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The Future of Food Processing—A Food Science and Technology Perspective. Proceedings of a Roundtable Event

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The Future of Food Processing – a food science and technology perspective. Proceedings of a roundtable event.

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Abstract

Rising interest in the links between processed food consumption and poor health outcomes often overlooks the perspectives of those working in food technology and innovation. To address this, a virtual roundtable was held in October 2024 to provide a setting for a technical discussion among those working in food processing, technology and engineering and related fields. The aims were to explore whether a) the concept of ultra-processed foods (UPF) as a whole (or any elements thereof) may be useful to consider in the development of healthier and more sustainable foods, including its strengths, opportunities, weaknesses and barriers and b) where there might be opportunities for food technologists to improve current approaches to food processing for human health in the future. Presentations focussed on reformulation and included a critique of the evidence and proposed mechanisms linking UPF consumption to food intake and health. Areas of discussion included use and replacement of ingredients deemed to be 'UPF'; material properties of foods; advances in food production; consumer communication; practicalities of consuming a healthy, sustainable diet; food

systems considerations; environmental sustainability in food processing and the role of meat alternatives.

Looking ahead, participants identified opportunities for improvements centred around four themes: target areas and considerations for innovation and reformulation that can be suggested based on current or future capability; potential definitions/targets that industry can work towards to improve the healthiness of products and related evidence needs; greater transdisciplinary working (cross-sector, food systems approaches); consumer-related issues and potential policy/regulatory changes. Caution was expressed around both 'overprocessing' and misplaced reformulation efforts to the detriment of health. However, a potential role for consumer education around food processing techniques and ingredients was identified and the importance of continued advancements in food processing and technology in the production of healthier, sustainable food was highlighted.

Keywords: food technology, food processing, food science, health, sustainability, reformulation, ultra processed foods, UPF.

Background

Poor diet is a leading cause of death and ill-health (Brauer *et al.* 2024). It has been estimated that the food-related cost of chronic disease in the UK is £268 billion annually (Jackson 2024). Based on the latest figures, in England 64% of adults are overweight or living with obesity, 36% of children are overweight or living with obesity (DHSC 2025b) and 7% of adults have type 2 diabetes (OHID 2025a), with estimates indicating that less than 1% of the population has a diet that adheres to dietary guidelines (Scheelbeek *et al.* 2020).

In recent years there has been considerable scientific interest in the topic of ultra-processed foods (UPF), a concept introduced within the Nova classification of foods (Monteiro 2009). Indeed, higher intake of foods/drinks that would be categorised as ultra-processed (commonly collectively referred to as UPF) according to Nova, which is described as grouping foods according to the extent and purpose of industrial processing (Monteiro *et al.* 2019b), has consistently been associated with increased risk of a plethora of poor health outcomes based on observational data (Lane *et al.* 2024; Barbaresko *et al.* 2024; Dai *et al.* 2024). This has sparked concern, particularly in the UK where foods/drinks that would be categorised as UPF contribute an estimated 57% of calories consumed (Rauber *et al.* 2018; Madruga *et al.* 2023). The level of activity surrounding the concept of UPF has captured the imagination of the British media (British Science Association 2024; Makinwa & He 2025) and has been the focus of a House of Lords Enquiry (Food Diet and Obesity Committee 2024; DHSC 2025a). Yet, whether the food processing *per se* is having a unique effect on human health that is independent of nutrient content and intakes of known nutrients of concern (i.e. saturated fat, sugars and salt), remains a contentious issue.

