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Nutritionism in a food policy context: the case of 'animal protein'

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ABSTRACT

Reductionist approaches to food focus on isolated nutritional criteria, ignoring the broader physiological and societal benefits and trade-offs involved. They can lead to the inadvertent or, potentially, intentional labelling of foods as good or bad. Both can be considered worrisome. Among our present-day array of issues is the disproportionate stigmatisation of animal-source foods as harmful for human and planetary health. The case for a protein transition reinforces this trend, overemphasising one particular nutritional constituent (even if an important one). In its strongest formulation, animal-source foods (reduced to the notion of 'animal protein') are represented as an intrinsically harmful food category that needs to be minimised, thereby falsely assuming that 'proteins' are nutritionally interchangeable. We caution against using the word 'protein' in food policy-making to describe a heterogenous set of foods. Rather, we suggest referring to said foods as 'protein-rich foods', while acknowledging the expanded pool of non-protein nutrients that they provide and their unique capabilities to support a much broader range of bodily functions. Several essential or otherwise beneficial nutrients are generally more bioavailable in animal-source foods than in plant-source foods. A similar complementarity exists in reverse. Nutritional and environmental metrics should be carefully interpreted, as considerable contextuality is involved. This needs to be undertaken, for instance, with respect to the biochemistry of food and in light of individual and genetically inherited human physiology. Also, the assessments of the environmental impact need a fine-grained approach, especially when examining a product at the system scale. Harms and benefits are multiple, multi-dimensional, and difficult to measure on the basis of the narrow sets of descriptive metrics that are often used (e.g. CO_2-eq/kg). A more appropriate way forward would consist of combining and integrating the best of animal and plant solutions to reconnect with wholesome and nourishing diets that are rooted in undervalued benefits such as conviviality and shared traditions, thus steering away from a nutrient-centric dogma. Humans do not consume isolated nutrients, they consume foods, and they do so as part of culturally complex dietary patterns that, despite their complexity, need to be carefully considered in food policy making.

Keywords: dairy, eggs, livestock, meat, plant-based, poultry, vegan, vegetarian.

Introduction

Nutritional *scientism*, or *nutritionism*, is the reductionist notion that food should be valued for its individual parts rather than the broader benefits offered, not only with respect to nourishment and health, but also regarding pleasure, i.e. hedonics and eudemonics, and cultural significance (Scrinis 2013; Carstairs 2014), in addition to other important community and ecosystem benefits (Horrocks *et al.* 2014; Provenza *et al.* 2021). As such, it condenses dietary advice to statements relating to a few favoured nutrients that are perceived as beneficial or benign (e.g. dietary fibre) or harmful (e.g. saturated fat). In reality, it is far more complicated than good versus bad nutrients, given that overall diet quality, quantity, food source, lifestyle and unique needs of individuals will play a major role in dictating health outcomes and whether a certain food or nutrient is 'problematic' or not. The basic nature of nutritionism decontextualises, simplifies and exaggerates the role of nutrients in human health and tends to conceal concerns related to food production and processing quality (Scrinis 2013). Nutritionism does not leave only the broader dietary context unaddressed, it also ignores, or downplays, conflicting scientific findings related to the nutrients it focusses on. This results in simplistic interpretations of their roles in bodily health and the illusion of nutritional and biomarker determinism (based on one-to-one, cause-and-effect relationships; Scrinis 2013). For instance, saturated fat comprises a suite of individual fatty acids with different physiological impacts on low-density lipoprotein cholesterol (Grundy 1994; Micha and Mozaffarian 2010), thereby providing a clear, contrasting example of simplified perspectives on nutrition. As a result, normal components of wholesome diets, including foods that contain saturated fat, can be unfairly portrayed as *de facto* unhealthy (Binnie *et al.* 2014; Gershuni 2018). Nutritionism thus manifests itself by oversimplifying complex science while simultaneously appealing to scientific authority to increase persuasiveness of its key messages, subsequently forcing public health authorities, consumer organisations, and the food industry into a fractured working paradigm (Jacobs and Orlich 2014). In the context of biopolitics, such nutritionism in action cannot only have unintended ethical implications for individual responsibility and freedom, but also lead to iatrogenic harm or other harmful impacts on societal wellbeing (Mayes and Thompson 2015).

A striking example of such a counterproductive approach is the excessive projection of contemporary dietary challenges on the notion of protein transition. The latter implies that the human population should shift to diets that restrict 'animal protein' (described usually with connotations of environmental- and health-related harm) and fill in the deficit with 'plant protein', often framed as 'plant-based alternatives' (Willett *et al.* 2019). There are many valid reasons, such as aforementioned concerns for health and the environment, to rethink contemporary diets (e.g. Western consumption patterns frequently involve high intakes of unhealthy foods), potentially leading to shifts in animal: plant ratios. However, we argue that naive binary and reductionist approaches that wish to resolve our food system's problems by simply arguing for a maximised replacement of animal protein by 'plant protein' hold no merit due to the overwhelming complexity of (a) the global food system and its (agricultural) constraints and (b) the human digestive system and metabolism. Eventually, this may cause more harm than benefit by ignoring many other food-related sustainability issues, such as the potential health (Hall *et al.* 2019; Costa de Miranda *et al.* 2021) and environmental impact of excessive ultra-processed food production and intake (Fardet and Rock 2020; Seferidi *et al.* 2020), the protection of national economies and local livelihoods, and the cultural relationships with foods, including those of animal origin (Leroy and Praet 2015). To sum up, nutritionism substantially oversimplifies the nutritional and environmental implications of a far-reaching protein transition.

Motivated by dangers of nutritional mis- and dis-information spreading, particularly given the rapid power of transmission via social media platforms, the present article explores unintended pitfalls of nutritionism approach related to the qualifier 'animal protein', hence pre-empting unhelpful conclusions and policies such a school of thought may result in.

