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A scientific transition to support the 21st century dietary transition

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A R T I C L E I N F O

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S T R U C T U R E D A B S T R A C T

Background: Eating habits must change substantially in order to address the urgent societal challenges of personal, public and planetary health. Research surrounding various facets of the dietary transition remains siloed, hindering breakthroughs.
Scope and approach: We argue the scientific case for transdisciplinary research centered around the transition to healthy, sustainable, and acceptable diets. This transition requires tackling the broad societal challenges of engaging consumers in the diet transition, improving nutritional health and achieving environmental sustainability of foods and food systems.
Key findings: The crucial synergies and trade-offs from addressing single challenges in isolation are discussed, as well as obstacles when considering the collaboration between the multiple scientific disciplines concerned with the dietary transition. Currently, interactions between these challenges remain understudied and/or ambiguous, in part due to a lack of interoperable data and standards. Intersectional research entry points acting at the intersection of the three challenges are explored: food taste and texture reformulation, food pricing strategies and food literacy. The implementation of such cross-cutting interventions urgently requires both the generation of new data and exploitation of the breadth of existing data. Researchers must therefore be facilitated to find, access and use interoperable data to model and measure food intake and all its determinants.
Conclusions: The dietary transition requires underpinning by a research infrastructure that supports access to transdisciplinary data, facilities and research tools, alongside training and capacity building. Filling these unmet data, tools and training needs is the first step towards delivering breakthrough innovations to foods and food environments, mobilizing consumers to engage in the dietary transition.

1. Introduction

Our society sits at a crossroads. A growing global epidemic of diet-related non-communicable diseases (NCDs) such as diabetes, cardiovascular disease and obesity threatens human health. At the same time, without radical changes to consumption and industry practices, we will fail to achieve meaningful climate action such as realisation of the Paris Agreement and the Sustainable Development Goals (SDGs). As the source of an estimated 22% of deaths globally (Collaborators, 2019), and a contributor to approximately 25–30% of greenhouse gas emissions (GHGs) (Change, 2019), food is the single most significant leverage point to address both health and climate change. Recent modeling has suggested that even with an immediate elimination of all fossil-fuel-related emissions, continuing emissions from the global food

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system would make it impossible to limit global warming to 1.5 °C, and difficult to limit warming to 2 °C (Clark et al., 2020). Recent landmark reports have linked malnutrition in all its forms, including undernutrition and obesity, with the complex systemic feedback loops which also perpetuate climate change – the so-called *Global Syndemic* (Swinburn et al., 2019).

Despite the urgency of these health and environmental challenges, most individuals have so-far failed to adopt a diet that is both good for their health and for the planet**.** Sustainable diets are defined by the FAO as those "with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations" (FAO, 2012). A diet transition is urgently needed, wherein a majority of individuals transition from diets that contribute to overweight, obesity, diet-associated NCDs, climate change and biodiversity loss - towards healthy, sustainable and acceptable (HSA) diets that foster individual and planetary health. The barriers to adopting a healthy and sustainable diet are multi-pronged, sitting at the level of individual psychology and physiology, the social environment, the physical environment and the policy sphere (Aiking & de Boer, 2020). Consumers' dietary choices are an important entry point to the transition towards the 21st century diet, as a large-scale diet transition will only materialise if consumers change their food choice patterns. There exists a knowledge gap between our understanding of the health and environmental impacts of diets and how these relate to the individual determinants of dietary choice. As a result, most models of healthy and sustainable diets do not or cannot account for individual consumer behaviour and its cultural and economic drivers, a key component of the transition to a sustainable food system. A paradigm shift in the way we research healthy and sustainable dietary choices is thus needed. This in-turn requires a paradigm shift in the way we conceptualize and perform research in the domain of nutrition, health, sustainability and consumer behaviour, generating insights into consumer food and dietary choice determinants. This will allow agriculture and the food industry to receive the appropriate feedback from consumers, enabling the food industry to create innovative products and services, unburden the health system and help governments in forming effective, contextually specific food policies. Recent landmark reports such as the EAT-Lancet commission on healthy diets from sustainable food systems have described what ideal healthy and sustainable diets might look like for a variety of eating habits and cultural practices (Willett et al., 2019). Despite this body of work and growing public concern, the mechanics of getting this healthy and sustainable diet onto consumers' plates remains unclear. The EAT Lancet report has provided conceptual motivation, but lacks integration of the more complex and nuanced nature of many diets.

Here, we consider the scientific motivation for transdisciplinary research centered around the transition to HSA diets, supported by a transdisciplinary research infrastructure (RI) on the determinants of food intake. Such an RI takes into account **three major scientific challenges** relevant to personal and planetary health, namely the consumer behaviour challenge - engaging consumers to choose healthy and sustainable foods; the nutritional health challenge - exemplified by the obesity epidemic and the environmental sustainability challenge - exemplified by the required shift towards plant-based proteins. We argue that research at the cutting edges of the three challenges is critical to achieve the central goal, and requires underpinning by a trans-disciplinary RI. We begin by discussing the intersections of the three major scientific challenges, highlighting the added value of considering multiple aspects of the diet transition. We further illustrate this by discussing specific research entry points. We then propose three pillars of a *trans*-disciplinary, pan-European RI aimed at facilitating the dietary transition: an original research data platform to collect standardized data on food intake and its determinants across settings, linked to existing datasets on the social, environmental and health impacts of food; supported by analytical services to enable data standardization and linking. Such an RI will facilitate researchers in making cross-cutting insights on food-related behaviours in an array of contexts, impacting on health and food policy.

2. Synergies and trade-offs in addressing the diet transition

Achieving nutritional health, environmental sustainability and consumer-accepted diets are all key challenges in the diet transition. Research questions concerning either the health, environmental or behavioural challenge of changing diets lead to synergies or trade-offs between desired outcomes in different challenges.

Here, we present an overview of the key concepts within each challenge, and important interactions between the three challenges. This illustrates the necessity of inter- and *trans*-disciplinary research on the diet transition, highlighting areas of overlap of relevance. These interactions are depicted in Fig. 1. Representative examples of synergies and trade-offs between the major challenges are shown in Table 1.

2.1. Research on consumer behaviour impacts and intersects on environmental sustainability and nutritional health

Eating patterns and food choices are the result of a complex interaction between consumer characteristics (biological, psychological, socio-cultural and demographic), social factors (norms, economic, and cultural), food provisioning factors (what supply chains offer) and contextual factors in the consumers' food environment in terms of food availability and accessibility (Monterrosa, Frongillo, Drewnowski, de Pee, & Vandevijvere, 2020). The **key challenge** is to understand at greater depth how these complex real-life food consumption patterns are determined in different contexts and amongst different populations. Food choice behaviours can be conceptualised as either fast and unconscious (also known as 'system 1'), or slow and conscious ('system 2') (Kahneman, 2011). Food policies and dietary interventions often target

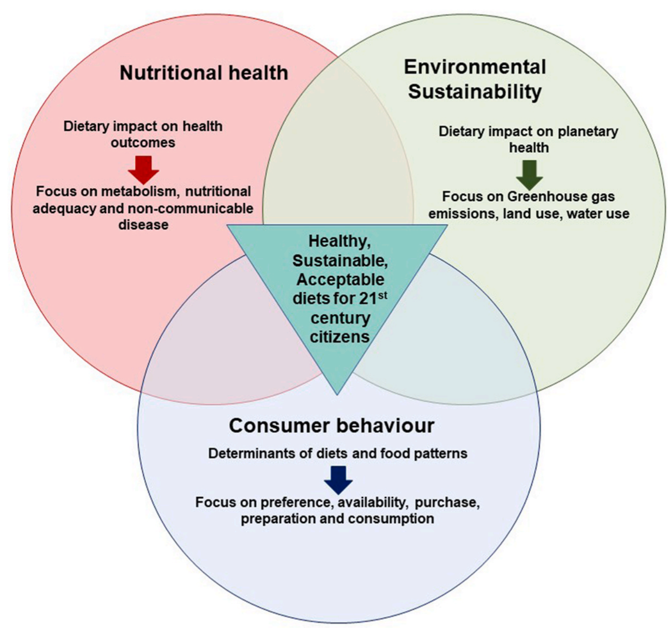

Fig. 1. Intersection of the scientific challenges key to the transition to HAS diets. Each challenge contains considerations and key topics addressed from the perspective of each individual. At the points of overlap between challenges sit interactions: both synergies and trade-offs. Addressing nutritional health alone delivers synergies (wins) to the environmental sustainability challenge, but also trade-offs (losses), described in section 2, with further examples given in Table 1. Identifying all these points is critical to qualify and quantify both the synergies and trade-offs for diets that are healthy, sustainable and acceptable; the central goal at the intersection of all three challenges: providing healthy, sustainable and acceptable diets for engaged 21st century citizens.

Table 1
Description of challenge-specific outcomes (white boxes), and examples of synergies and trade-offs from approaching individual scientific challenges (orange boxes), described in section 2. The focal challenges are indicated in the top row, and the synergies and trade-offs in relation to the other two challenges within each row.