Dietary guidelines for several countries include advice to avoid/limit processed food (or UPF) consumption (Quinn *et al.* 2021; Koios *et al.* 2022; Northcott *et al.* 2025), while scientific advisory committees in others (including the UK, US, Europe and Scandinavia) have acknowledged associations between UPF and health, but called for more direct evidence (AESAN Scientific Committee 2020; Bröder *et al.* 2023; Blomhoff 2023; SACN 2023; ANSES 2024; DGAC 2024; SACN 2025a). The concept of UPF is therefore not universally accepted and the topic is one of debate, including around whether food processing techniques, or any particular attributes of/ingredients present in UPF (and if so which one(s)), are responsible for the observed links with poor health

(Touvier *et al.* 2023; Valicente *et al.* 2023b; Dicken & Batterham 2024; Maki *et al.* 2024; O'Leary 2024; Robinson & Johnstone 2024). Whilst there has been a rapid expansion in the number of dietary epidemiological association studies, there remains a lack of biologically plausible mechanistic studies that have reached a consensus on the drivers of higher energy intake, metabolic dysfunction and poor health associated with foods from within this category. Many of the items captured by Nova group 4 include known foods/drinks containing higher amounts of nutrients of concern, and analysis of UPF consumed in the UK indicate that on average UPF have a higher energy density and lower micronutrient contents (per 100 kcal) than those described as minimally processed foods (Dicken *et al.* 2024b; Dicken *et al.* 2025a). However, not all foods/drink classified as ultra-processed meet the UK definition of being high in fat, sugars or salt ('HFSS') (Kesaite *et al.* 2025) and the positive nutritional contribution of some UPF to healthy, balanced diets has been highlighted (Estell *et al.* 2022; Hallinan *et al.* 2021; Hess *et al.* 2023).

In 2023 the UK's Scientific Advisory Committee on Nutrition (SACN) acknowledged that the observed associations between higher consumption of (ultra-) processed foods and adverse health outcomes are of concern. However, they noted limitations in the Nova classification system itself, the potential for confounding in the observational findings, and the possibility that existing UK dietary recommendations (e.g. for fat, sugar and salt) already cover the observed adverse health associations with (ultra-) processed foods (SACN 2023). SACN further stated that there are uncertainties around the quality of available evidence and that consumption of (ultra-) processed foods may be an indicator of other unhealthy dietary patterns and lifestyle behaviours. SACN's statement recognised that food processing has a number of roles including ensuring foods that would otherwise be inedible are edible (e.g. by cooking), ensuring food safety (e.g. pasteurisation), increasing the shelf life, preservation and retention of nutrients for some foods (e.g. freezing), modifying nutrient composition or bioavailability as well as increasing palatability and convenience (SACN 2023). SACN recognised the importance of further monitoring of the UPF issue and published a rapid update report in 2025 (SACN 2025a).

The UPF concept has sparked many discussions among professionals working within nutrition science and related fields (Capozzi *et al.* 2021; Astrup & Monteiro 2022; Gustafson *et al.* 2022; Lockyer *et al.* 2023; O'Connor *et al.* 2023; Percival *et al.* 2024; Trumbo *et al.* 2024) and has caught the attention of food scientists, technologists and engineers (Knorr & Augustin 2021; Göncüoğlu Taş *et al.* 2022; Fitzgerald 2023; IFT 2023b; McClements 2024; Ubbink & Levine 2024; Ahrné *et al.* 2025; Estévez 2025).

The British Nutrition Foundation had previously hosted a discussion that centred around examination of the evidence base underpinning relationships between UPF consumption and adverse health outcomes and any potential unintended nutritional consequences that might arise from the categorisation of foods with beneficial nutritional attributes as UPF (Lockyer *et al.* 2023). To widen the debate, the Foundation set up a roundtable to provide a setting for a technical discussion among those working in food processing, technology and engineering and related fields to explore whether:

- The concept of ultra-processed foods as a whole (or any elements thereof) may be useful to consider in the development of healthier and more sustainable foods, in terms of its strengths, opportunities, weaknesses and barriers.
- There might be opportunities for food technologists to improve current approaches to food processing for human health in the future.

The virtual event took place on 4th October 2024 via Microsoft Teams. The British Nutrition Foundation invited an event chair, two speakers and eight additional participants consisting of academics with wide-ranging areas of expertise including food technology and engineering, food safety, packaging, transport, food quality, food formulation, sensory properties of food, eating behaviour, metabolism, food structure, plant-based foods, nutrient bioavailability, dietary fibre, oral processing, food education and policy; as well as an independent development chef and a product innovation expert. Three British Nutrition Foundation staff members observed the event but did not take part in the discussion.