Misleading category descriptors

Within dietary policy making and its intention to shift global diets, the denomination based on a single nutrient (i.e. protein) is often used to indicate much broader nutritional categories contained in animal and plant foods, despite each category being highly heterogeneous and biochemically complex to begin with. For example, each individual nutrient's potential uptake by humans, known as bioavailability, varies depending on the product carrying the said nutrient (e.g. protein), the individual's nutrient status, the over- or under-supply of a given nutrient in an individual's diet, the dietary pattern in which a given nutrient is consumed, and many other factors such as genetics, which affect how nutrients are absorbed and metabolised (Gibson *et al.* 2006; Beal *et al.* 2017). For instance, several nutrients in animal-source foods (e.g. amino acids, zinc, iron), tend to be more bioavailable than when they are obtained from plant foods (Ertl *et al.* 2016), which is sometimes due to the presence of anti-nutrients in plant foods, such as phytates (Gilani *et al.* 2012; Gibson *et al.* 2018). Describing animal-source foods or plants primarily as protein foods is especially noticeable in English scientific literature and policy documents, but is now also becoming more widespread globally. Whether either category is net harmful or beneficial (and should be consumed less or more) depends on the type of food, where and how it is produced, how it is prepared and consumed, and who is consuming it (and in the context of what diet), at which stage of life, in which condition of health, and in which socio-cultural foodscapes. While this certainly complicates food policy messaging, these factors need to be carefully considered in policy making.

As outlined elsewhere, there are various cultural and historical reasons to explain why this complexity has been narrowed down to the simplistic animal–plant divide we are currently experiencing (Leroy and Hite 2020; Leroy *et al.* 2020). This divide may be more related to social dynamics and anxieties of the urban centres of the West than to actual physiological or environmental considerations. As such, the terminology of animal protein has become commonplace for either the defence (e.g. Imai *et al.* 2014;

Thorisdottir et al. 2014; Eilert 2020; Yuan et al. 2021) or stigmatisation of animal-source foods in the context of health and/or sustainability (e.g. Tharrey et al. 2018; Sabaté et al. 2015; Chung et al. 2020; Huang et al. 2020; Zhao et al. 2020).

Although, as a nutrient, protein is certainly one of the cornerstones of food security worldwide, with 1 billion people being estimated to have inadequate intake (Wu et al. 2014), the argument for deep systemic change with protein as a main target overlooks the many other roles and contributions of food, whether it be biological (e.g. provision of lesser-discussed micronutrients such as iron, selenium and zinc), socio-economical (e.g. maintaining animals as economic assets or for familial prestige or farm work), or cultural (e.g. religious significance, gastronomic legacy and regional identities). Ideally, food policy should be a holistic assessment of nourishment, livelihoods, ecology and culture, rather than a narrow attempt to create a measurable change in a specific nutrient through the use of specific levers (taxes, dietary guidelines, etc.) In reality, the role of what is described as 'protein' is one that also touches on such significant community aspects, including ethnicity, religion and education (Drewnowski et al. 2020). Nutricentric policies, therefore, undermine the multiple other ways humans engage with and understand food (Scrinis 2013).

Below, we will specifically focus on the nutritional and environmental implications of a nutritionism-driven outlook on the place of animal-source foods in dietary change, without assuming that the other societal aspects mentioned above would be of lesser importance.

Nutritional implications

The substitution of plant protein for animal protein comes with several nutritional constraints. A first point of attention is that the interchangeability of animal and plant proteins on a per mass basis is not straightforward. Not only should both the amounts and the spectrum of essential amino acids be considered, but differences in protein digestibility can also create considerable variation in protein value. Although the latter effect can be attenuated through more intense processing, as for pea protein isolate compared with cooked peas (Rutherfurd et al. 2015), the digestibility of plant protein is often reduced due to structural resistance, fibre and anti-nutritional factors (Wolfe et al. 2018; Sá et al. 2020). Animal-source foods are highly digestible while generally offering amino acids that may otherwise be in short supply, leading to a higher whole body (Park et al. 2021) and skeletal muscle anabolic response (van Vliet et al. 2015) than do plant proteins.

While food policy reports often discuss animal and plant proteins as being exchangeable (Willett et al. 2019; WBCSD 2020), plant proteins consistently show a reduced anabolic potential when considered both in terms of ounce-equivalents (Park et al. 2021) and as gram-for-gram protein comparisons (Wilkinson et al. 2007; Phillips 2012; Gorissen et al. 2016). Therefore, such narrative assumes that all proteins are equal and exchangeable, which they are not. It is only at very high intakes (likely 35–60 g per meal; Phillips 2012; Yang et al. 2012; Gorissen et al. 2016) or >1.6 g protein/kg bodyweight.day (Hevia-Larraín et al. 2021) that the anabolic potential between protein-rich plant and animal foods may become comparable, although mixed meal feeding (animal sources complemented with plant sources) can overcome the lower anabolic potential of plant sources (Reidy et al. 2013). The dose-responsiveness issue is not trivial, as it is often stated that we eat too much protein (Fontana and Partridge 2015; Longo et al. 2015), and that policy targets, such as the RDA value, recommend a daily intake of 0.8 g per kg body weight (Institute of Medicine 2002). Although the latter can be considered as a minimal level for protein intake to avoid deficiency and loss of lean body mass in healthy young adults, it is not necessarily optimal and is considered insufficient for certain populations (Layman 2009; Phillips et al. 2020). Many could benefit from substantially higher protein intakes to increase or maintain lean body mass, reduce fat mass, and maintain good health (Tagawa et al. 2021). This is especially valid for individuals with elevated needs, such as, pregnant and lactating women, the elderly, the acutely or chronically diseased, athletes, and others who are looking to increase skeletal muscle (Bauer et al. 2013; Semba et al. 2016; Traylor et al. 2018; Groenendijk et al. 2019; Rasmussen et al. 2020; Meroño et al. 2021).