Synergies and trade-offs to other challenges	Research challenge: Consumer Behaviour		Research challenge: Nutritional Health		Research challenge: Environmental Sustainability	
	Synergies	**Trade-offs**	**Synergies**	**Trade-offs**	**Synergies**	**Trade-offs**
Consumer Behaviour	• Identification of most effective tactics, drivers and schemes for behavioural change • Changing dietary habits while maintaining affordability satisfaction, cultural relevance and acceptability		• Nutritional insights increase transparency and nurture autonomy as a basis for engagement	• Product development without attention to acceptability promotes more consumption for lower price/effort rather than healthier choice	• Improved consumer engagement accompanied by literacy surrounding dietary impacts on environment	• Higher cost of sustainable diets widens socioeconomic disparities
Nutritional Health	• More effective interventions (i.e., labelling, point of purchase) for healthier choices, nutritional health, weight control.	• Reformulation for consumer acceptability struggles to make healthy, low calorie foods favourable in terms of taste and texture	• Insights into energy balance and energy requirements (intake and expenditure) • Nutrient requirements per health status and health vulnerable groups • Systems maps (e.g. Foresight model) of factors influencing energy balance		• Plant-based diets are often be healthier and less obesogenic	• Reduced animal protein reduces nutritional quality of diet: impact on micronutrient status, musculoskeletal function
Environmental Sustainability	• Engaged consumers act as 'influencers': social pressure as the biggest motivator of diet shifts	• Replacement of ingredients for consumer preference may lead to increased emissions and/or biodiversity losses	• Nutritionally complete diets are generally closer to traditional diets, associated with lower greenhouse gas emissions	• Focus on reduction in caloric intake can result in diets high in animal proteins with large GHG footprint (e.g. high protein weight loss diets)	• Planetary impact/life-cycle analysis of individual food types and diet patterns • Target diets to ensure earth system processes stay within planetary boundaries • Innovative sustainable protein alternatives	

system 2, whereas food choices are predominantly shaped by system 1, heavily influenced by both bio-psycho-social factors and the immediate food environment. Dietary change involves engagement of both systems 1 and 2. As conceptualised by the 'COM-B' model of behavioural change: individuals must have the **C**apability (i.e. ability to afford and prepare), **O**pportunity (i.e. availability of HSA food choices in their food environment), and **M**otivation (i.e. an understanding of the relevance of food choice) to change their **B**ehaviour (Michie, van Stralen, & West, 2011). Research on the consumer behaviour challenge requires a more in-depth and nuanced understanding of the determinants, drivers and barriers to dietary behavioural change. Consumers engaged with environmental sustainability as a motivator of food choice are more likely to make more sustainable food choices – such as shifting to plant-based protein sources and reducing animal protein consumption. This largely involves conscious, motivational thinking, engaging system 2. More sustainability-conscious consumers could potentially act as role models for broader population groups, as social pressure and norm-following has been recently purposed to be the most important motivator of the shift to sustainable diets, ahead of health or environmental concerns (Eker, Reese, & Obersteiner, 2019). In this line, consumption has become increasingly 'reflexive', or identity-based, exemplified by the movement towards veganism (Lowe, Phillipson, & Lee, 2008). Similarly, consumers motivated by the issue of nutritional health are more open to nutritional information and education, and more likely to follow food-based dietary guidelines (FBDGs), such as increasing fruit, vegetable and whole-grain consumption. This requires both conscious deliberation (system 2), together with changes to the food environment to trigger unconscious/reflexive (system 1) decisions – for example placing more healthy options at eye-level in the retail context, or changes to school lunch program policies. Efforts to improve literacy surrounding food groups, preparation of balanced, home-cooked meals and plant-based protein sources have made small steps towards fostering individual motivation towards healthy and sustainable diets. The challenge remains to foster dietary shift on a larger scale.

The aforementioned identity-based consumption can also have negative implications for health and environmental sustainability. Exemplifying this is the social dilemma surrounding veganism, with studies showing that simply naming something "vegan" can significantly reduce purchase of the product (Jonathan Wise, 2019). Similarly, a focus on greater individualisation, 'identity-based' consumption (e.g. vegan, paleo or ketogenic-only eaters) may either foster diet-hypes or benefit certain high-risk groups, but is thought to be ineffective from a broader public health perspective, as they do not typically engage vulnerable and marginalised populations with the highest prevalence of diet-related NCDs (Rosenfeld & Tomiyama, 2020). From a biodiversity perspective, the replacement of *trans*-fats by palm oil contributed to high rates of deforestation due to increased demand, and its damaging impacts on land use and biodiversity continue to worsen (Hyseni et al., 2017; Kadandale, Marten, & Smith, 2019; Yan, 2017). These examples demonstrate the synergies and trade-offs for environmental sustainability and nutritional health when consumer preferences are prioritized.

2.2. Research on nutritional health impacts and intersects on consumer behaviour and environmental sustainability

The impact of diet on nutritional health ranges from critical roles in growth and development, where nutrient deficiencies can lead to wasting, stunting and underweight; nutritional (in)adequacy, such as vitamin and mineral deficiencies; and chronic diseases including overweight, obesity and diet-related NCD risk factors (WHO, 2021). As an intermediate between eating patterns and NCDs such as type II diabetes and cardiovascular disease, the overweight and obesity epidemic in particular is a key indicator for nutritional health status, particularly as the built and social food environments easily trigger obesogenic and unhealthy eating behaviours. The **key challenge** in improving nutritional health is to understanding the complex interactions between the physical and social environment, inherited and acquired susceptibility, and vulnerability across the life course that contribute to nutrition-related health outcomes. This includes both biophysical and health status levels (metabolism, nutrient status, NCDs), as well as socio-cultural aspects of food intake, such as the surrounding food environment and adherence to, or availability of, traditional diets. Nutritional insights boost food product innovation, thereby broadening healthy food assortment, and presumably more opportunity to engage in dietary change. These actions better ensure that the consumer is "able to act"; knowledge *combined* with the availability of healthy and sustainable food options can facilitate desirable behavioural change (Adam Drewnowski & Monsivais, 2020). Despite improvements in health food availability, recent food choice experiments have indicated that an increased assortment of unhealthy food options has a larger effect on food choice than does an increased assortment of healthy food options (Adam Drewnowski & Monsivais, 2020; Pechey & Marteau, 2018). Increased selection of nutritionally healthy foods likely needs to be coupled to reduced selection of unhealthy foods in order to sufficiently impact healthy food choices. From an environmental sustainability perspective, obesity is associated with a 20% increase in greenhouse gas emissions relative to the normal weight state due to excess food consumed (Magkos et al., 2020), meaning lowered body mass implies lower energy needs and less food intake, reducing the environmental footprint of the diet as a whole. From a broader nutritional health perspective, emphasizing the health and/or environmental impacts of diets is a long-term and – for many individuals - abstract benefit; while abundant food availability, and the prevalence of dense and overwhelming food environments in most western societies, remains a hidden societal norm. This interacts with unconscious, fast 'system 1' thinking in a rich and seductive (obesogenic) food environment, making it difficult or impossible for many to make healthy choices on a consistent basis (Cohen & Babey, 2012; Kahneman, 2011). Low calorie diets could be a more direct way to gradually reduce body weight and subsequent food and energy intake. Despite the purposed environmental benefits of lower calorie diets, low calorie diets targeting weight loss are often high in animal-sourced proteins, with large implications for the environmental footprint of diets (Astrup, Raben, & Geiker, 2015). Restricting caloric intake without specifying the share of different energy sources could lead to diets with lowered food and caloric intake, but not necessarily improved environmental sustainability. For example, substituting (saturated) animal fat or *trans*-fats by palm oil contributes to shifting environmental footprint from greenhouse gas emissions to loss of biodiversity (Kadandale et al., 2019). These examples highlight some of the implications for consumer behaviour and environmental sustainability from a nutritional health perspective.

2.3. Research on environmental sustainability impacts and intersects on consumer behaviour and nutritional health

Our current diets undermine the planetary systems we rely on for life, with agriculture contributing to up to 33% of GHG emissions and occupying 71% of habitable land (Campbell et al., 2017; Sala, Crenna, Secchi, & Sanyé-Mengual, 2020; Tubiello et al., 2021). While other aspects of food contribute to environmental impacts (e.g. packaging, food loss and waste), the largest culprit is livestock production and consumption. Transitioning to sustainable diets is therefore often framed as the 'protein transition', which implies the shift to less animal-derived proteins, or towards animal proteins with a lower footprint (i.e. from ruminant protein towards fish and poultry). Achieving the protein transition has the potential to result in dual direct benefits for personal and planetary health, and a multitude of indirect possible benefits. The **key challenge** with regards to environmental sustainability is catalysing a widespread shift towards sustainable food choices in order to reduce the collective impact of diets on planetary health, including indicators such as GHG emissions, land use and water use. This is therefore intimately linked to the consumer behaviour challenge, with additional implications for the nutritional health challenge. Behavioural diet-shift models have indicated that the most potent motivator of the shift to healthy and sustainable diets is social norms, rather than health or environmental concerns (Eker et al., 2019). For some populations and geographical regions where a widespread shift to plant-based protein may not be feasible or is undesirable, this could instead resemble reduced reliance on grassland-raised ruminant protein, which has a significantly higher environmental footprint, and increased consumption of poultry and seafood (Van Zanten et al., 2018). Indeed, dietary changes need not be dramatic: smaller diet shifts by the majority of people, as in the adoption of flexitarian diets or a shift in source of animal protein, have been suggested to deliver sufficient health and environmental sustainability gains (Himics et al., 2022). From a health standpoint, environmentally sustainable diets may in some cases be less likely to be obesogenic, with a higher nutrient and fiber density. A meta-analysis of 31 cohort studies found that increased intake of plant protein was associated with a lower risk of all-cause mortality, and of cardiovascular disease-related mortality in particular (Naghshi, Sadeghi, Willett, & Esmaillzadeh, 2020). Recently, data from the European Prospective Investigation into Cancer and Nutrition (EPIC) study was used to estimate the association between dietary environmental footprint and all-cause and specific mortality (Laine et al., 2021). Dietary greenhouse gas emissions and land use were both associated with increased all-cause mortality and all-cause cancer incidence. Adherence to the EAT-Lancet reference diet was estimated to lead to a prevention of 19–63% of deaths and 10–29% of cancers (Laine et al., 2021). While animal and plant proteins are similar in composition, animal proteins are often considered higher-quality – in that they offer more readily available essential amino acids and additional vitamins and minerals such as Calcium, heme-iron and Vitamin B12. A transition to plant-based proteins may therefore adversely impact the nutritional quality of diets, increasing the risk of micronutrient deficiencies, particularly in groups higher micronutrient requirements (e.g., children, elderly). For example, animal protein, rather than plant protein, was recently shown to be critical for maintenance of strength and protection against musculoskeletal functional impairment in a large longitudinal study of elderly individuals (Yuan et al., 2021). Although such effects of the diet transition can in theory be alleviated by fortification of meat-replacers and other alternative proteins, these shifts must also be accompanied by interventions which promote adherence to FBDGs, whether via conscious (system 2; e.g. educational campaigns or nudging) or unconscious (system 1; e.g. food reformulation, changes to portion sizes) means (Bilman, van Kleef, & van Trijp, 2017).