The British Nutrition Foundation distributed suggested pre-read materials to all participants (Monteiro *et al.* 2019b; Gibney 2021; Dicken & Batterham 2022; SACN 2023; Valicente *et al.* 2023b) and devised three questions, which were sent in advance and posed to the group by the event chair (Professor Christine Williams).

- **Question 1:** What could the concept of ultra-processed foods (as most commonly defined by Nova) mean for the development of healthier foods/drinks and reformulation?
- **Question 2**: What could the concept of ultra-processed foods mean for the production of environmentally sustainable foods/drinks?
- **Question 3**: What could food technologists be working towards in the future to aid in the development of healthier and more sustainable foods/drinks and how might this be achieved?

Participants were invited to share their ideas, including highlighting practical solutions or barriers, established concepts, relevant emerging research, current gaps in knowledge and suggestions for future priority areas which may include recommendations for research or best practice, whether linked to the concept of UPF or otherwise. Abbreviations used within this article are listed as supplementary material.

Of the many aspects of the UPF debate that may concern those with expertise in food science, technology and engineering, reformulation is a likely priority, since this is often achieved through innovation and the application of knowledge generated from these fields (Trumbo *et al.* 2024). Food reformulation, the process of altering the processing or composition of a food or beverage product to improve its nutritional profile or to reduce its content of ingredients or nutrients of concern (WHO 2022), is often described as an important part of a suite of policy actions to support healthy and sustainable diets (Buttriss 2020; European Union 2020; Department of Health (Government of Ireland) 2021; Food Standards Scotland 2025) and has the potential to improve dietary intakes by stealth (Gressier *et al.* 2021; Nesta 2023). At the roundtable, participants heard from Michael Adams about the main drivers that are incentivising the food industry to reformulate products, tools being utilised to achieve targets and key future considerations. Below is a summary of the presentation.

Box 1: Invited presentation: 'Why the food industry is reformulating foods - are ultra processed ingredients the problem or the solution?' *Michael Adams, Product Innovation Lead, Campden BRI*

What is driving food and drink manufacturers to reformulate their foods?

Reformulation typically involves the removal of ingredients (e.g. fat, sugars, salt) that often have multiple functions within a product. Therefore, achieving this without significantly impacting quality attributes such as taste and appearance, as well as price, can be challenging. The food and drink industry encounters multiple drivers and external pressures to reformulate, including marketing restrictions on less healthy foods; voluntary schemes; internal company standards; authorised nutrition claims; front-of-pack labelling schemes; public place food criteria; taxes (e.g. the soft drinks industry levy (SDIL)) and consumer demand/trends. While numerical targets can drive reformulation, it is not always possible due to technological challenges, with commercial decisions also at play. Other drivers that can result in changes to nutritional composition include sustainability; supply chain disruption; regulatory changes; inflationary pressure and market competitors. Barriers and enablers to reformulation were recently described (FSA 2024c), with barriers more likely to be faced by smaller businesses lacking sufficient technical knowledge or resource.

HFSS marketing restrictions, introduced to protect children from television advertising of less healthy foods (Ofcom 2007) and expanded more recently to restrict prominent placement in stores and online (DHSC 2023), are thought to be one of the largest drivers of reformulation in the UK. HFSS foods and drinks are categorised using the UK's nutrient profile model (NPM) a scoring system that balances the contribution made by 'positive' nutrients/ingredients (e.g. fibre, fruit, vegetables) with 'negative' components (e.g. fat, sugars, salt) (DHSC 2011). Voluntary reformulation schemes are also in existence (OHID 2024b). Among these, salt targets have largely been hailed as successful, with dietary intake data indicating reductions during particular time periods (DHSC 2012; PHE 2016) and reformulation thought to have played a part (Gressier *et al.* 2021), though reductions have not been fully sustained (PHE 2020). Sugar and calorie reduction programmes form part of the government's *Childhood Obesity Plan*. Better progress has been made in relation to sugar reduction in some product categories than others, though the ambition of a 20% reduction was not achieved in any individual category (OHID 2022a). To date, the calorie reduction programme is reported to have shown limited progress (OHID 2024a). However, the SDIL has stimulated a large amount of reformulation (OHID 2022b; OHID 2025c) with a recent analysis reporting a reduction in free sugars intakes from beverages (Rogers *et al.* 2024a). Overall, it is suggested that regulatory strategies have so far been more effective than voluntary schemes in the UK.