Second, the protein transition policy framework creates a disproportionate focus on protein a such. Yet, one should bear in mind that protein-rich foods, largely regardless of being animal- or plant-based, are not just providing protein, but also offer a wide range of other essential nutrients, and thereby have unique capabilities to support a much broader range of bodily functions. For example, animal-source foods are optimal sources (in terms of density) of commonly lacking micronutrients globally, which can have severe impacts on health and wellbeing, including iron, vitamin A, zinc, folate, vitamin B12 and calcium (Beal et al. 2021; White et al. 2021). Several essential or otherwise beneficial nutrients are generally more bioavailable in animal-source foods than in plant-source foods (e.g. zinc, iron, vitamin A, omega-3 fatty acids, protein) or (nearly) exclusively available in animal-source foods (e.g. vitamin B12, dietary vitamin D, creatine, carnosine, taurine, anserine). To make the determination of a single, optimally sustainable source of protein even more complicated, a similar nutritional complementarity exists in reverse. Namely, certain plant-based proteins, particularly unprocessed or minimally processed sources, provide fibre, phytochemicals, and several micronutrients (e.g. vitamin C, vitamin E, magnesium and manganese) that are more difficult to obtain from animal-derived foods

(Zhu *et al.* 2018; Päivärinta *et al.* 2020). It should also be noted that while animals can provide organic fertiliser, leguminous plants such as white clover can replenish soils with nitrogen through atmospheric fixation, further demonstrating the complexities, but also the complementarities, of a sustainable food system; namely; the answer is not black and white and various food producers need to work together to ensure circularity and maximisation of resource utilisation. This suggests that an appropriate complementary balance between animal and plant foods may offer the most holistic benefits and robust dietary angle, whereby protein is just part of the equation, albeit an important one.

Third, a potential concern with respect to the protein transition relates to the heavily promoted option of plant-based imitation products that are aiming to displace animal protein forms (e.g. meat, dairy and eggs). While increased consumption of minimally processed legumes and pulses has been associated with improved health in Western diet patterns (Richter *et al.* 2015), some authors have cautioned against extending this finding to novel plant-based (meat) imitation products (Hu *et al.* 2019). Several plant-based imitation products can be categorised as processed-reconstituted foods with little direct relation to whole foods, being made from refined or extracted ingredients thereof, in addition to synthesised chemicals (Scrinis 2013). Some imitation products correspond broadly to the category of ultraprocessed foods, a dietary group that is associated with the westernisation of diets and consists of 'branded, convenient (durable, ready-to-consume), attractive (hyper-palatable) and highly profitable (low-cost ingredients) food products' (cf. Monteiro *et al.* 2018). As a larger category, and acknowledging that there is considerable heterogeneity within that group and often issues of confounding (Scrinis 2013), ultra-processed foods have been associated with health disorders (Costa de Miranda *et al.* 2021; Ostfeld and Allen 2021; Zhang *et al.* 2021) and are known to increase daily *ad libitum* calorie intake (Hall *et al.* 2019), while some of their specific constituents raise concern on a more mechanistic basis. It is only recently that we have begun to consider the possibility that several food additives, typically considered safe, could also have less measurable effects on health via modulation of the gut microbiota. This seems to be the case for emulsifiers and texturisers (Halmos *et al.* 2019), trehalose (Collins *et al.* 2018) and artificial sweeteners (Suez *et al.* 2014). A multitude of such additives is required for food engineering purposes, because of the many difficulties associated with the mimicking of complex animal-source food matrices starting from plant protein isolates, starches, and/or refined oils that lack the proper flavour, colour and texture. There is a historical parallel with highly processed spreads, which were aiming to imitate butter (and ultimately to be 'better' than the original, or hyper-real), but required various additives to simulate the appearance, taste, texture, and nutrient profile of the original (Scrinis 2013). This is probably also the reason why the presented solutions are offered as fast-food products, rather than wholesome foods, as the latter are still too challenging to imitate. Yet, the concern goes beyond these specific additives; is what is conventionally assessed as safe, through toxicological assessment, not overlooking more subtle and long-term effects on human health? Or, are the highly engineered foods that are now presented as alternatives for traditional protein-source foods sufficiently robust to form the basis for a mass dietary transition, which would consist of replacing foods such as meat, legumes, nuts, eggs, fish and dairy, all of which have been part of human diets for millennia, by very recent fabrications with no historical validation of providing human sustenance? This does not imply that there is no potential place for such products in current and future food choices, especially for those people preferring to minimise their intake of foods from animal origin. Initial work suggests that plant-based imitations of animal source foods can be part of healthy omnivorous diets (e.g. Gardner *et al.* 2007; Toribio-Mateas *et al.* 2021), while their ability to promote positive or negative impacts is likely to depend on individual nutrient profiles and the background diet in which these are consumed (Satija *et al.* 2017). However, what we do suggest is that their widespread incorporation in food systems as one-to-one replacements for animal-source foods, which provide vastly different nutrient profiles when viewed beyond nutritional reductionism, may have to be looked on with scrutiny. In the current confusing marketing landscape, better information is needed to help consumers understand *how* and *if* plant-based imitations may support healthy sustainable diets (Kraak 2021).