Alternative protein sources and options for sustainable diets are widely available in many countries, but still not sufficiently consumed *in place* of animal protein by consumers in high income countries. Different consumer sub-groups react highly differently to meat-substitutes (legumes, soy) and alternative protein sources (algae, insects, cultured meat). Acceptability has been found to be dependent on the product itself (i.e. sensory attributes) and the context of the encounter with meat replacement (so-called 'product framing'- i.e. as an individual food or part of a larger meal) (Onwezen, Bouwman, Reinders, & Dagevos, 2021; Possidonio, Prada, Graca, & Piazza, 2021). Next to cultural preferences, food prices are key to food choice. Most studies suggest an increase in price for more sustainable diets (Barosh, Friel, Engelhardt, & Chan, 2014; A. Drewnowski, 2020), as meat replacers and an increased share of fresh fruits and vegetables tend to be more expensive than widely available highly processed foods. This therefore risks exacerbating the socioeconomic disparities observed between those who can and those who cannot afford a healthy and sustainable diet (A. Drewnowski, 2020; OECD, 2019). A recent systematic review indicated that overall consumer willingness to replace meat with alternative proteins (insects and meat substitutes) is low; thus increased knowledge on the motivational aspects of protein consumption, as well as research and innovation into improved consumer acceptance of sustainable proteins is needed (Hartmann & Siegrist, 2017). Policy measures are also needed to intervene on supply chains and provide subsidies to decrease the cost of fruits and vegetables and healthy food choices in relation to unhealthy and unsustainable choices.

Practically, assessing synergies and trade-offs across challenges will mean reconciling data compatibility and varying levels of evidence (i.e. data types, sources, standards for certainty and interoperability), as well as fostering interdisciplinary research practices and interdisciplinary trust; a necessary pre-requisite for the transdisciplinary research required to achieve the diet transition. These issues have begun to be addressed by Joint Research Center Initiatives, for example the Innovation for Well-being and Environment (Martini et al., 2021), yet will require additional wide-reaching initiatives. Moreover, inter- and *trans*-disciplinary researchers and global bodies will be required to set priorities concerning the hierarchy of challenges, in order to appraise trade-offs and manage competing concerns between e.g. health versus sustainability policies at regional or global scales. These considerations are further elaborated below, in the outline and discussion of a research infrastructure centered around the diet transition.

3. Interdisciplinary research entry points to act on the dietary transition

While advances in each of the three challenges are critical for producing the healthy and sustainable diet of the 21st century, no single challenge can be solved in isolation. An integrated food systems perspective requires consideration of synergies and trade-offs between consumer acceptability, health, and environmental sustainability, discussed above, which are relevant to the challenges in practice. In order to achieve a widespread diet transition, research needs to acknowledge their joint effects at the central intersection point: providing diets that are healthy, sustainable *and* acceptable. To reach this goal, diverse, complementary approaches could contribute, involving the research entry points of the food supply chain, food environments, and behavioural drivers.

The breakthrough in bringing about widespread diet transition will be in using a balanced combination of research entry points relevant to all three challenges, each of limited effectiveness, yet together providing momentum by acting on complementary challenges and time scales, hastening the diet transition (Plackett, 2020). For each of the three research entry points, the examples below illustrate what *could* work as innovative research entry points to steer individual dietary change. As depicted in Fig. 2, these research entry points impact consumer behaviour and the ensuing food choices and dietary patterns. These food choices are modified by short-term situational and eating behaviour determinants, to a varying degree of intrusiveness illustrated by the Nuffield intervention ladder (Lancet, 2007). In turn, these choices result in varying degrees of effectiveness, as exemplified by the prevention paradox, where broadening intervention targets to a large population may result in small within-individual changes, while delivering comparatively large effects on population health as a whole. Tweaking these research entry points brings about desired impacts on consumer behaviour, nutritional health and environmentally sustainability on varying time-scales, ranging from immediate effects on personal well-being to years for public health and decades for the planetary ecosystem.

3.1. Research entry points in the food supply chain

Modifications to the food supply chain can play a critical role in promoting more healthy and sustainable diets, particularly in making healthier and more sustainable food more attractive and salient (acceptable) to consumers, such as innovations in packaging to prolong the shelf-life of healthy and sustainable foods, or innovations in processing which improve food safety. Here, we narrow in on modifications to food taste and texture, a strategy which can play an important role in the shift to more healthy and sustainable diets. Taste and texture impact

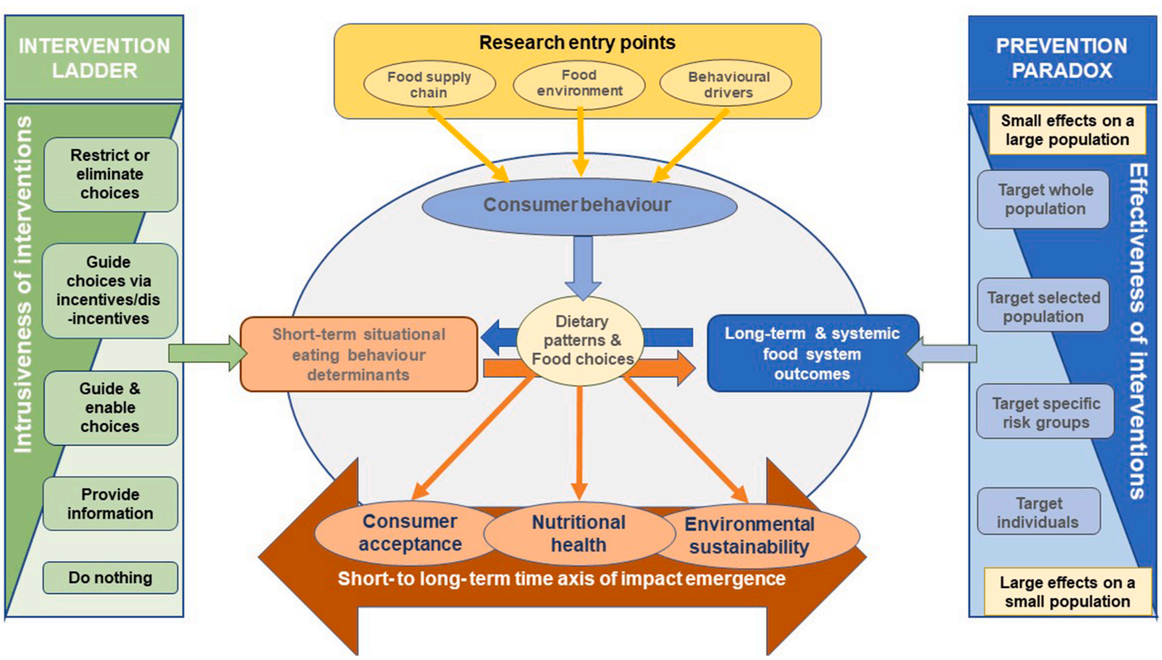

Fig. 2. Research entry points and their effects for the transition to healthy, sustainable, acceptable diets. Food supply chain entry points (e.g. modifications to taste and texture), food environment entry points (e.g. price strategies), and behavioural drivers (e.g. food knowledge and literacy) converge on consumer behaviour to alter dietary patterns and food choices, described in detail in section 3. These lead to impacts on the three challenges of consumer acceptance, achieving nutritional health, and environmental sustainability of diets on short and long-term time scales (bottom arrow). Research entry points can be described in terms of their effectiveness (right blue scale), where small effects are brought about on a large population, or large effects on a small population, known as the prevention paradox. Research entry points also vary in their intrusiveness to consumers, exemplified by the intervention ladder (left green scale). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

the eating experience and the diet as a whole, in all its dimensions – acting on both the system 1 and system 2 choice pathways. The experienced taste and texture of foods as a food choice motivation needs to be linked to the health and sustainability profile of different foods, while accounting for their acceptability to consumers. This begins with reformulation – particularly among alternative proteins such as meat-replacers, algae, insects and cultured meat (Hartmann & Siegrist, 2017), which can deliver beneficial changes to nutrient composition and satiety index. As such, the goal is to reformulate foods to make them not only more healthy (e.g. reduced fat, sugar and salt) and more sustainable (acceptable alternative proteins and meat replacers), but also more acceptable to consumers, appealing to both system 1 and system 2 in different contexts and moments (purchase, preparation and eating).

3.1.1. Core research questions

Reformulated foods that deliver on health, sustainability and acceptability require an improved understanding of how the taste and texture of the food matrix affects eating rate, satiety, bioavailability, metabolism, and how perceived taste and texture drive food choice. Furthermore, the socio-cultural dimension seeks to understand how perceptions of taste and satiety can be impacted by setting and socio-culture preferences. At the level of food choice/preference, intake and metabolism, unbiased, non-market-driven insights are needed to address:

How can the taste, texture and convenience of both healthy and sustainable foods be altered to make them more acceptable and preferable? This can be studied by means of controlled and natural experiments in e.g. supermarkets and restaurants, as has begun to be explored for meat-replacers, such as by examining the effect of perceived naturalness of meat-replacers on multi-modal measures of product acceptance (Siegrist, Sütterlin, & Hartmann, 2018). This could be further elaborated to real-life settings using e.g. recently piloted physiological sensors for chewing and swallowing (van den Boer et al., 2018).

Which types of food reformulations can deliver on all the challenges: a high sustainability 'score', nutritionally healthy, and acceptable to a wide segment of consumers? This includes assessing both the physiological effects and acceptability of, for example, non-detectable sugar reformulations with lower glycemic index or tasty and acceptable protein reformulations with low sodium and other additives. For example, the use of sugar substitute L-arabinose has been shown to lower peak insulin levels in drinks and solid foods without changing appetite or food intake (Pol & Mars, 2021). Such questions can be studied using physiological investigations into gastric emptying and glucose levels or MRI investigations of gastric and neural correlates of satiety.