Reformulation schemes may focus on reducing one nutrient but adjustments to more than one may be required for some products to change from being classified as HFSS to non-HFSS (e.g. pizza). Back-of-pack (macronutrient) values are generally used to judge success, but may not be a good measure of overall healthiness. For example, in breakfast cereals, sugar reduction is largely achieved using bulking ingredients (e.g. fibres, starches) that can all have different physiological effects compared to sugars. Sugar reduction in beverages is one of the most established areas of reformulation. Although the health effects of non-nutritive sweeteners vs. sugars is a complex area and widely debated (WHO 2023), these are authorised for use by EFSA and other national bodies, albeit in some product categories and subject to conditions, and therefore are commonly used (SACN 2025b). The biscuit category is particularly technically challenging, with fat-reduced biscuits tending to contain emulsifiers, which can allow manufacturers to use lower levels of fat whilst delivering similar technological and organoleptic properties as higher fat levels. Sweeteners and emulsifiers are among the types of additives often cited in the UPF debate, with suggestions around whether they may have biological effects beyond those captured by current toxicological safety assessments. Additives and other 'UPF ingredients' described within the UPF definition provided by Nova are often relied upon by industry to reduce nutrients of concern, rather than making fundamental changes to products or manufacturing techniques, which are costly investments (due to the need for equipment and research). Yet their inclusion may result in the classification of products changing from being viewed as Nova 3 to being viewed as Nova 4. Better understanding as to whether reduction in salt/fat/sugar/calories using such ingredients has a net positive effect on the health of the product or whether the focus should be on removing these rather than changing the nutrient profile of products is needed.

Box 2: Invited presentation: 'A Critical Appraisal of the Evidence and Mechanisms linking UPF Consumption to Food Intake and Health'

Professor Ciarán Forde, Professor and Chair in Sensory Science and Eating Behaviour, Wageningen University and Research

Traditionally dietary guidelines are based on well-evidenced diet-nutrient relationships (Brink *et al.* 2019; WHO 2019; DGAC 2020). In response to frustration at the lack of progress made with traditional dietary advice and the rising consumption of packaged foods, a Brazilian research group launched the Nova classification system as an alternative to the what was viewed as reductionist nutrient-based advice, instead focused on categorising food based on the degree to which they are processed (Monteiro 2009). Supporters suggest that Nova should be considered in dietary guidelines and action taken against foods classified as UPF (Monteiro *et al.* 2019b; Crimarco *et al.* 2022), yet Nova has been widely critiqued for its subjectivity and inappropriateness for use in public health guidance (Gibney *et al.* 2017; Forde & Decker 2022). Therefore, does the amount of processed food consumed matter, if diets score highly on agreed measures of optimal nutrient intake?

A large number of publications report associations between intakes of UPF and health outcomes from observational data. The limitations of methodologies used to classify foods using Nova, correction for covariates, inappropriate use of exposure assessment models and the nature of confounding data in observational studies have been highlighted elsewhere (O'Connor *et al.* 2024; Visioli *et al.* 2025). Examples of foods that would be classified as UPF according to Nova range from milk drinks, wholemeal bread, fruit yogurts, to carbonated drinks, savoury snacks and confectionery (Monteiro *et al.* 2019a). More recent analyses indicate that specific UPF subgroups are primarily responsible for driving many of the observed associations with poor health outcomes (e.g. animal-based products, artificially and sugar-sweetened beverages), as opposed to the whole UPF category (typically includes 12-14 food groups), with suggested neutral or even protective associations between some subgroups and some health outcomes (e.g. breads and cereals, plant-based alternatives) (Duan *et al.* 2022; Cordova *et al.* 2023; Mendoza *et al.* 2024).