Environmental implications

The first major implication that reductionist views have on environmental footprints of agri-food systems pertains to the fact that assessments of the environmental impacts of individual foods or composite diets are usually based on product (or diet)-level comparisons of certain subjectively defined metrics, either in combination (e.g. multi-impact category life cycle assessment (LCA) and, more recently, the choice of nutrients in density scores, McAuliffe *et al.* 2020) or isolation (e.g. carbon footprint). In terms of comparative scaling factors, known in LCA jargon as 'functional units', it is most common to adopt such functional units as, for example, kilograms liveweight or tonnes per hectare in the case of greenhouse-gas emissions for animal- and plant-based products respectively, at the farmgate exit (usually reported as kg CO_2-eq). In the case of total land use or agricultural land use, the denominator is typically hectares or square metres. Perhaps of more concern, burdens to nature are often scaled on the basis of basic nutritional metrics such as total protein (Moughan 2021), which omits complexities such as amino acid balances. These simplistic scaling factors are ideal for comparisons of systems that produce products with similar nutritive value; however, when the nutritional quantity and quality varies considerably, which is often the case when comparing plant-source foods to animal-source foods, a more robust consideration of human nutrition is required to determine how much of a given product is needed to satisfy daily requirements compared with another product with different nutritive properties (Beal *et al.* 2021). While it is important to bear in mind that the 'greater' carbon footprint of nutritious foods and beverages can, in certain circumstances, be somewhat offset by a greater nutritional value and/or supply of nutraceutical properties such as the anti-inflammatory benefits of long-chain omega-3 fatty acids (Smedman *et al.* 2010; Drewnowski *et al.* 2015; McAuliffe *et al.* 2018, 2020), it is also of critical importance to note that these product- or diet-level relative-ranking reversals and/or impact off-setting are heavily dependent on the assumptions underlying each model. Therefore, such assumptions need to be tested robustly to determine how sensitive model conclusions are to subjective decision-making. For protein, in particular, the nutritional differences in amino acid composition and digestibility can have a considerable impact on the environmental comparisons (Tessari *et al.* 2016; Marinangeli and House 2017; Sonesson *et al.* 2017; Moughan 2021).

A second consideration is that a narrow focus on CO_2-eq and land use per unit of nutrition (even on the hypothetical condition that this would be properly expressed) risks overlooking various contextual factors (Smith *et al.* 2021). This is related to the use of global averages masking large regional and even local variations in efficiency, a difference in global warming between CO_2 from fossil fuels and biogenic methane from ruminants, poor suitability of marginal land for crop agriculture, often failing to account for soil carbon stock changes (for better or worse), the amount of existing woodland on a farm, which will be actively capturing carbon from the atmosphere, lack of accountancy for co-products, etc. Although external input-dependent livestock systems often come with an important environmental impact (reduction of biodiversity, invasion of crop-producing lands, feed production from vast monocultures, disruption of nutrient cycles, etc.) that needs to be addressed, an inconsiderate and drastic switch to plant-based alternatives would create its own trade-offs.

Sustainably produced crops can obviously offer a valuable alternative when it comes to some of the more destructive practices in animal agriculture. However, it can as well be postulated that, in other cases, monoculture-based systems, typically used for the mass production of mainstream plant-based alternatives, would lead to a food production system that makes the planet worse off than the one obtained with holistically managed low-input livestock, particularly in the context of diversified farming systems (Kremen and Miles 2012; Petersen-Rockney *et al.* 2021). Often it is a matter of adapting the most appropriate agricultural system to the local context, rather than imposing a generalised top-down choice away from animal agriculture. Moreover, the system does not need to be binary; rotation-based options, offering the best of both worlds, so to speak, with the nitrogen being fixed from leguminous crops and the nutrients being deposited by grazing animals go some way to naturally replenish soils, sequester carbon, and reduce reliance on fossil fuels for the production of inorganic fertiliser (Kronberg *et al.* 2021). Indeed, natural ecosystems have evolved with a diversity of plants, animals and micro-organisms, each playing a unique role in the system. If managed properly, building biodiversity and integrating animals into agricultural systems can provide numerous ecological services and thus improve the sustainability and resilience of food production, while producing numerous ecosystem services and ensuring profits for farmers (Kremen and Miles 2012; LaCanne and Lundgren 2018; Fenster *et al.* 2021) .

Conclusions

We argue that diets need to combine the best of animal and plant solutions by re-emphasising wholesome diets as a shared experience of nourishing conviviality, steering away from ultra-processed foods and nutrient-centric dogma, and by tailoring agricultural production to the ecological assets and constraints of each region. Whereas nutritionism is often a food corporation-serving instrument, a food quality paradigm would couple scientific analysis to guidance by personal engagement, practical and cultural knowledge, and traditional dietary patterns, without necessarily romanticising them (cf. Scrinis 2013). Depending on the context, this may imply that animal:plant ratios are altered, but decision-making should at all times resist the oversimplification of this problematic binary categorisation (Smith *et al.* 2021). Moreover, we contend that animal-source foods should not be reduced to the quantity of protein they provide, but rather appreciated for their high density in numerous bioavailable nutrients, many of which are difficult to obtain in adequate quantities through plant-source foods alone and *vice versa*. We, therefore, caution against using the word 'proteins' in food policy making to describe a heterogenous set of foods in the human diet. Rather, we suggest referring to said foods as 'protein-rich foods', while acknowledging the expanded pool of non-protein nutrients that they provide and their unique capabilities to support a much broader range of bodily functions and health outcomes.

