*(1), 1137. https://doi.org/10.1186/s12889-022-13535-9

Velzeboer, R., Li, E., Gao, N., Sharp, P., & Oliffe, J. L. (2024). Masculinity, Meat, and Veg*nism: A Scoping Review. *American Journal of Men's Health*, *18*(2), 15579883241247173. https://doi.org/10.1177/15579883241247173

Verain, M. C. D., & Dagevos, H. (2022). Comparing meat abstainers with avid meat eaters and committed meat reducers. *Frontiers in Nutrition*, *9*. https://doi.org/10.3389/fnut.2022.1016858

Verbeke, W., Marcu, A., Rutsaert, P., Gaspar, R., Seibt, B., Fletcher, D., & Barnett, J. (2015). 'Would you eat cultured meat?': Consumers' reactions and attitude formation in Belgium, Portugal and the United Kingdom. *Meat Science*, *102*, 49–58. https://doi.org/10.1016/j.meatsci.2014.11.013

Verkuijl, C., Dutkiewicz, J., Scherer, L., Behrens, P., Lazarus, M., Hötzel, M. J., Nordquist, R., & Hayek, M. (2024). FAO's 1.5 °C roadmap for food systems falls short. *Nature Food*, 1–3. https://doi.org/10.1038/s43016-024-00950-x

Verly-Jr, E., de Carvalho, A. M., Marchioni, D. M. L., & Darmon, N. (2022). The cost of eating more sustainable diets: A nutritional and environmental diet optimisation study. *Global Public Health*, *17*(6), 1073–1086. https://doi.org/10.1080/17441692.2021.1900315

Verni, M., Rizzello, C. G., & Coda, R. (2019). Fermentation Biotechnology Applied to Cereal Industry By-Products: Nutritional and Functional Insights. *Frontiers in Nutrition*, *6*. https://doi.org/10.3389/fnut.2019.00042

Verraes, C., Van Boxstael, S., Van Meervenne, E., Van Coillie, E., Butaye, P., Catry, B., de Schaetzen, M.-A., Van Huffel, X., Imberechts, H., Dierick, K., Daube, G., Saegerman, C., De Block, J., Dewulf, J., & Herman, L. (2013). Antimicrobial Resistance in the Food Chain: A Review. *International Journal of Environmental Research and Public Health*, *10*(7), 2643–2669. https://doi.org/10.3390/ijerph10072643

Ververis, E., Ackerl, R., Azzollini, D., Colombo, P. A., de Sesmaisons, A., Dumas, C., Fernandez-Dumont, A., Ferreira da Costa, L., Germini, A., Goumperis, T., Kouloura, E., Matijevic, L., Precup, G., Roldan-Torres, R., Rossi, A., Svejstil, R., Turla, E., & Gelbmann, W. (2020). Novel foods in the European Union: Scientific requirements and challenges of the risk assessment process by the European Food Safety Authority. *Food Research International*, *137*, 109515. https://doi.org/10.1016/j.foodres.2020.109515

Vieux, F., Rémond, D., Peyraud, J.-L., & Darmon, N. (2022). Approximately Half of Total Protein Intake by Adults Must be Animal-Based to Meet Nonprotein, Nutrient-Based Recommendations, With Variations Due to Age and Sex. *The Journal of Nutrition*, *152*(11), 2514–2525. https://doi.org/10.1093/jn/nxac150

Viguiliouk, E., Stewart, S. E., Jayalath, V. H., Ng, A. P., Mirrahimi, A., De Souza, R. J., Hanley, A. J., Bazinet, R. P., Blanco Mejia, S., Leiter, L. A., Josse, R. G., Kendall, C. W. C., Jenkins, D. J. A., & Sievenpiper, J. L. (2015). Effect of Replacing Animal Protein with Plant Protein on Glycemic Control in Diabetes: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Nutrients*, *7*(12), Article 12. https://doi.org/10.3390/nu7125509

Vijver, M. (2005). *PROTEIN POLITICS*.