When setting dietary guidance, observational data are often regarded as preliminary and ought to be supported by plausible biological mechanisms ideally supported by data from independently replicated randomised controlled trials (RCTs). Such studies are difficult to design and carry out, and to date there have been very few in this area. An inpatient RCT (n=20) conducted at the NIH compared *ad libitum* ultra-processed or minimally processed diets for 2-weeks (Hall *et al.* 2019). Energy intake was lower on the minimally processed diet and greater during the UPF diet (average net difference of 508 kcal/day between the two diets) and participants gained 0.9 kg during the UPF diet and lost 0.9 kg during the minimally processed diet. Interestingly, the intervention (~80% UPF) was similar to the average US diet (~60-70% UPF), whereas it could be argued that the minimally processed diet (<15% UPF), was the stronger intervention, and should not be considered as a 'control' diet in the comparison.

The NIH trial was not designed to identify mechanisms but stimulated speculation on the specific drivers responsible for the observed differences in energy intake, as explored and appraised within the literature. These include ‘hyper-palatability’ (Monteiro *et al.* 2018; Forde 2023; Fazzino *et al.* 2024; Rogers *et al.* 2024b) and the proposed unfavourable effects of food additives and ‘cosmetic’ ingredients (Neumann & Fasshauer 2022; Teo *et al.* 2022b). A ‘Cocktail Theory’ of additives has been proposed whereby selected food additives may have additive or synergistic effects, that are not captured by current additive safety assessments (Chazelas *et al.* 2021; Gibney & Forde 2022; Payen de la Garanderie *et al.* 2025). Despite claims that UPF’s are hyper-palatable, meal ‘pleasantness’ was rated equally across both diets in the NIH RCT. However, non-beverage energy density was significantly higher for UPF diet (1.957 kcal/g on UPF compared to 1.057 kcal/g for the minimally processed diet), and meals tended to be softer and easier to consume which in combination, lead to a 50% higher average energy intake rate (48 vs. 31 kcal/min). Meal texture and eating rate have been demonstrated to promote higher meal energy intakes (Teo *et al.* 2022a; Lasschuijt *et al.* 2023), yet higher energy intake rates are seen across foods from different processing categories and are not unique to UPF (Forde et al. 2020).

Given these potential confounds, it remains to be seen whether a high degree of processing or faster eating rates and higher energy density are responsible for observed differences between minimally processed and UPF diets. It seems unlikely that a single mechanism explains the link between higher intake of a category of foods as broad as ‘UPF’ and the associated increased risk of such a diverse range of different health outcomes. Careful consideration is needed as to whether these relationships are explained by novel aspects of the food that result from processing or the many established links between nutrients of concern and health. Many of the putative mechanisms linking UPF to higher energy intakes have either not been tested or are not supported by currently available evidence. There is therefore a need for priority setting and better data on what drives observed higher energy intake from certain UPF, if we are to provide novel solutions to mitigate the risk of adverse health outcomes.

A presentation from Professor Ciarán Forde included a summary of the evidence linking ultra-processed food to health, discussion of some of the proposed mechanisms that may promote higher energy intakes from processed foods and future considerations on processed food and health. A summary of the presentation can be found in Box 2.

Details of some of the discussion and comments contributed during the roundtable in response to three questions used as stimuli are summarised below.

Could the concept of UPF (as most commonly defined by Nova) provide an opportunity for the development of healthier foods and reformulation?