References

Bauer J, Biolo G, Cederholm T, Cesari M, Cruz-Jentoft AJ, Morley JE, Phillips S, Sieber C, Stehle P, Teta D, Visvanathan R, Volpi E, Boirie Y (2013) Evidence-based recommendations for optimal dietary protein intake in older people: a position paper from the PROT-AGE

Study Group. *Journal of the American Medical Directors Association* **14**, 542–559. doi:10.1016/j.jamda.2013.05.021
Beal T, Massiot E, Arsenault JE, Smith MR, Hijmans RJ (2017) Global trends in dietary micronutrient supplies and estimated prevalence of inadequate intakes. *PLoS ONE* **12**, e0175554. doi:10.1371/journal.pone.0175554
Beal T, White JM, Arsenault JE, Okronipa H, Hinnouho G-M, Murira Z, *et al.* (2021) Micronutrient gaps during the complementary feeding period in South Asia: a comprehensive nutrient gap assessment. *Nutrition Reviews* **79**(Supplement_1), 26–34. doi:10.1093/nutrit/nuaa144
Binnie MA, Barlow K, Johnson V, Harrison C (2014) Red meats: time for a paradigm shift in dietary advice. *Meat Science* **98**, 445–451. doi:10.1016/j.meatsci.2014.06.024
Carstairs C (2014) 'Our sickness record is a national disgrace': Adelle Davis, nutritional determinism, and the anxious 1970s. *Journal of the History of Medicine and Allied Sciences* **69**, 461–491. doi:10.1093/jhmas/jrs057
Chung S, Chung M-Y, Choi H-K, Park JH, Hwang J-T, Joung H (2020) Animal protein intake is positively associated with metabolic syndrome risk factors in middle-aged Korean men. *Nutrients* **12**, 3415. doi:10.3390/nu12113415
Collins J, Robinson C, Danhof H, Knetsch CW, van Leeuwen HC, Lawley TD, Auchtung JM, Britton RA (2018) Dietary trehalose enhances virulence of epidemic *Clostridium difficile*. *Nature* **553**, 291–294. doi:10.1038/nature25178
Costa de Miranda R, Rauber F, Levy RB (2021) Impact of ultra-processed food consumption on metabolic health. *Current Opinion in Lipidology* **32**, 24–37. doi:10.1097/MOL.0000000000000728
Drewnowski A, Rehm CD, Martin A, Verger EO, Voinnesson M, Imbert P (2015) Energy and nutrient density of foods in relation to their carbon footprint. *The American Journal of Clinical Nutrition* **101**, 184–191. doi:10.3945/ajcn.114.092486
Drewnowski A, Mognard E, Gupta S, Ismail MN, Karim NA, Tibère L, Laporte C, Alem Y, Khusun H, Februhartanty J, Anggraini R, Poulain J-P (2020) Socio-cultural and economic drivers of plant and animal protein consumption in Malaysia: the SCRiPT study. *Nutrients* **12**, 1530. doi:10.3390/nu12051530
Eilert SJ (2020) The future of animal protein: feeding a hungry world. *Animal Frontiers* **10**, 5–6. doi:10.1093/af/vfaa033
Ertl P, Knaus W, Zollitsch W (2016) An approach to including protein quality when assessing the net contribution of livestock to human food supply. *Animal* **10**, 1883–1889. doi:10.1017/S1751731116000902
Fardet A, Rock E (2020) Ultra-processed foods and food system sustainability: what are the links?. *Sustainability* **12**, 6280. doi:10.3390/su12156280
Fenster TLD, LaCanne CE, Pecenka JR, Schmid RB, Bredeson MM, Busenitz KM, *et al.* (2021) Defining and validating regenerative farm systems using a composite of ranked agricultural practices [version 1; peer review: 2 approved]. *Food1000Research* **10**, 115. doi:10.12688/f1000research.28450.1
Fontana L, Partridge L (2015) Promoting health and longevity through diet: from model organisms to humans. *Cell* **161**, 106–118. doi:10.1016/j.cell.2015.02.020
Gardner CD, Messina M, Kiazand A, Morris JL, Franke AA (2007) Effect of two types of soy milk and dairy milk on plasma lipids in hypercholesterolemic adults: a randomized trial. *Journal of the American College of Nutrition* **26**, 669–677. doi:10.1080/07315724.2007.10719646
Gershuni VM (2018) Saturated fat: part of a healthy diet. *Current Nutrition Reports* **7**, 85–96. doi:10.1007/s13668-018-0238-x
Gibson RS, Perlas L, Hotz C (2006) Improving the bioavailability of nutrients in plant foods at the household level. *Proceedings of the Nutrition Society* **65**, 160–168. doi:10.1079/PNS2006489
Gibson RS, Raboy V, King JC (2018) Implications of phytate in plant-based foods for iron and zinc bioavailability, setting dietary requirements, and formulating programs and policies. *Nutrition Reviews* **76**, 793–804. doi:10.1093/nutrit/nuy028
Gilani GS, Wu Xiao C, Cockell KA (2012) Impact of antinutritional factors in food proteins on the digestibility of protein and the bioavailability of amino acids and on protein quality. *British Journal of Nutrition* **108**, S315–S332. doi:10.1017/S0007114512002371
Gorissen SHM, Horstman AMH, Franssen R, Crombag JJR, Langer H, Bierau J, Respondek F, van Loon LJC (2016) Ingestion of wheat protein increases *in vivo* muscle protein synthesis rates in healthy older men in a randomized trial. *The Journal of Nutrition* **146**, 1651–1659. doi:10.3945/jn.116.231340
Groenendijk I, den Boeft L, van Loon LJC, de Groot LCPGM (2019) High versus low dietary protein intake and bone health in older adults: a systematic review and meta-analysis. *Computational and Structural Biotechnology Journal* **17**, 1101–1112. doi:10.1016/j.csbj.2019.07.005
Grundy SM (1994) Influence of stearic acid on cholesterol metabolism relative to other long-chain fatty acids. *The American Journal of Clinical Nutrition* **60**, 986S–990S. doi:10.1093/ajcn/60.6.986S
Hall KD, Ayuketah A, Brychta R, Cai H, Cassimatis T, Chen KY, *et al.* (2019) Ultra-processed diets cause excess calorie intake and weight gain: an inpatient randomized controlled trial of *ad libitum* food intake. *Cell Metabolism* **30**, 67–77.e3. doi:10.1016/j.cmet.2019.05.008
Halmos EP, Mack A, Gibson PR (2019) Review article: emulsifiers in the food supply and implications for gastrointestinal disease. *Alimentary Pharmacology & Therapeutics* **49**, 41–50. doi:10.1111/apt.15045
Hevia-Larraín V, Gualano B, Longobardi I, Gil S, Fernandes AL, Costa LAR, *et al.* (2021) High-protein plant-based diet versus a protein-matched omnivorous diet to support resistance training adaptations: a comparison between habitual vegans and omnivores. *Sports Medicine* **51**, 1317–1330. doi:10.1007/s40279-021-01434-9
Horrocks CA, Dungait JAJ, Cardenas LM, Heal KV (2014) Does extensification lead to enhanced provision of ecosystems services from soils in UK agriculture? *Land Use Policy* **38**, 123–128. doi:10.1016/j.landusepol.2013.10.023
Hu FB, Otis BO, McCarthy G (2019) Can plant-based meat alternatives be part of a healthy and sustainable diet? *JAMA* **322**, 1547–1548. doi:10.1001/jama.2019.13187
Huang J, Liao LM, Weinstein SJ, Sinha R, Graubard BI, Albanes D (2020) Association between plant and animal protein intake and overall and cause-specific mortality. *JAMA Internal Medicine* **180**, 1173–1184. doi:10.1001/jamainternmed.2020.2790
Imai E, Tsubota-Utsugi M, Kikuya M, Satoh M, Inoue R, Hosaka M, Metoki H, Fukushima N, Kurimoto A, Hirose T, Asayama K, Imai Y, Ohkubo T (2014) Animal protein intake is associated with higher-level functional capacity in elderly adults: the Ohasama study. *Journal of the American Geriatrics Society* **62**, 426–434. doi:10.1111/jgs.12690
Institute of Medicine (2002) Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids. (The National Academies of Sciences, Engineering, and Medicine). Available at https://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=s10490
Jacobs Jr DR, Orlich MJ (2014) Diet pattern and longevity: do simple rules suffice? A commentary. *The American Journal of Clinical Nutrition* **100**, 313S–319S. doi:10.3945/ajcn.113.071340
Kraak VI (2021) Perspective: Unpacking the wicked challenges for alternative proteins in the United States: can highly processed plant-based and cell-cultured food and beverage products support healthy and sustainable diets and food systems? *Advances in Nutrition*, nmab113. doi:10.1093/advances/nmab113
Kremen C, Miles A (2012) Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities, and trade-offs. *Ecology and Society* **17**, 40. doi:10.5751/ES-05035-170440
Kronberg SL, Provenza FD, van Vliet S, Young SN (2021) Review: closing nutrient cycles for animal production – current and future agroecological and socio-economic issues. *Animal* **15**, 100285. doi:10.1016/j.animal.2021.100285
LaCanne CE, Lundgren JG (2018) Regenerative agriculture: merging farming and natural resource conservation profitably. *PeerJ* **6**, e4428. doi:10.7717/peerj.4428
Layman DK (2009) Dietary Guidelines should reflect new understandings about adult protein needs. *Nutrition & Metabolism* **6**, 12. doi:10.1186/1743-7075-6-12
Leroy F, Hite AH (2020) The place of meat in dietary policy: an exploration of the animal/plant divide. *Meat and Muscle Biology* **4**, 2. doi:10.22175/mmb.9456
Leroy F, Praet I (2015) Meat traditions. The co-evolution of humans and meat. *Appetite* **90**, 200–211 doi:10.1016/j.appet.2015.03.014