Vinnari, E., & Vinnari, M. (2022). Making the invisibles visible: Including animals in sustainability (and) accounting. *Critical Perspectives on Accounting*, *82*, 102324. https://doi.org/10.1016/j.cpa.2021.102324

Vissamsetti, N., Simon-Collins, M., Lin, S., Bandyopadhyay, S., Kuriyan, R., Sybesma, W., & Tomé, D. (2023). Local Sources of Protein in Low- and Middle-Income Countries: How to Improve the Protein Quality? *Current Developments in Nutrition*, 102049. https://doi.org/10.1016/j.cdnut.2023.102049

Vollmann, J., Fritz, C. N., Wagentristl, H., & Ruckenbauer, P. (2000). Environmental and genetic variation of soybean seed protein content under Central European growing conditions. *Journal of the Science of Food and Agriculture*, *80*(9), 1300–1306. https://doi.org/10.1002/1097-0010(200007)80:9<1300::AID-JSFA640>3.0.CO;2-I von Keyserlingk, M. A. G., Amorim Cestari, A., Franks, B., Fregonesi, J. A., & Weary, D. M. (2017). Dairy cows value access to pasture as highly as fresh feed. *Scientific Reports*, *7*(1), 44953. https://doi.org/10.1038/srep44953

Vranken, L., Avermaete, T., Petalios, D., & Mathijs, E. (2014). Curbing global meat consumption: Emerging evidence of a second nutrition transition. *Environmental Science & Policy*, *39*, 95–106. https://doi.org/10.1016/j.envsci.2014.02.009

Vullo, C., Barbieri, S., Catone, G., Graïc, J.-M., Magaletti, M., Di Rosa, A., Motta, A., Tremolada, C., Canali, E., & Dalla Costa, E. (2020). Is the Piglet Grimace Scale (PGS) a Useful Welfare Indicator to Assess Pain after Cryptorchidectomy in Growing Pigs? *Animals*, *10*(3), Article 3. https://doi.org/10.3390/ani10030412

Waldmann, A., Koschizke, J. W., Leitzmann, C., & Hahn, A. (2003). Dietary intakes and lifestyle factors of a vegan population in Germany: Results from the German Vegan Study. *European Journal of Clinical Nutrition*, *57*(8), 947–955. https://doi.org/10.1038/sj.ejcn.1601629

Walpole, S. C., Prieto-Merino, D., Edwards, P., Cleland, J., Stevens, G., & Roberts, I. (2012). The weight of nations: An estimation of adult human biomass. *BMC Public Health*, *12*, 439. https://doi.org/10.1186/1471-2458-12-439

Walters, J. P., Archer, D. W., Sassenrath, G. F., Hendrickson, J. R., Hanson, J. D., Halloran, J. M., Vadas, P., & Alarcon, V. J. (2016). Exploring agricultural production systems and their fundamental components with system dynamics modelling. *Ecological Modelling*, *333*, 51–65. https://doi.org/10.1016/j.ecolmodel.2016.04.015

Wang, C., Min, R., Zhou, Q., Qi, Y., Ma, Y., & Zhang, X. (2024). Multiple health outcomes associated with algae and its extracts supplementation: An umbrella review of systematic reviews and meta-analyses. *Phytotherapy Research*, *38*(11), 5162–5183. https://doi.org/10.1002/ptr.8305

Wang, H., Xu, J., Liu, X., Sheng, L., Zhang, D., Li, L., & Wang, A. (2018). Study on the pollution status and control measures for the livestock and poultry breeding industry in northeastern China. *Environmental Science and Pollution Research*, *25*(5), 4435–4445. https://doi.org/10.1007/s11356-017-0751-2

Wang, J., Liu, Q., Hou, Y., Qin, W., Lesschen, J. P., Zhang, F., & Oenema, O. (2018). International trade of animal feed: Its relationships with livestock density and N and P balances at country level. *Nutrient Cycling in Agroecosystems*, *110*(1), 197–211. https://doi.org/10.1007/s10705-017-9885-3

Wang, Y., Rassler, S., Stefanovski, D., Bender, J., Deutsch, J., Chen, T., Cui, Z., & Dou, Z. (2024). Evidence of animal productivity outcomes when fed diets including food waste: A systematic review of global primary data. *Resources, Conservation and Recycling*, *203*, 107411. https://doi.org/10.1016/j.resconrec.2024.107411

Watanabe, F., Yabuta, Y., Bito, T., & Teng, F. (2014). Vitamin B12-Containing Plant Food Sources for Vegetarians. *Nutrients*, *6*(5), Article 5. https://doi.org/10.3390/nu6051861

Webb, L. E., Verwer, C., & Bokkers, E. A. M. (2023). The future of surplus dairy calves – an animal welfare perspective. *Frontiers in Animal Science*, *4*. https://doi.org/10.3389/fanim.2023.1228770

Wehbe, L. H., Duncan, S., Banas, K., & Papies, E. K. (2024). To stand out or to conform: Stereotypes and meta-stereotypes as barriers in the transition to sustainable diets. *Appetite*, *200*, 107506. https://doi.org/10.1016/j.appet.2024.107506

Weiler, M., Hertzler, S. R., & Dvoretskiy, S. (2023). Is It Time to Reconsider the U.S. Recommendations for Dietary Protein and Amino Acid Intake? *Nutrients*, *15*(4), Article 4. https://doi.org/10.3390/nu15040838

Weis, T. (2016). *The Meatification of Diets* (pp. 124–136).