Impact on reformulation including use and replacement of additives

Some participants commented on the misuse of the term ‘ultra-processed’ because in food technology, ultra-processing is used to describe intensive heat treatment processes (i.e. ultra-high temperature milk), that significantly change the structure and behaviour of the original ingredients. Although some examples of particular processing techniques are listed within the definition of UPF (e.g. extrusion, moulding) (Martinez-Steele *et al.* 2023), participants were not supportive of the definition and argued that the Nova classification mainly refers to formulation (changes in content) and does not define degree/extent/level/intensity of processing (Botelho *et al.* 2018; Monteiro Cordeiro de Azeredo & Monteiro Cordeiro de Azeredo 2022; Visioli *et al.* 2022; Ubbink & Levine 2024). Indeed, different approaches for classifying foods according to Nova have been described, including searching ingredients lists for 'cosmetic' additives and other particular ingredient types (Zancheta Ricardo *et al.* 2023). However, processing methods used are typically much less evident from packaging information (Neumann *et al.* 2023). It has been pointed out that while more intense processing methods are used to produce some UPF and indeed some of the ingredients that are described as being characteristic of UPF (e.g. isolates and fractionated ingredients), others are made using more simple processes yet are undoubtedly less healthy choices due to their recipe (Levine & Ubbink 2023).

The potential adverse impact of the adoption of Nova into dietary guidelines on reformulation and the application of science to make food healthier was raised in the discussion. Challenges in reducing nutrients of concern could arise if industry chooses to avoid specific ingredients in an effort to shift products into a more favourable Nova group. Given the level of discussion of UPF in the media, it is possible that such changes could be made in response to consumer concerns and demand (Henson 2024; EIT Food 2024). Without a sound understanding of whether and how changes in individual or grouped ingredients would improve the health impact of a product, it is challenging to predict overall healthiness should nutritional composition, particularly saturated fat, sugars and salt, be altered unfavourably as a consequence of removing 'UPF ingredients'. For example, it was suggested that avoiding the use of non-nutritive or low-calorie sweeteners in combination with appropriate bulking agents to avoid a Nova 4 label, may impede efforts to reduce added sugar from the food supply and have a net deleterious effect on consumer health.

Participants highlighted the value of fortified foods and expressed concern over widespread additive removal by industry to achieve reduced additive formulation goals, should this expand to include those that extend shelf life/increase stability. A recent study comparing 'more processed' and 'less processed' menus, both described as nutrient-poor and mimicking the standard American diet, was highlighted. This reported a longer shelf stability and a lower cost of the 'more processed' diet (Hess *et al.* 2024). Removal of preservatives could create more food wastage (globally up to 40% of food produced ends up as waste (WRAP 2025)) and even food safety issues if carried out by SMEs/start-ups that may lack relevant technical expertise. It is useful to note that Nova does not class fortification as a UPF marker when used generally to replace nutrients lost during processing (Martinez-Steele *et al.* 2023). Furthermore, the UPF definition appears to focus specifically on 'cosmetic' additives (described as colourings, flavourings, non-sugar sweeteners and emulsifiers) and the classification system recognises the role of some additives in food safety; the presence of additives that prolong product duration, protect original properties or prevent proliferation of microorganisms (such as preservatives and antioxidants) alone does not appear to define a food as ultra-processed (O'Connor *et al.* 2024). However, the inclusion of 'substances of no culinary use' within the definition makes this unclear. Overall, the participants felt there was risk that reformulation activity in response to the concept of UPF could be misplaced or at worst, regressive and lead to reduced nutrient intakes and increased costs and food waste.

Despite these concerns, some of the participants pointed out that a positive outcome of the concept of UPF could be providing an opportunity for manufacturers to think more critically about how foods are formulated, whether all of the ingredients used are really necessary and whether there may be scope for the removal and/or replacement of some additives, provided regulations are followed and food safety is ensured. For example, some additives aid in the creation of products that are uniform (e.g. in colour) from ingredients that can vary in their sensory properties due to natural variation. These attributes are thought to be required for purchaser satisfaction but may be unimportant in the eyes of some consumers. Refined, isolated ingredients are often used by manufacturers for consistency of quality. It must be acknowledged that while increasing consistency and practicality of use (e.g.

eliminating off-flavours), refining steps employed in creating isolated ingredients often remove compounds that may be beneficial to health such as phytochemicals (McClements 2024). Consumers may view unrefined ingredients as being more natural however, the latter often have difference techno-functional properties and require more complex processing techniques to facilitate their use within products, thereby driving up costs to the consumer. Conversely, milder food processing techniques such as dry fractionation are more sustainable, lower in cost and potentially beneficial to metabolic health (Schutyser *et al.* 2025). Interestingly, ongoing research into plant-based Pickering particles, composed of polysaccharides, proteins or polyphenols, suggests that these may be able to replace currently used emulsifiers within certain products (Gould *et al.* 2016; Sarkar & Dickinson 2020).