Leroy F, Hite AH, Gregorini P (2020) Livestock in evolving foodscapes and thoughtscapes. *Frontiers in Sustainable Food Systems* **4**, 105. doi:10.3389/fsufs.2020.00105

Longo VD, Antebi A, Bartke A, Barzilai N, Brown-Borg HM, Caruso C, *et al.* (2015) Interventions to slow aging in humans: are we ready? *Aging Cell* **14**, 497–510. doi:10.1111/acel.12338

Marinangeli CPF, House JD (2017) Potential impact of the digestible indispensable amino acid score as a measure of protein quality on dietary regulations and health. *Nutrition Reviews* **75**, 658–667. doi:10.1093/nutrit/nux025

Mayes CR, Thompson DB (2015) What should we eat? Biopolitics, ethics, and nutritional scientism. *Journal of Bioethical Inquiry* **12**, 587–599. doi:10.1007/s11673-015-9670-4

McAuliffe GA, Takahashi T, Lee MRF (2018) Framework for life cycle assessment of livestock production systems to account for the nutritional quality of final products. *Food and Energy Security* **7**, e00143. doi:10.1002/fes3.143

McAuliffe GA, Takahashi T, Lee MRF (2020) Applications of nutritional functional units in commodity-level life cycle assessment (LCA) of agri-food systems. *The International Journal of Life Cycle Assessment* **25**, 208–221. doi:10.1007/s11367-019-01679-7

Meroño T, Zamora-Ros R, Hidalgo-Liberona N, Rabassa M, Bandinelli S, Ferrucci L, *et al.* (2021) Animal protein intake is inversely associated with mortality in older adults: the InCHIANTI study. *The Journals of Gerontology: Series A*, glab334. doi:10.1093/gerona/glab334

Micha R, Mozaffarian D (2010) Saturated fat and cardiometabolic risk factors, coronary heart disease, stroke, and diabetes: a fresh look at the evidence. *Lipids* **45**, 893–905. doi:10.1007/s11745-010-3393-4

Monteiro CA, Cannon G, Moubarac J-C, Levy RB, Louzada MLC, Jaime PC (2018) The UN Decade of Nutrition, the NOVA food classification and the trouble with ultra-processing. *Public Health Nutrition* **21**, 5–17. doi:10.1017/S1368980017000234

Moughan PJ (2021) Population protein intakes and food sustainability indices: the metrics matter. *Global Food Security* **29**, 100548. doi:10.1016/j.gfs.2021.100548