Welfare Quality. (2009). *Welfare Quality Network | Assessment Protocols*. https://www.welfarequalitynetwork.net/en-us/reports/assessment-protocols?utm_source=chatgpt.com

Werkheiser, I. (2020). Technology and responsibility: A discussion of underexamined risks and concerns in Precision Livestock Farming. *Animal Frontiers*, *10*(1), 51–57. https://doi.org/10.1093/af/vfz056

Werner, C., Reiners, K., & Wicke, M. (2007). Short as well as long transport duration can affect the welfare of slaughter pigs. *Animal Welfare*, *16*(3), 385–389. https://doi.org/10.1017/S0962728600027202

West, R., & Michie, S. (2020). A brief introduction to the COM-B Model of behaviour and the PRIME Theory of motivation. *Qeios*. https://doi.org/10.32388/WW04E6.2

Westerterp-Plantenga, M. S., Lemmens, S. G., & Westerterp, K. R. (2012). Dietary protein—Its role in satiety, energetics, weight loss and health. *The British Journal of Nutrition*, *108 Suppl 2*, S105-112. https://doi.org/10.1017/S0007114512002589

Westhoek, H., Rood, G., van den Berg, M., Janse, J., Nijdam, D., Reudink, M., Stehfest, E., Lesschen, J. P., Oenema, O., & Woltjer, G. (2011). The protein puzzle: The consumption and production of meat, dairy and fish in the European Union. *Eur. J. Food Res.Rev.*, *1*.

Wickramasinghe, K., Breda, J., Berdzuli, N., Rippin, H., Farrand, C., & Halloran, A. (2021). The shift to plant-based diets: Are we missing the point? *Global Food Security*, *29*, 100530. https://doi.org/10.1016/j.gfs.2021.100530

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L. J., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J. A., Vries, W. D., Sibanda, L. M., … Murray, C. J. L. (2019). Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet*, *393*(10170), Article 10170. https://doi.org/10.1016/S0140-6736(18)31788-4

Wilson, B. (2019, January 4). Protein mania: The rich world's new diet obsession. *The Guardian*. https://www.theguardian.com/news/2019/jan/04/protein-mania-the-rich-worlds-new-diet-obsession

Wolk, A. (2017). Potential health hazards of eating red meat. *Journal of Internal Medicine*, *281*(2), 106–122. https://doi.org/10.1111/joim.12543

Wood, A., Swan, J., Masino, T., Tørnqvist, B., & Röös, E. (2025). Meat is healthy, green and vital to social and economic sustainability: Frames used by the red meat industry during development of the Nordic Nutrition Recommendations. *Environmental Research: Food Systems*, *2*(1), 015010. https://doi.org/10.1088/2976-601X/ad8e6b

Woodhead, A. J., Abernethy, K. E., Szaboova, L., & Turner, R. A. (2018). Health in fishing communities: A global perspective. *Fish and Fisheries*, *19*(5), 839–852. https://doi.org/10.1111/faf.12295

Wright, G. (2022, September 6). *Dutch city of Haarlem may be world's first to ban most meat ads*. https://www.bbc.com/news/world-europe-62810867

Xia, S., Takakura, J., Wu, W., Blanchard, J. L., Heneghan, R. F., Yamakawa, T., Tsuchiya, K., Hasegawa, T., Fujimori, S., & Takahashi, K. (2023). Potential environmental and nutritional benefits of replacing ruminant meat with forage fish. *Sustainable Production and Consumption*, *40*, 265–276. https://doi.org/10.1016/j.spc.2023.07.005

Xie, C., Coda, R., Chamlagain, B., Edelmann, M., Varmanen, P., Piironen, V., & Katina, K. (2021). Fermentation of cereal, pseudo-cereal and legume materials with *Propionibacterium freudenreichii* and *Levilactobacillus brevis* for vitamin B12 fortification. *LWT*, *137*, 110431. https://doi.org/10.1016/j.lwt.2020.110431