What role does habitual taste preference play in making the health and sustainability trade-off? This can be assessed using e.g. implicit association tests and controlled choice experiments. Recent discrete choice experiments on consumer preferences for meat hybrids have indicated that meat-hybrids, rather than fully plant-based proteins, may be a promising intermediary step to reducing animal protein in habitual meat consumers (Profeta et al., 2020).

3.1.2. Impacts

The ***efficacy*** (Fig. 2, prevention paradox) of taste interventions could in principle be high, for example, replacing high fructose syrups and impacting various diet-related NCDs. In reality, however, the efficacy of taste and texture modifications will depend on a wider interplay of factors, chiefly whether classical 'default' food choices continue to be available and accessible, and competitive in terms of preferred choice. This is particularly the case for meat-replacers, and whole-grain or fiber-fortified cereals which are less preferred than their animal-derived or white/refined counterparts, in-part due to taste preference. Supply-chain driven modifications to the taste and texture of foods can be inherently low-***intrusive*** (Fig. 2, intervention ladder), occurring either entirely behind the scenes, or via labelling and positioning (guiding and enabling choices) (Aschemann-Witzel, Ares, Thøgersen, & Monteleone, 2019). Taste profiling in relation to the healthiness and sustainability of diets recently revealed that less healthy and less sustainable diets had a higher umami, salt and fat taste profile, providing guidance to reformulated taste profiles of healthier and more sustainable foods without changing (and therefore without 'intruding on') taste profiles (van Bussel, Kuijsten, Mars, Feskens, & van 't Veer, 2019). Observational studies of US adults showed that labeling which emphasised taste and satisfaction, was more effective at increasing purchases of vegetable and vegetarian purchases than labels that emphasised health or nutritional properties (Turnwald & Crum, 2019). Reformulated taste and texture can act at the very shortest ***timescale*** of eating: regulating energy intake via hunger and satiety. For example, tasty and acceptable food products with lowered sugar or heightened satiating effects contribute to the regulation of energy metabolism and weight on a medium time-scale, impacting NCDs and overweight on the scale of years. Increased adoption of tasty and acceptable alternative proteins and meat replacers can lower the planetary impact of diets on the time-scale of years, considering appropriate food chain and market adjustments.

3.2. Research entry points in the food environment

Attributes of the immediate food environment critically shape food choice. These include a wide array of determinants, such as product placement and labelling, to food availability and accessibility (i.e. density and diversity of food retail outlets). In most developed countries, unhealthy, highly processed and high-sugar/salt-containing foods are cheaper than fresh, unprocessed foods. Likewise, unsustainable foods remain artificially cheap as they do not reflect the true cost of production due to the environmental impact (e.g. for meat and dairy). Price is therefore a major barrier for consumers to shift from their status quo diets, exacerbating the socioeconomic disparities seen in nutrition-related NCDs (Steenhuis, Waterlander, & de Mul, 2011). Price is a strong driver of consumer behaviour in both a system 1 and system 2 manner, as has been evidenced by the moderate effectiveness of sugar-sweetened beverage taxes at reducing intake (von Philipsborn et al., 2019). Habitual purchases of specific food types and/or brands can operate strongly and on a largely unconscious level; price is therefore an appropriate strategy to target engrained, habitual food choices.

3.2.1. Core research questions

Disincentivizing unhealthy food choices via economic measures has the potential to deliver health gains on a population level. Understanding the psychological and contextual dynamics of rapid food choice at different price-points requires addressing questions such as:

How do individuals make either rapid or slow and deliberate trade-offs for healthiness, sustainability and preference, at differing price points? As with investigations of taste and texture reformulations, this could also employ implicit association tests and observational supermarkets. This has been explored via virtual web-based supermarkets, where moderate (20–40%) price changes have been found to result in healthier choices amongst a large spectrum of consumers (Waterlander et al., 2019). This is being furthered with natural experiments involving e.g. eye-tracking glasses and full head-mounted virtual-reality immersion to provide highly controlled and realistic virtual shopping environments (Xu, Siegrist, & Hartmann, 2021).

What are the most effective economic incentives (and in which contexts) to shift consumption towards healthy and sustainable options? Economic modeling 'playgrounds' which employ the true-price (i.e. incorporate the medium- and long-term health and environmental impacts) of dietary patterns on the level of populations will be critical to mature this line of research and inform food and nutrition policy. This has begun to be explored via price modeling studies. In a case study of the Netherlands, the combination of dietary intake data, food consumption, health impact and environmental impact models found that only a 15% increased in meat price could lead to a net benefit of €3100–7400 million over a 30-year horizon (Broeks et al., 2020).

3.2.2. Impacts

Recent modeling studies such as those described above have strongly promoted taxes and subsidies for use as an ***effective*** policy lever to shift towards healthy and sustainable diets among a wide segment of the population. These indicate that taxes and subsidies would be sufficient to result in substantial reductions in healthcare costs, improved quality of life (as measured in terms of disability-adjusted life years), and substantial environmental payoffs from avoided GHG emissions and feed-forward benefits of improved ecosystems services (Broeks et al., 2020). Additional recent studies suggest that very slight price changes making the more healthy or sustainable option marginally more affordable are sufficient to nudge consumer choice (Hoek, Pearson, James, Lawrence, & Friel, 2017). Despite this, taxes are inherently ***intrusive***, and for many individuals risk being prohibitive if not directly coupled to subsidies. While the introduction of economic policies is often viewed as politically risky and unpopular, it is a measure less reliant on individual consumer-led behavioural change. Nevertheless, many individuals have limited agency to change their diet in the absence of higher-level interventions. This highlights the necessity of coupling taxes on unhealthy and unsustainable foods (in most cases animal protein) to subsidies for healthy and sustainable foods (i.e. fruits and vegetables). Price decisions are made on very short ***timescales***, often employing rapid, system-1 type thinking, for instance, 'split' decisions between two similar product types of differing nutritional value. Pricing strategies could have the potential to act fairly rapidly (weeks to months) to shift consumption habits, and over the time horizon of decades to make broad impacts on population and environmental health.

3.3. Research entry points on behavioural drivers

Subconscious and conscious behavioural drivers ultimately shape food choice. On the short-term time-horizon, food choices are informed by availability, habits and immediate satiety and satisfaction goals, while on the longer-term, engrained preferences, habits and longer-term health and financial goals play a role. Providing consumers with the capability and motivation to change their diets implies a shift in the way individuals view and conceptualize food intake; in part by way of education and literacy surrounding food choices and their implications. For long-term, abstract health and environmental goals, this means widening the time horizon within which individuals view and understand food's origins, effects and impacts on both personal and planetary health. Interventions centering around food knowledge and education, particularly in young children and adolescents while habits are still being formed, will bolster internalised consumer competences in making healthy and sustainable choices, with long-term and broad effects. Educational policies (e.g. public-school curriculum and early-childhood development campaigns) promoting healthy and sustainable food literacy are critical: starting at a young age, individuals must become 'nutritionally' literate, with improved knowledge of how to identify, prepare and consume diets which are more healthy and sustainable. Also important are policies which strengthen connections to traditional food cultures and sustainable means of production. The food system-wide challenge is to build a facilitating food environment in line with diverse food cultures, fed by sustainable food production, inhabited by a new generation of engaged, 'food literate' citizens. Food knowledge acts not only at the individual level, but as an integrated characteristic of regional, social and cultural spheres wherein individuals exist (Aiking & de Boer, 2020).

3.3.1. Core research questions

Bolstering food knowledge to promote healthy and sustainable food choices is a complex, multi-stakeholder task, which can be addressed at several levels of research. On an individual level, key research questions include:

What are the most critical interactions between biological, psychological and social mechanisms that determine an individual's food choice, for specific population sub-groups? Behavioural change approaches must be tailored to different target groups, via interventions informed by a diverse array of subjective and objective data collection; i.e. actual food intake, demographic and socioeconomic data and characteristics of the food environment. In the recent pan-European project BigO: Big data against childhood obesity, big and rich data on children's food environments, physical activity and eating behaviour was collected, processed at speed, and analysed (Diou et al., 2020; Filos et al., 2021; Tufford et al., 2022). This approach may serve as an important framework for future investigations seeking to employ the COM-B model in the study of healthy and sustainable dietary determinants for specific population groups, particularly as this involves big data and difficult to measure aspects of the food environment.

What types of educational and behavioural change strategies are most effective at shifting consumption towards healthy and sustainable diets, and in which age-groups/contexts? Multi-pronged intervention approaches should target selected populations most receptive to change, and/or specific risk groups for which a dietary transition would provide the greatest long-term pay-offs in terms of health and environmental sustainability gains, such as young children and families. Intervention approaches based on dietary behaviour change games have received recent attention for their efficacy in shifting eating behaviour (Baranowski, Ryan, Hoyos-Cespedes, & Lu, 2018). For example, Joyner et al. reported a doubling of vegetable intake amongst 6–11 year old children, following a multi-day participatory school game wherein vegetable consumption influenced events in a good vs. evil narrative (Joyner et al., 2017). Cross-cutting educational interventions are needed which consider a wider variety of contextual attributes such as socioeconomic position, the environmental footprint of diets and measures of accessibility, acceptance and longevity of the behaviour change beyond the intervention period.