Ostfeld RJ, Allen KE (2021) Ultra-processed foods and cardiovascular disease: where do we go from here?. *Journal of the American College of Cardiology* **77**, 1532–1534. doi:10.1016/j.jacc.2021.02.003

Päivärinta E, Itkonen ST, Pellinen T, Lehtovirta M, Erkkola M, Pajari A-M (2020) Replacing animal-based proteins with plant-based proteins changes the composition of a whole Nordic diet: a randomised clinical trial in healthy Finnish adults. *Nutrients* **12**, 943. doi:10.3390/nu12040943

Park S, Church DD, Schutzler SE, Azhar G, Kim I-Y, Ferrando AA, Wolfe RR (2021) Metabolic evaluation of the dietary guidelines' ounce equivalents of protein food sources in young adults: a randomized controlled trial. *The Journal of Nutrition* **151**, 1190–1196. doi:10.1093/jn/nxaa401

Petersen-Rockney M, Baur P, Guzman A, Bender SF, Calo A, Castillo F, *et al.* (2021) Narrow and brittle or broad and nimble? Comparing adaptive capacity in simplifying and diversifying farming systems. *Frontiers in Sustainable Food Systems* **5**, 56. doi:10.3389/fsufs.2021.564900

Phillips SM (2012) Nutrient-rich meat proteins in offsetting age-related muscle loss. *Meat Science* **92**, 174–178. doi:10.1016/j.meatsci.2012.04.027

Phillips SM, Paddon-Jones D, Layman DK (2020) Optimizing adult protein intake during catabolic health conditions. *Advances in Nutrition* **11**, S1058–S1069. doi:10.1093/advances/nmaa047

Provenza FD, Anderson C, Gregorini P (2021) We are the Earth and the Earth is us: how palates link foodscapes, landscapes, heartscapes, and thoughtscapes. *Frontiers in Sustainable Food Systems* **5**, 547822. doi:10.3389/fsufs.2021.547822

Rasmussen B, Ennis M, Pencharz P, Ball R, Courtney-Martin G, Elango R (2020) Protein requirements of healthy lactating women are higher than the current recommendations. *Current Developments in Nutrition* **4**, 653. doi:10.1093/cdn/nzaa049_046

Reidy PT, Walker DK, Dickinson JM, Gundermann DM, Drummond MJ, Timmerman KL, *et al.* (2013) Protein blend ingestion following resistance exercise promotes human muscle protein synthesis. *The Journal of Nutrition* **143**, 410–416. doi:10.3945/jn.112.168021

Richter CK, Skulas-Ray AC, Champagne CM, Kris-Etherton PM (2015) Plant protein and animal proteins: do they differentially affect cardiovascular disease risk? *Advances in Nutrition* **6**, 712–728. doi:10.3945/an.115.009654

Rutherfurd SM, Fanning AC, Miller BJ, Moughan PJ (2015) Protein digestibility-corrected amino acid scores and digestible indispensable amino acid scores differentially describe protein quality in growing male rats. *The Journal of Nutrition* **145**, 372–379. doi:10.3945/jn.114.195438

Sá AGA, Moreno YMF, Carciofi BAM (2020) Food processing for the improvement of plant proteins digestibility. *Critical Reviews in Food Science and Nutrition* **60**, 3367–3386. doi:10.1080/10408398.2019.1688249

Sabaté J, Sranacharoenpong K, Harwatt H, Wien M, Soret S (2015) The environmental cost of protein food choices. *Public Health Nutrition* **18**, 2067–2073. doi:10.1017/S1368980014002377

Satija A, Bhupathiraju SN, Spiegelman D, Chiuve SE, Manson JE, Willett W, *et al.* (2017) Healthful and unhealthful plant-based diets and the risk of coronary heart disease in US adults. *Journal of the American College of Cardiology* **70**, 411–422. doi:10.1016/j.jacc.2017.05.047

Seferidi P, Scrinis G, Huybrechts I, Woods J, Vineis P, Millett C (2020) The neglected environmental impacts of ultra-processed foods. *The Lancet Planetary Health* **4**, e437–e438. doi:10.1016/S2542-5196(20)30177-7

Scrinis G (2013) 'Nutritionism: the science and politics of dietary advice.' (Colombia University Press: New York, NY, USA)

Semba RD, Shardell M, Sakr Ashour FA, Moaddel R, Trehan I, Maleta KM, *et al.* (2016) Child stunting is associated with low circulating essential amino acids. *EBioMedicine* **6**, 246–252. doi:10.1016/j.ebiom.2016.02.030

Smedman A, Månsson HL, Drewnowski A, Edman A-KM (2010) Nutrient density of beverages in relation to climate impact. *Food & Nutrition Research* **54**, 5170. doi:10.3402/fnr.v54i0.5170

Smith NW, Fletcher AJ, Hill JP, McNabb WC (2021) Animal and plant-sourced nutrition: complementary not competitive. *Animal Production Science*, in press. doi:10.1071/an21235

Sonesson U, Davis J, Flysjö A, Gustavsson J, Witthöft C (2017) Protein quality as functional unit: a methodological framework for inclusion in life cycle assessment of food. *Journal of Cleaner Production* **140**, 470–478. doi:10.1016/j.jclepro.2016.06.115

Suez J, Korem T, Zeevi D, Zilberman-Schapira G, Thaiss CA, Maza O, Israeli D, Zmora N, Gilad S, Weinberger A, Kuperman Y, Harmelin A, Kolodkin-Gal I, Shapiro H, Halpern Z, Segal E, Elinav E (2014) Artificial sweeteners induce glucose intolerance by altering the gut microbiota. *Nature* **514**, 181–186. doi:10.1038/nature13793

Tagawa R, Watanabe D, Ito K, Ueda K, Nakayama K, Sanbongi C, Miyachi M (2021) Dose–response relationship between protein intake and muscle mass increase: a systematic review and meta-analysis of randomized controlled trials. *Nutrition Reviews* **79**, 66–75. doi:10.1093/nutrit/nuaa104