Xu, X., Sharma, P., Shu, S., Lin, T.-S., Ciais, P., Tubiello, F. N., Smith, P., Campbell, N., & Jain, A. K. (2021). Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods. *Nature Food*, *2*(9), Article 9. https://doi.org/10.1038/s43016-021-00358-x

Yang, Y., Zheng, Y., Ma, W., Zhang, Y., Sun, C., & Fang, Y. (2023). Meat and plant-based meat analogs: Nutritional profile and *in vitro* digestion comparison. *Food Hydrocolloids*, *143*, 108886. https://doi.org/10.1016/j.foodhyd.2023.108886

Yeates, J. W. (2011). Is 'a life worth living' a concept worth having? *Animal Welfare*, *20*(3), 397–406. https://doi.org/10.1017/S0962728600002955

Yip, C. S. C., Yip, Y. C., & Chan, W. (2023). The associations of soya intakes with non-communicable diseases: A scoping review of meta-analyses. *British Journal of Nutrition*, *129*(1), 135–146. https://doi.org/10.1017/S0007114522000691

Young, J. F., Skrivergaard, S., Therkildsen, M., & Rasmussen, M. K. (2024). Cultured meat production—Scale and quality. *Cell Reports Sustainability*, *1*(1), 100012. https://doi.org/10.1016/j.crsus.2023.100012

Zaleskiewicz, H., Kulis, E., Siwa, M., Szczuka, Z., Banik, A., Grossi, F., Chrysochou, P., Nystrand, B. T., Perrea, T., Samoggia, A., Xhelili, A., Krystallis, A., & Luszczynska, A. (2024). Characteristics of built food environments associated with alternative protein food choices: A systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, *21*(1), 58. https://doi.org/10.1186/s12966-024-01606-6

Zapata-Cardona, J., Ceballos, M. C., & Rodríguez, B. de J. (2024). Music and Emotions in Non-Human Animals from Biological and Comparative Perspectives. *Animals*, *14*(10), Article 10. https://doi.org/10.3390/ani14101491

Zech, K. M., & Schneider, U. A. (2019). Carbon leakage and limited efficiency of greenhouse gas taxes on food products. *Journal of Cleaner Production*, *213*, 99–103. https://doi.org/10.1016/j.jclepro.2018.12.139

Zhang, Y., Peng, Z., Chang, S., Wang, Z., Li, D., An, Y., Hou, F., & Ren, J. (2022). Growing season grazing promotes the shallow stratification of soil nutrients while non-growing season grazing sequesters the deep soil nutrients in a typical alpine meadow. *Geoderma*, *426*, 116111. https://doi.org/10.1016/j.geoderma.2022.116111

Zhao, H., Chang, J., Havlík, P., van Dijk, M., Valin, H., Janssens, C., Ma, L., Bai, Z., Herrero, M., Smith, P., & Obersteiner, M. (2021). China's future food demand and its implications for trade and environment. *Nature Sustainability*, *4*(12), 1042–1051. https://doi.org/10.1038/s41893-021-00784-6

Zheng, Y., Wang, J., Wang, Y., Xu, K., & Chen, X. (2023). The Hidden Dangers of Plant-Based Diets Affecting Bone Health: A Cross-Sectional Study with U.S. National Health and Nutrition Examination Survey (NHANES) Data from 2005–2018. *Nutrients*, *15*(7), 1794. https://doi.org/10.3390/nu15071794

Ziegler, F., & Hornborg, S. (2014). Stock size matters more than vessel size: The fuel efficiency of Swedish demersal trawl fisheries 2002–2010. *Marine Policy*, *44*, 72–81. https://doi.org/10.1016/j.marpol.2013.06.015

Ziegler, F., & Hornborg, Sara. (2023). *Decarbonising the fishing sector: Energy efficiency measures and alternative energy solutions for fishing vessels | Think Tank | European Parliament*. https://www.europarl.europa.eu/thinktank/en/document/EPRS_STU(2023)740225

Ziegler, F., Tyedmers, P. H., & Parker, R. W. R. (2022). Methods matter: Improved practices for environmental evaluation of dietary patterns. *Global Environmental Change*, *73*, 102482. https://doi.org/10.1016/j.gloenvcha.2022.102482

Zwolińska, J., & Żakowska-Biemans, S. (2020). Is an Animal Welfare Label Enough? Role of Farm Animal Welfare Voluntary Labelling Schemes in the Development of Sustainable Livestock Production. *Proceedings*, *73*(1), Article 1. https://doi.org/10.3390/IECA2020-08831