3.3.2. Impacts

Informed food choice sits at the interface of individual capabilities, opportunities and motivations, unconscious food preferences, and context (the food environment). Although ***effective*** combinations of interventions are available (e.g. school lunch programs, food taxes), implementation of such policies over the past decades has largely failed. Conflicting interests have hindered the full implementation of evidence-based interventions in food environments and in public health policy needed to tackle the obesity epidemic, unsustainable diets and its sequelae. The highest public health gains can be anticipated for relatively small system changes that lead to modest shifts in eating patterns for the population at large. Measures that empower individuals to make more healthy and sustainable choices, by way of food literacy ('providing information' on the Nuffield intervention ladder), may be particularly effective when aligned to specific food cultures. Real-life behavioural interventions indicate that targeting individual determinants (such as increasing consumers' level of self-regulation) is relatively effective to promote more plant-based and less animal-based food consumption (Taufik, Verain, Bouwman, & Reinders, 2019), as is a strong connection to cultural knowledge (Kapelari, Alexopoulos, Moussouri, Sagmeister, & Stampfer, 2020). Synergizing food literacy with cultural aspects of diets reduces the ***intrusiveness*** of interventions, for example, by equipping individuals to appropriately select plant-based proteins and limit source and serving size of animal protein in-line with regional diets. Healthier and more sustainable diets involve seasonal variation of locally-produced and endemic food types, and are also more closely adherent to traditional diets (Fanzo & Davis, 2019). Effective bolstering of food knowledge to the level needed to change consumption norms acts on the ***timescale*** of decades. Just as overweight and obesity prevention programs are recognized to be most effective in childhood (Williams et al., 2020), food knowledge is also likely most effective when implemented in the school learning context, as food choice norms are being established. Food knowledge-boosting also has the capacity to act on more short-term time scales to impact food choice.

In one of the first studies to directly examine the impact of behavioural nudges on healthy and sustainable food choices among adults, Morren et al. found that providing procedural information (i.e. how to use and prepare food items) was more effective than declarative information (i.e. information on the health or environmental impact) at reducing the environmental impact of food choices (Morren, Mol, Blasch, & Malek, 2021).

All three of these research entry points must be employed in the diet transition, which themselves act at the intersection of the three scientific challenges. Addressing the core research questions posed at each entry point will require both rich, cross-contextual information on dietary intake as such, as well as a wide array of measures of the environmental and behavioural determinants of different dietary patterns. Providing researchers with the tools to investigate interventions at the interface of disciplines will be necessary, comprising of a central platform to assess the determinants of individual food intake in a wide array of settings. The blueprint for this will be discussed in the following section.

4. Towards a research infrastructure on the determinants of healthy, sustainable and acceptable diet transition

In current health and food research, research on the interface between personal/public health, environmental sustainability and consumer eating patterns, behaviour and acceptance is an almost empty space. Key elements needed to support such interdisciplinary research include cross-disciplinary co-operation between researchers of differing backgrounds, and facilitation of transdisciplinary research involving societal stakeholders in the health and food domain, supported by structures and guidelines to facilitate cross-disciplinary trust. Critically, research services are needed to study the integration of food characteristics (as arising from the food supply chain), the food environment, and consumer behavioural determinants across national and regional food systems. Research must address how characteristics of the food environments in these food systems modify what is acceptable to consumers, in order to identify context-specific dietary determinants and context-specific solutions for the transition to HSA diets. Ambitious transdisciplinary projects aimed at facilitating food systems transition need support from a not-yet existent network of data, tools and training services that spans multiple disciplines. Critically, this will also require platforms and procedures to unite the differing levels of data structures and evidence inherent in transdisciplinary research. We therefore propose the prioritization of a research infrastructure (RI) that facilitates cross-contextual research on dietary intake and its determinants within the same individuals, in both the long-term (patterns and habits) and immediate (real-time choice determinants) time frames. This builds upon work presented recently by (Timotijevic et al., 2021), first proposed by the EuroDISH project (Snoek et al., 2018) and further explored in the RICHFIELDS project (Bogaardt et al., 2018; Maringer et al., 2018). This prior work revealed the importance of providing services such as data FAIR-ification and cross-linking, GDPR-proofing, and intellectual property rights and responsible research and innovation activities in the field of consumer food behaviour.

The unique core of the proposed RI is the so-called Citizen's Data Platform (CDP), where individuals consent to providing information on their food consumption, purchase and preparation. The RI as a whole comprises three building blocks: original research data on dietary determinants (CDP), linkage to existing data, and analytical services. These are described in Fig. 3 and in detail below, followed by discussion on the additional research impact and action on the transdisciplinary research entry points that will arise.

4.1. Original research data on dietary determinants

At the front-end of the RI is a service that allows researchers to upload and retrieve data relevant to the determinants of food intake, spanning the challenges of nutritional health, environmental sustainability and consumer behaviour. The core of the CDP will be a digital platform which allows standardised, *trans*-national collection and uploading of relevant food intake and intake determinant data from e.g. sensors, mobile apps, wearables, and virtual supermarkets, combined with information on the food environment, in order to monitor dietary behaviours. There have so-far been very few *trans*-national studies that have incorporated advanced methods to measure both dietary intake and the food environment. The aforementioned Horizon2020 project BigO was the first European project to employ big data on food environment and individual behaviour, linked to health outcomes, across different cultural and socioeconomic contexts (Diou et al., 2020; Tufford et al., 2022). The closing of data gaps in the determinants of eating behaviour would be facilitated by researchers sharing and accessing data from e.g. observational (virtual or physical) restaurants and supermarkets, as well as neighbourhoods which act as living labs to study the food environment and consumption behaviour *in vivo*. The research

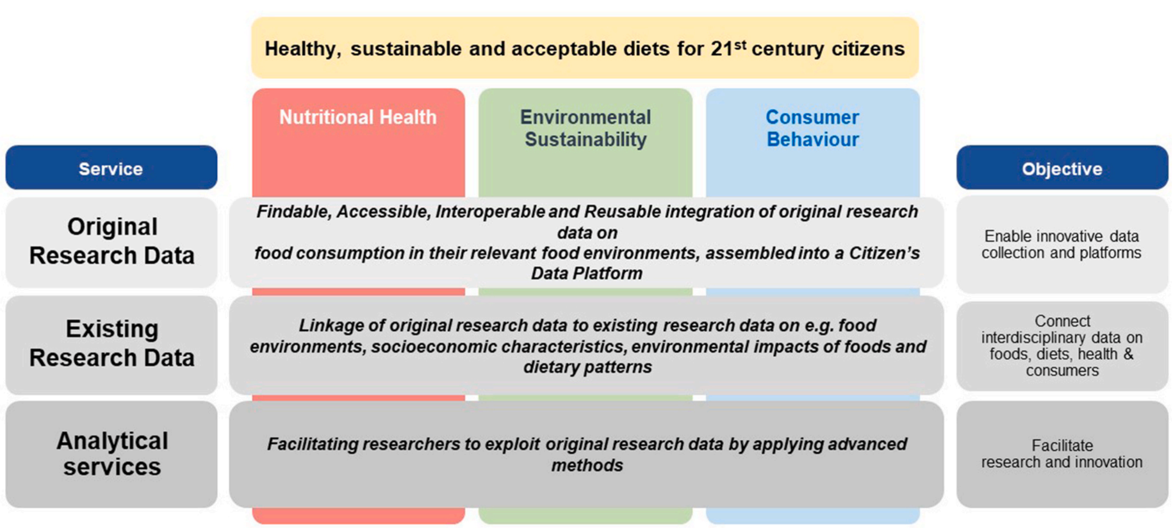

Fig. 3. Pillars of a transdisciplinary research infrastructure on the diet transition. Three key scientific challenges (pillars) are envisioned for a research infrastructure that supports transdisciplinary research on the transition to healthy, sustainable and acceptable diets. Integration requires collecting determinants of diets across challenges, and supportive services to link original research data, existing domain specific disciplinary data and analytical services; described in detail in section 4.

output of these approaches could then be coupled to virtual tools to access, manipulate and compare data. Towards this vision, the Community on Food Consumer Science (COMFOCUS) project will build the technical building blocks for the harmonization of consumer behaviour and nutritional data (Cloud, 2021).

4.2. Linkage to existing research data

At the back-end, the RI will facilitate linking to external research and data resources on food (e.g. nutrient composition, bio-actives, safety, allergenicity), the natural environment (impacts of food on planetary boundaries), the built environment and related socioeconomic characteristics (e.g. retail, outlets, price, availability). There exists a large volume of scattered data on nutritional health and food intake, environmental indicators of foods and diets, and consumer behaviour. In order to comprehensively calculate synergies and trade-offs at the intersection of challenges and accurately model dietary behaviour in different food systems, the original research data described above must be connected to existing data, taking into account disciplinary differences in data quality and certainty. This ranges from the level of individual foods, ensuring interoperability between (inter)national food classification systems, FCDBs and LCA repositories, up to FBDGs and FAO food balance sheets and aggregated data for diet-related risks (e.g., Global Burden of Disease, Vos et al., 2019); outlined in Table 2. These can be used to stimulate standardized and data-driven derivation of FBDGs for HSA diets. Food consumption and impact databases must also be aligned with standardized but rich data on food environments, which could expand on multi-center studies concerning aspects of the food environment such as those arising from COSI (Korzycka, Jodkowska, Oblacińska, & Fijałkowska, 2020), BigO (Diou et al., 2020) and EPIC (Biesbroek et al., 2019), incorporating standardised food consumption data (i.e., EU-Menu methodology; (Authority, 2021). A recent scoping review did not identify any *trans*-national studies providing both food intake and GPS data of participants, highlighting the data gap at the intersection of diets and the built environment (Giabbanelli & Crutzen, 2017). A third element of the data structure would be linkage the individual health data, both self-reported (e.g., body-mass index, well-being, physical activity), and facilitating IPR-proof linkage to clinical data (e.g., cholesterol, blood pressure, non-communicable disease outcomes). This will allow direct correlation of health outcomes to food environments and dietary patterns within the same individual. First steps towards *trans*-nationally accessible data structures are being made in the FNS Cloud project ("FNS Cloud," 2021), integrated within the European Open Science Cloud (Koers et al., 2020), which aims for FAIR-ified data on food, nutrition and the socioeconomic links to diet and health.

4.3. Analytical services

Thirdly, the RI will make dedicated analytical services available to researchers to exploit original research data. This will comprise the FAIR-ification of deposited original research data from various sources, enabling its linkage to existing data. This will also entail training and facilitation for researchers on advanced methods needed to exploit the original research data, such as machine learning and complex adaptive systems (CAS) modeling/agent-based modeling. This will allow the

Table 2
Overview of research activities and outcomes core to the proposed research infrastructure (yellow rows), and spin-off activities and outcomes (orange rows) that would benefit from a research infrastructure on dietary intake and its determinants.