Tessari P, Lante A, Mosca G (2016) Essential amino acids: master regulators of nutrition and environmental footprint? *Scientific Reports* **6**, 26074. doi:10.1038/srep26074

Tharrey M, Mariotti F, Mashchak A, Barbillon P, Delattre M, Fraser GE (2018) Patterns of plant and animal protein intake are strongly associated with cardiovascular mortality: the Adventist Health Study-2 cohort. *International Journal of Epidemiology* **47**, 1603–1612. doi:10.1093/ije/dyy030

Thorisdottir B, Gunnarsdottir I, Palsson GI, Halldorsson TI, Thorsdottir I (2014) Animal protein intake at 12 months is associated with growth factors at the age of six. *Acta Paediatrica* **103**, 512–517. doi:10.1111/apa.12576

Toribio-Mateas MA, Bester A, Klimenko N (2021) Impact of plant-based meat alternatives on the gut microbiota of consumers: a real-world study. *Foods* **10**, 2040. doi:10.3390/foods10092040

Traylor DA, Gorissen SHM, Phillips SM (2018) Perspective: protein requirements and optimal intakes in aging: are we ready to recommend more than the recommended daily allowance? *Advances in Nutrition* **9**, 171–182. doi:10.1093/advances/nmy003

van Vliet S, Burd NA, van Loon LJC (2015) The skeletal muscle anabolic response to plant- versus animal-based protein consumption. *The Journal of Nutrition* **145**, 1981–1991. doi:10.3945/jn.114.204305

WBCSD (2020) Food and Agriculture Roadmap. Chapter: healthy and sustainable diets. (World Business Council for Sustainable

Development) Available at https://www.wbcsd.org/Programs/Food-and-Nature/Food-Land-Use/FReSH/Resources/Food-Agriculture-Roadmap-Chapter-on-Healthy-and-Sustainable-Diets

White JM, Beal T, Arsenault JE, Okronipa H, Hinnouho G-M, Chimanya K, *et al.* (2021) Micronutrient gaps during the complementary feeding period in 6 countries in eastern and southern Africa: a comprehensive nutrient gap assessment. *Nutrition Reviews* **79**(Supplement_1), 16–25. doi:10.1093/nutrit/nuaa142

Wilkinson SB, Tarnopolsky MA, MacDonald MJ, MacDonald JR, Armstrong D, Phillips SM (2007) Consumption of fluid skim milk promotes greater muscle protein accretion after resistance exercise than does consumption of an isonitrogenous and isoenergetic soy-protein beverage. *The American Journal of Clinical Nutrition* **85**, 1031–1040. doi:10.1093/ajcn/85.4.1031

Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, *et al.* (2019) Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. *The Lancet* **393**, 447–492. doi:10.1016/S0140-6736(18)31788-4

Wolfe, R.R., Baum JI, Starck C, Moughan PJ (2018) Factors contributing to the selection of dietary protein food sources. *Clinical Nutrition* **37**, 130–138. doi:10.1016/j.clnu.2017.11.017

Wu G, Fanzo J, Miller DD, Pingali P, Post M, Steiner JL, Thalacker-Mercer AE (2014) Production and supply of high-quality food protein for human consumption: sustainability, challenges, and innovations. *Annals of the New York Academy of Sciences* **1321**(1), 1–19. doi:10.1111/nyas.12500

Yang Y, Churchward-Venne TA, Burd NA, Breen L, Tarnopolsky MA, Phillips SM (2012) Myofibrillar protein synthesis following ingestion of soy protein isolate at rest and after resistance exercise in elderly men. *Nutrition & Metabolism* **9**, 57. doi:10.1186/1743-7075-9-57

Yuan M, Pickering RT, Bradlee ML, Mustafa J, Singer MR, Moore LL (2021) Animal protein intake reduces risk of functional impairment and strength loss in older adults. *Clinical Nutrition* **40**, 919–927. doi:10.1016/j.clnu.2020.06.019

Zhang Z, Jackson SL, Martinez E, Gillespie C, Yang Q (2021) Association between ultraprocessed food intake and cardiovascular health in US adults: a cross-sectional analysis of the NHANES 2011–2016. *The American Journal of Clinical Nutrition* **113**, 428–436. doi:10.1093/ajcn/nqaa276

Zhao H, Song A, Zheng C, Wang M, Song G (2020) Effects of plant protein and animal protein on lipid profile, body weight and body mass index on patients with hypercholesterolemia: a systematic review and meta-analysis. *Acta Diabetologica* **57**, 1169–1180. doi:10.1007/s00592-020-01534-4

Zhu F, Du B, Xu B (2018) Anti-inflammatory effects of phytochemicals from fruits, vegetables, and food legumes: a review. *Critical Reviews in Food Science and Nutrition* **58**, 1260–1270. doi:10.1080/10408398.2016.1251390

Data availability. Data sharing is not applicable as no new data were generated or analysed during this study.

Conflicts of interest. FL is a non-remunerated board member of various academic non-profit organisations including the Belgian Association for Meat Science and Technology (President), the Belgian Society for Food Microbiology (Secretary), and the Belgian Nutrition Society. On a non-remunerated basis, he also has a seat in the scientific committee of the Institute Danone Belgium, the Scientific Board of the World Farmers' Organization, and the Advisory Commission for the 'Protection of Geographical Denominations and Guaranteed Traditional Specialties for Agricultural Products and Foods' of the Ministry of the Brussels Capital Region. PG is an Associate Editor of *Animal Production Science* but was blinded from the peer-review process for this paper. SvV reports financial renumeration for academic talks, but does not accept honoraria, consulting fees, or other personal income from food industry groups/companies. All authors consume omnivorous diets.

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