	Services	Research activities	Outcomes
Research Infrastructure-centered	Citizen's Data Platform (Original Research Data)	• ***Standardised tools for assessing behavioural determinants and food intake*** • ***Surveys for integrated assessments across population groups***	• Central resource to assess and compare eating behaviour determinants across populations • Standardized collection and comparison of consumption data across populations
	Linkage of Existing data	• ***Data interoperability*** • ***Alignment of existing data*** • ***Harmonized food consumption data*** • ***Linked food classification data*** • ***Linked food environment data***	• Interoperability between food classification systems and food-based dietary guidelines, e.g. national guidelines to GloboDiet (WHO), FoodEx2 (European Food Safety Administration) and the Food and Agriculture Organisation. • Aligned data on on food composition, life cycle analyses, epidemiological and health data, intervention data and cohorts • Harmonisation of food consumption databases with other consumer data sources • Linked food classification data (standardized food composition databases) to price and purchase data, sensory data (taste, texture), food life cycle analysis-data, eating patterns, food advertisements • Linked data on socio-economic characterization to food and physical activity points of interest
	Capacity building to exploit data	• ***Training on use of Citizen's Data Platform and analytical services*** • ***Training on data use across food, nutrition, health, consumer behaviour and environment sustainability***	• Research community uses and contributes to original research data of Citizen's Data Platform • Findable, accessible, interoperable, reusable, linked data across disciplines forms core of research infrastructure
Spin-offs	Physical facilities	• ***Sensors, apps and wearables*** • ***Living lab food environments*** • ***Observational supermarkets and restaurants*** • ***Industry/ food engineering test labs***	• Monitoring of personal and social behaviour to advance understanding of food choice, preparation, food waste • Selected neighbourhoods turned into living food environment labs to study interventions • Supermarkets and restaurants to test proposed diet transition interventions • Labs for the development of new foods, e.g. meat replacers and next generation proteins
	Virtual facilities & tools	• ***Data linkage e-facilities*** • ***Food-based dietary guideline tools*** • ***Virtual modeling playgrounds*** • ***Virtual supermarkets*** • ***Food consumption data-base comparison tools***	• Linked meta-data and standardisation of research apps and wearables • Analytical tools to derive food-based dietary guidelines from consumption and environmental/health impact data • Direct testing of the effectiveness of food environment interventions at low input cost • Exploration of the planetary and health outcomes of real-life and modelled interventions and policies; research on dietary behaviour in different contexts, with associated tools and cross-linking to data on food composition and consumption
	Capacity building	• ***Training in advanced modeling*** • ***Training in the assessment of Environmental impact for non-specialists*** • ***Training on effective dissemination and communication techniques*** • ***Training for researchers and governmental policy analysts to utilise advanced and emerging tools*** • ***Training in effective cross-sectorial dissemination***	• Training in advanced modeling of planetary/health impacts of food and exploitation of data science tools to understand complex determinants of eating patterns • Programs allowing Nutrition or Biomedical Scientists with limited knowledge of Environmental Sciences to effectively assess the planetary impact of their interventions. • Researchers appropriately convey nutritional findings to consumers and other societal stakeholders • Practical, accessible data-science approaches linking regional food production/Graphical Information Systems data to aligned regional consumption data: generating realistic health and environmental impact assessments. • Researchers translate successful intervention outcomes into policy momentum at the national and regional levels.

modelling of individual dietary choices using rich datasets, techniques only beginning to emerge in the field of eating behaviour (Giabbanelli & Crutzen, 2017). This will allow incorporation of rich systems maps of food environments in different contexts; allowing advanced modeling of behaviour and its health and sustainability outcomes at a much finer level of granularity.

4.4. Spinoff and impacts of an RI on research into dietary behaviour and its determinants

Cross-cutting research on the entry points of food supply chain, food environments and individual behavioural drivers (as depicted in Fig. 2) is required to shift diets in a large enough proportion of individuals to impact on population and planetary health. The building blocks of the consumer-centered CDP will result in services that boost innovative research on the synergies and trade-offs at the level of individual consumers in their daily food environments, across heterogeneous food systems, instead of domain specific, long-term individual or ecological averaged data in aggregated population groups. The CDP will spark the development of new tools and facilities for data exploitation, collection, monitoring and surveillance; capacity-building for transdisciplinary research on HSA diets, as well as strategies and policies for diet transition amongst diverse populations. More generally, the RI will also stimulate additional capacity building for the training required to perform advanced data sciences involved in data linkage and FAIR-ification across challenges, accounting for different data types and levels of certainty across disciplines. In this way, an RI will lead to wide-ranging impact on research and research communities; possible impacts in the advancement of facilities and tools, and training, education and dissemination are outlined in Table 2, and discussed in relation to the research entry points below.

At the level of the *food supply chain,* resulting data on food choice determinants will allow better informed design of virtual tools and modeling playgrounds, accelerating the introduction of nutritious and appealing food types. This will allow the exploration of which particular characteristics of food (e.g. taste aspects vs. texture vs. satiating properties) can be altered for the highest impact on healthy and sustainable consumption habits and greatest consumer acceptance in different contexts. This will also provide researchers with standards and advanced methods to address how sociocultural setting influences the subjective experience of taste, satiety and food choice. At the level of *food environments*, *trans*-national, food systems-oriented research could address which elements of food environments across different regions and populations are consistently and with high intervention efficacy related to the health and sustainable profile of diets. The role that varying socioeconomic contexts and food cultures play in shaping dietary habits could be compared cross-contextually, allowing the determination of to which extent certain aspects of dietary behaviours are modifiable.

At the level of *behavioural drivers* of dietary choice, improved availability of standardised dietary intake data, for a wider variety of countries and contexts, will facilitate more advanced models on, for example, the determinants of adherence to healthy and sustainable diets. Trade-offs within dietary patterns, particularly those which consider consumer taste preference and acceptability, have recently begun to be modelled in more detail. For example, the DIETRON model of health impacts of consumption changes has been extended to integrate consumer preferences in healthy diet recommendations (Irz, Leroy, Réquillart, & Soler, 2016). Integration of these models with intake determinant data from a greater variety of contexts, as provided by a RI, will provide the requirements for impact modeling approaches to predict the outcomes of dietary innovations and interventions. An RI can also lead to improved insight on how - and what type of - knowledge and education is relevant to dietary choice, by facilitating data linking on interventions (e.g., targeted advice and educational campaigns) and actual food intake. Untested health or food policy changes can also be modelled, leading to the holistic integration of individual-level effects (consumer behaviour and food intake) and system-level effects (public health and sustainable food supply). So-called 'mega-studies' have recently emerged as a way to gather insights on behavioural change arising from multiple interventions (Milkman et al., 2021). Applying these methods to food system interventions, particularly those aimed at dietary behavioural change, will ultimately lead to more targeted and effective interventions and policy instruments at behavioural change towards healthy and sustainable diets.

4.5. Next steps in research policy

The systems-level insights emerging from the RI-enabled research allow modeling and testing, and subsequent implementation of policy interventions that act on the inherently transdisciplinary EU Farm to Fork and Biodiversity strategy, and towards the goals and recommendations set forth in the Healthy Food Environment Policy Index (Food-EPI) (Network, 2021). Besides attention to interventions in specific policy domains, research on intersectoral action to co-ordinate trade, agriculture, environment and health, is critical (Marmot, Friel, Bell, Houweling, & Taylor, 2008). This could include coherent and accessible policy planning and cost calculation tools for the diet transition, compiled from existing and emerging data on dietary trends and their impacts. The complexity of the challenge of shifting to HSA diets, as well as its multi-stakeholder nature, demands not only a coherent research program, but also integrated knowledge hubs centered around the transition (Graça, Godinho, & Truninger, 2019). A permissive policy environment is maturing for *trans*-disciplinary, multi-stakeholder and *trans*-national research supporting the diet transition, such as recent RI directives from Horizon Europe calling for cross-domain research on health and environment (Horizon Europe, 2022), as well as the European Strategy for Research Infrastructures 2025 roadmap agenda (ESFRI, 2022). These explicit agendas which promote and accommodate this perspective is necessary to support the RI approach described above.

5. Conclusion

Understanding the intersection of factors that determine an individual's diet, and delivering innovations and policies to shift to HSA diets, involves the convergence of research in nutrition, environmental science and consumer behavioural sciences, along with many other domains. It is a truly transdisciplinary challenge, requiring research at the cutting edges of disciplines and advanced data methods in order to connect the physiological and psycho-social determinants of diets, in collaboration with industry and policy stake-holders to plan and implement appropriate interventions. Recent intergovernmental reports on climate change call for urgent and drastic changes to social infrastructure, including food systems (Change, 2019). Moreover, the COVID-19 pandemic has demonstrated that technical or medical solutions alone are insufficient to mitigate the pandemic; a parallel very much applicable to the diet transition. Technical solutions must be aligned with behavioural policies targeting both individual behaviour and population measures carried out by other societal stakeholders; what the European Centers for Disease Control have termed a "Systemic Resilience Approach" (OECD, 2021). Moving towards integrated, systems models and research practices for healthy and sustainable diets by engaged consumers means considering the complex interactions between individual and systems. For the transition to HSA diets for national and global food systems, this requires that RIs provide standards, methods, tools and training at the intersection of nutritional health, environmental sustainability and consumer behaviour. This will help to overcome the current fragmentation in research fields concerned with healthy and sustainable diets, creating synergies between the life and social sciences, and delivering cross-cutting innovations to support the diet transition.

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Declaration of competing interest

None.

Data availability

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References

Aiking, H., & de Boer, J. (2020). The next protein transition. *Trends in Food Science & Technology, 105*, 515–522. https://doi.org/10.1016/j.tifs.2018.07.008

Aschemann-Witzel, J., Ares, G., Thøgersen, J., & Monteleone, E. (2019). A sense of sustainability? – how sensory consumer science can contribute to sustainable development of the food sector. *Trends in Food Science & Technology, 90*, 180–186. https://doi.org/10.1016/j.tifs.2019.02.021

Astrup, A., Raben, A., & Geiker, N. (2015). The role of higher protein diets in weight control and obesity-related comorbidities. *International Journal of Obesity, 39*(5), 721–726. https://doi.org/10.1038/ijo.2014.216, 2005.

Authority, E. F. S. (2021). Food consumption data. Retrieved from https://www.efsa.europa.eu/en/data-report/food-consumption-data. (Accessed 15 October 2021).

Baranowski, T., Ryan, C., Hoyos-Cespedes, A., & Lu, A. S. (2018). Nutrition education and dietary behavior change games: A scoping review. *Games for Health Journal, 8*(3), 153–176. https://doi.org/10.1089/g4h.2018.0070

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

Biesbroek, S., Verschuren, W. M. M., Boer, J. M. A., van der Schouw, Y. T., Sluijs, I., & Temme, E. H. M. (2019). Are our diets getting healthier and more sustainable? Insights from the European prospective investigation into cancer and nutrition – Netherlands (EPIC-NL) cohort. *Public Health Nutrition, 22*(16), 2931–2940. https://doi.org/10.1017/S1368980019001824

Bilman, E., van Kleef, E., & van Trijp, H. (2017). External cues challenging the internal appetite control system—overview and practical implications. *Critical Reviews in Food Science and Nutrition, 57*(13), 2825–2834. https://doi.org/10.1080/10408398.2015.1073140

van den Boer, J., van der Lee, A., Zhou, L., Papapanagiotou, V., Diou, C., Delopoulos, A., et al. (2018). The SPLENDID eating detection sensor: Development and feasibility study. *JMIR mHealth and uHealth, 6*(9). https://doi.org/10.2196/mhealth.9781. e170-e170.

Bogaardt, M. J., Geelen, A., Zimmermann, K., Finglas, P., Raats, M. M., Mikkelsen, B. E., … van't Veer, P. (2018). Designing a research infrastructure on dietary intake and its determinants. *Nutrition Bulletin, 43*(3), 301–309. https://doi.org/10.1111/nbu.12342

Broeks, M. J., Biesbroek, S., Over, E. A. B., van Gils, P. F., Toxopeus, I., Beukers, M. H., et al. (2020). A social cost-benefit analysis of meat taxation and a fruit and vegetables subsidy for a healthy and sustainable food consumption in The Netherlands. *BMC Public Health, 20*(1), 643. https://doi.org/10.1186/s12889-020-08590-z

van Bussel, L. M., Kuijsten, A., Mars, M., Feskens, E. J. M., & van 't Veer, P. (2019). Taste profiles of diets high and low in environmental sustainability and health. *Food Quality and Preference, 78*, Article 103730. https://doi.org/10.1016/j.foodqual.2019.103730

Campbell, B. M., Beare, D. J., Bennett, E. M., Hall-Spencer, J. M., Ingram, J. S. I., Jaramillo, F., … Shindell, D. (2017). Agriculture production as a major driver of the Earth system exceeding planetary boundaries. *Ecology and Society, 22*(4). https://doi.org/10.5751/ES-09595-220408

Change, I. P.o. C. (2019). *Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* (Retrieved from).

Clark, M. A., Domingo, N. G. G., Colgan, K., Thakrar, S. K., Tilman, D., Lynch, J., & 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

Cloud, F. N. S. (2021). Retrieved from https://www.fns-cloud.eu/overview/.

Cohen, D. A., & Babey, S. H. (2012). Contextual influences on eating behaviours: Heuristic processing and dietary choices. *Obesity Reviews : An Official Journal of the International Association for the Study of Obesity, 13*(9), 766–779. https://doi.org/10.1111/j.1467-789X.2012.01001.x

Collaborators, G. B. D. D. (2019). Health effects of dietary risks in 195 countries, 1990-2017: A systematic analysis for the global burden of disease study 2017. *Lancet, 393*(10184), 1958–1972. https://doi.org/10.1016/S0140-6736(19)30041-8

Diou, C., Sarafis, I., Papapanagiotou, V., Alagialoglou, L., Lekka, I., Filos, D., … Delopoulos, A. (2020). BigO: A public health decision support system for measuring obesogenic behaviors of children in relation to their local environment. *Annu Int Conf IEEE Eng Med Biol Soc, 2020*, 5864–5867. https://doi.org/10.1109/embc44109.2020.9175361

Drewnowski, A. (2020). Analysing the affordability of the EAT-Lancet diet. *Lancet Global Health, 8*(1), e6–e7. https://doi.org/10.1016/s2214-109x(19)30502-9

Drewnowski, A., & Monsivais, P. (2020). Chapter 10 - taste, cost, convenience, and food choices. In B. P. Marriott, D. F. Birt, V. A. Stallings, & A. A. Yates (Eds.), *Present knowledge in nutrition* (11th ed., pp. 185–200). Academic Press.

Eker, S., Reese, G., & Obersteiner, M. (2019). Modelling the drivers of a widespread shift to sustainable diets. *Nature Sustainability, 2*(8), 725–735. https://doi.org/10.1038/s41893-019-0331-1

Fanzo, J., & Davis, C. (2019). Can diets Be healthy, sustainable, and equitable? *Current Obesity Reports, 8*(4), 495–503. https://doi.org/10.1007/s13679-019-00362-0

FAO. (2012). *Sustainable Diets and Biodiversity: Directions and solutions for policy, research and action*. Rome: Food and Agricultural Organisation of the United Nations. Retrieved from.

Filos, D., Lekka, I., Kilintzis, V., Stefanopoulos, L., Karavidopoulou, Y., Maramis, C., … Maglaveras, N. (2021). Exploring associations between children's obesogenic behaviors and the local environment using big data: Development and evaluation of the obesity prevention dashboard. *JMIR Mhealth Uhealth, 9*(7), Article e26290. https://doi.org/10.2196/26290

Giabbanelli, P. J., & Crutzen, R. (2017). Using agent-based models to develop public policy about food behaviours: Future directions and recommendations. *Computational and Mathematical Methods in Medicine, 2017*, Article 5742629. https://doi.org/10.1155/2017/5742629

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

Hartmann, C., & Siegrist, M. (2017). Consumer perception and behaviour regarding sustainable protein consumption: A systematic review. *Trends in Food Science & Technology, 61*, 11–25. https://doi.org/10.1016/j.tifs.2016.12.006

Himics, M., Giannakis, E., Kushta, J., Hristov, J., Sahoo, A., & Perez-Dominguez, I. (2022). Co-benefits of a flexitarian diet for air quality and human health in Europe. *Ecological Economics, 191*, Article 107232. https://doi.org/10.1016/j.ecolecon.2021.107232

Hoek, A. C., Pearson, D., James, S. W., Lawrence, M. A., & Friel, S. (2017). Healthy and environmentally sustainable food choices: Consumer responses to point-of-purchase actions. *Food Quality and Preference, 58*, 94–106. https://doi.org/10.1016/j.foodqual.2016.12.008

Hyseni, L., Bromley, H., Kypridemos, C., O'Flaherty, M., Lloyd-Williams, F., Guzman-Castillo, M., … Capewell, S. (2017). Systematic review of dietary trans-fat reduction interventions. *Bulletin of the World Health Organization, 95*(12), 821–830G. https://doi.org/10.2471/BLT.16.189795

Irz, X., Leroy, P., Réquillart, V., & Soler, L. G. (2016). Beyond wishful thinking: Integrating consumer preferences in the assessment of dietary recommendations. *PLoS One, 11*(6), Article e0158453. https://doi.org/10.1371/journal.pone.0158453

Jonathan Wise, D. V. (2019). It's all in a name: How to boost the sales of plant-based menu items. Retrieved from https://www.wri.org/insights/its-all-name-how-boost-sales-plant-based-menu-items.

Joyner, D., Wengreen, H. J., Aguilar, S. S., Spruance, L. A., Morrill, B. A., & Madden, G. J. (2017). The FIT game III: Reducing the operating expenses of a game-based approach to increasing healthy eating in elementary schools. *Games for Health Journal, 6*(2), 111–118. https://doi.org/10.1089/g4h.2016.0096

Kadandale, S., Marten, R., & Smith, R. (2019). The palm oil industry and noncommunicable diseases. *Bulletin of the World Health Organization, 97*(2), 118–128. https://doi.org/10.2471/BLT.18.220434

Kahneman, D. (2011). *Thinking, fast and slow* (1st ed.). New York: Farrar, Straus and Giroux.

Kapelari, S., Alexopoulos, G., Moussouri, T., Sagmeister, K. J., & Stampfer, F. (2020). Food heritage makes a difference: The importance of cultural knowledge for improving education for sustainable food choices. *Sustainability, 12*(4), 1509. Retrieved from https://www.mdpi.com/2071-1050/12/4/1509.

Koers, H., Bangert, D., Hermans, E., van Horik, R., de Jong, M., & Mokrane, M. (2020). Recommendations for services in a FAIR data ecosystem. *Patterns (N Y), 1*(5), Article 100058. https://doi.org/10.1016/j.patter.2020.100058

Korzycka, M., Jodkowska, M., Oblacińska, A., & Fijałkowska, A. (2020). Nutrition and physical activity environments in primary schools in Poland – COSI study. *Annals of Agricultural and Environmental Medicine, 27*(4), 605–612. https://doi.org/10.26444/aaem/114223

Laine, J. E., Huybrechts, I., Gunter, M. J., Ferrari, P., Weiderpass, E., Tsilidis, K., … Vineis, P. (2021). Co-Benefits from sustainable dietary shifts for population and environmental health: An assessment from a large European cohort study. *The Lancet Planetary Health, 5*(11), e786–e796. https://doi.org/10.1016/s2542-5196(21)00250-3

Lancet. (2007). The ethics of public health. *The Lancet, 370*(9602), 1801. https://doi.org/10.1016/S0140-6736(07)61748-6

Lowe, P., Phillipson, J., & Lee, R. P. (2008). Socio-technical innovation for sustainable food chains: Roles for social science. *Trends in Food Science & Technology, 19*(5), 226–233. https://doi.org/10.1016/j.tifs.2007.11.005

Magkos, F., Tetens, I., Bügel, S. G., Felby, C., Schacht, S. R., Hill, J. O., … Astrup, A. (2020). The environmental foodprint of obesity. *Obesity, 28*(1), 73–79. https://doi.org/10.1002/oby.22657

Maringer, M., van't Veer, P., Klepacz, N., Verain, M. C. D., Normann, A., Ekman, S., … Geelen, A. (2018). User-documented food consumption data from publicly available apps: An analysis of opportunities and challenges for nutrition research. *Nutrition Journal, 17*(1), 59. https://doi.org/10.1186/s12937-018-0366-6

Marmot, M., Friel, S., Bell, R., Houweling, T. A. J., & Taylor, S. (2008). Closing the gap in a generation: Health equity through action on the social determinants of health. *The Lancet, 372*(9650), 1661–1669. https://doi.org/10.1016/S0140-6736(08)61690-6

Martini, D., Ragone, G., Cazzini, F., Cheli, F., Formici, G., La Porta, C. A. M., … Violini, L. (2021). The need for A multidisciplinary approach to face challenges related to food, health, and sustainability: The contribution of CRC I-we. *Sustainability, 13*(24), Article 13720. Retrieved from https://www.mdpi.com/2071-1050/13/24/13720.

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*, 42. https://doi.org/10.1186/1748-5908-6-42

Monterrosa, E. C., Frongillo, E. A., Drewnowski, A., de Pee, S., & Vandevijvere, S. (2020). Sociocultural influences on food choices and implications for sustainable healthy diets. *Food and Nutrition Bulletin, 41*(2_suppl), 59S–73S. https://doi.org/10.1177/0379572120975874

Morren, M., Mol, J. M., Blasch, J. E., & Malek, Ž. (2021). Changing diets - testing the impact of knowledge and information nudges on sustainable dietary choices. *Journal of Environmental Psychology, 75*, Article 101610. https://doi.org/10.1016/j.jenvp.2021.101610

Naghshi, S., Sadeghi, O., Willett, W. C., & Esmaillzadeh, A. (2020). Dietary intake of total, animal, and plant proteins and risk of all cause, cardiovascular, and cancer mortality: Systematic review and dose-response meta-analysis of prospective cohort studies. *BMJ, 370*, m2412. https://doi.org/10.1136/bmj.m2412

Network, J. P. E. (2021). The healthy food environment policy index (Food-EPI) European union. Retrieved from https://www.jpi-pen.eu/images/reports/Food-EPI_EU_FINAL_20210305.pdf.

OECD. (2019). *The heavy burden of obesity*.

OECD. (2021). A systemic resilience approach to dealing with Covid-19 and future shocks. Retrieved from https://www.oecd.org/coronavirus/policy-responses/a-systemic-resilience-approach-to-dealing-with-covid-19-and-future-shocks-36a5bdfb/.

Onwezen, M. C., Bouwman, E. P., Reinders, M. J., & Dagevos, H. (2021). A systematic review on consumer acceptance of alternative proteins: Pulses, algae, insects, plant-based meat alternatives, and cultured meat. *Appetite, 159*, Article 105058. https://doi.org/10.1016/j.appet.2020.105058

Pechey, R., & Marteau, T. M. (2018). Availability of healthier vs. less healthy food and food choice: An online experiment. *BMC Public Health, 18*(1), 1296. https://doi.org/10.1186/s12889-018-6112-3

von Philipsborn, P., Stratil, J. M., Burns, J., Busert, L. K., Pfadenhauer, L. M., Polus, S., … Rehfuess, E. (2019). Environmental interventions to reduce the consumption of sugar-sweetened beverages and their effects on health. *Cochrane Database of Systematic Reviews, 6*(6), Article Cd012292. https://doi.org/10.1002/14651858.CD012292.pub2

Plackett, B. (2020). Changing diets at scale. *Nature*. https://doi.org/10.1038/d41586-020-03450-7

Pol, K., & Mars, M. (2021). L-Arabinose and D-xylose: Sweet pentoses that may reduce postprandial glucose and insulin responses. *Food & Nutrition Research, 65*. https://doi.org/10.29219/fnr.v65.6254

Possidonio, C., Prada, M., Graca, J., & Piazza, J. (2021). Consumer perceptions of conventional and alternative protein sources: A mixed-methods approach with meal and product framing. *Appetite, 156*, Article 104860. https://doi.org/10.1016/j.appet.2020.104860

Profeta, A., Baune, M. C., Smetana, S., Broucke, K., Royen, G. V., Weiss, J., … Terjung, N. (2020). Discrete choice analysis of consumer preferences for meathybrids-findings from Germany and Belgium. *Foods, 10*(1). https://doi.org/10.3390/foods10010071

Rosenfeld, D. L., & Tomiyama, A. J. (2020). Taste and health concerns trump anticipated stigma as barriers to vegetarianism. *Appetite, 144*, Article 104469. https://doi.org/10.1016/j.appet.2019.104469

Sala, S., Crenna, E., Secchi, M., & Sanyé-Mengual, E. (2020). Environmental sustainability of European production and consumption assessed against planetary boundaries. *Journal of Environmental Management, 269*, Article 110686. https://doi.org/10.1016/j.jenvman.2020.110686

Siegrist, M., Sütterlin, B., & Hartmann, C. (2018). Perceived naturalness and evoked disgust influence acceptance of cultured meat. *Meat Science, 139*, 213–219. https://doi.org/10.1016/j.meatsci.2018.02.007

Snoek, H. M., Eijssen, L. M. T., Geurts, M., Vors, C., Brown, K. A., Bogaardt, M.-J., … van 't Veer, P. (2018). Advancing food, nutrition, and health research in Europe by connecting and building research infrastructures in a DISH-RI: Results of the EuroDISH project. *Trends in Food Science & Technology, 73*, 58–66. https://doi.org/10.1016/j.tifs.2017.12.015

Steenhuis, I. H. M., Waterlander, W. E., & de Mul, A. (2011). Consumer food choices: The role of price and pricing strategies. *Public Health Nutrition, 14*(12), 2220–2226. https://doi.org/10.1017/S1368980011001637

Swinburn, B. A., Kraak, V. I., Allender, S., Atkins, V. J., Baker, P. I., Bogard, J. R., … Dietz, W. H. (2019). The global syndemic of obesity, undernutrition, and climate change: The Lancet commission report. *Lancet, 393*(10173), 791–846. https://doi.org/10.1016/S0140-6736(18)32822-8

Taufik, D., Verain, M. C. D., Bouwman, E. P., & Reinders, M. J. (2019). Determinants of real-life behavioural interventions to stimulate more plant-based and less animal-based diets: A systematic review. *Trends in Food Science & Technology, 93*, 281–303. https://doi.org/10.1016/j.tifs.2019.09.019

Timotijevic, L., Astley, S., Bogaardt, M. J., Bucher, T., Carr, I., Copani, G., … Zimmermann, K. (2021). Designing a research infrastructure (RI) on food behaviour and health: Balancing user needs, business model, governance mechanisms and technology. *Trends in Food Science & Technology, 116*, 405–414. https://doi.org/10.1016/j.tifs.2021.07.022

Tubiello, F. N., Rosenzweig, C., Conchedda, G., Karl, K., Gütschow, J., Xueyao, P., … Sandalow, D. B. (2021). Greenhouse gas emissions from food systems: Building the evidence base. *Environmental Research Letters, 16*.

Tufford, A. R., Diou, C., Lucassen, D. A., Ioakimidis, I., O'Malley, G., Alagialoglou, L., … Mars, M. (2022). Toward systems models for obesity prevention: A big role for big data. *Curr Dev Nutr, 6*(9), nzac123. https://doi.org/10.1093/cdn/nzac123

Turnwald, B. P., & Crum, A. J. (2019). Smart food policy for healthy food labeling: Leading with taste, not healthiness, to shift consumption and enjoyment of healthy foods. *Preventive Medicine, 119*, 7–13. https://doi.org/10.1016/j.ypmed.2018.11.021

Van Zanten, H. H. E., Herrero, M., Van Hal, O., Röös, E., Muller, A., Garnett, T., … De Boer, I. J. M. (2018). Defining a land boundary for sustainable livestock consumption. *Global Change Biology, 24*(9), 4185–4194. https://doi.org/10.1111/gcb.14321

Waterlander, W. E., Jiang, Y., Nghiem, N., Eyles, H., Wilson, N., Cleghorn, C., … Blakely, T. (2019). The effect of food price changes on consumer purchases: A randomised experiment. *The Lancet Public Health, 4*(8), e394–e405. https://doi.org/10.1016/s2468-2667(19)30105-7

WHO. (2021). Malnutrition. Retrieved from https://www.who.int/news-room/fact-sheets/detail/malnutrition.

Willett, W., Rockstrom, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., … Murray, C. J. L. (2019). Food in the anthropocene: The EAT-lancet commission on healthy diets from sustainable food systems. *Lancet, 393*(10170), 447–492. https://doi.org/10.1016/S0140-6736(18)31788-4

Williams, J., Buoncristiano, M., Nardone, P., Rito, A. I., Spinelli, A., Hejgaard, T., … Breda, J. (2020). A snapshot of European children's eating habits: Results from the fourth round of the WHO European childhood obesity surveillance initiative (COSI). *Nutrients, 12*(8), 2481. https://doi.org/10.3390/nu12082481

Xu, C., Siegrist, M., & Hartmann, C. (2021). The application of virtual reality in food consumer behavior research: A systematic review. *Trends in Food Science & Technology, 116*, 533–544. https://doi.org/10.1016/j.tifs.2021.07.015

Yan, W. (2017). A makeover for the world's most hated crop. *Nature, 543*(7645), 306–308. https://doi.org/10.1038/543306a

Yuan, M., Pickering, R. T., Bradlee, M. L., Mustafa, J., Singer, M. R., & Moore, L. L. (2021). Animal protein intake reduces risk of functional impairment and strength loss in older adults. *Clinical Nutrition, 40*(3), 919–927. https://doi.org/10.1016/j.clnu.2020.06.019