Changes in texture and material properties of foods - physiological effects

Besides additives, other non-nutritive aspects of foods that have gained increased attention and research focus as a result of the concept of UPF include the influence of food processing on food texture and the food matrix (see Box 2 [invited talk by Professor Ciaran Forde]). Diets consist of a mixture of diverse textures which have been demonstrated to influence average bite size, how long foods are chewed in the oral cavity and the duration of signalling the arrival of nutrients to the brain and gut (Forde & Bolhuis 2022). The participants discussed the fact that while reformulation typically focuses on food composition (i.e. removing nutrients of concern or adding beneficial nutrients while aiming for minimal changes to product taste and consumer acceptability (Gillison *et al.* 2021)), material properties of foods could be considered reformulation opportunities in the future to change not just what is eaten, but how the food is eaten and digested through combinations of food textures and matrix structures. For example, food technology may be used to favourably slow down (i.e. lengthen) the duration of the consumption rate of foods by changing their structure and breakdown properties to extend mastication duration. When combined with reductions in energy density (kcal/g), this could have a synergistic effect in reducing the risk of overconsumption (Forde & Bolhuis 2022). Combining a food's energy density with its eating rate allows the identification of foods with higher energy intakes rates (kcals/min). This could provide a useful basis for comparing products and pinpointing those that are both energy dense and consumed quickly. Such products could be favourable targets for reformulation.

Across the vast range of different processing techniques many will affect nutrient digestion, stability, bioavailability, absorption and metabolism once consumed (Ubbink & Levine 2024; Aguilera 2025), though effects differ widely and bio-accessibility of specific compounds can be both enhanced or reduced by processing (Sundborn *et al.* 2019; Musa-Veloso *et al.* 2020; Givens 2022; Visioli *et al.* 2022; Li *et al.* 2023). Foods can be structured at the macro-, meso- and microscale to have specific breakdown trajectories thus impacting the delivery of nutrients to different regions of the alimentary canal including differing rates of absorption and metabolism, postprandial responses (Forde & Bolhuis 2022) and post-ingestive psychological reinforcement (Dhillon *et al.* 2016; Valicente *et al.* 2023a). Food structure is therefore a key aspect that can induce significant changes in physiological responses and requires further understanding in order to be considered as part of the development of healthier foods (Bolhuis & Forde 2020). However, it was suggested that blanket policies linked to this, for example for wholesale changes to make all foods harder in texture or chewier, are unlikely to be realistic or appropriate in all cases, and may require adjustment for consumers in some instances. Nevertheless, emerging evidence suggests that it is possible for food microstructures to be altered to improve physiological responses, whilst still retaining desirable textures and consumer acceptability (Bajka *et al.* 2021; Bajka *et al.* 2023).

Benefits of advances in food production

The participants suggested that while there are undoubtedly issues with the current food supply and challenges that need to be overcome (FAO 2024), important progress has been made including increased efficiency of food production, distribution and sustainability that should be acknowledged (Michel *et al.* 2024). In recent years, issues including the Covid-19 pandemic, trade constraints as a result of Brexit, conflicts and extreme weather conditions have impacted the availability of particular foods and ingredients at certain times in the UK and demonstrated the fragility of the food system (Defra 2024). There may be a lack of appreciation for the complexity of the food system among the public that needs to be better communicated in order to manage consumer expectations. The participants acknowledged the fact that while the food industry has a crucial role to play in feeding populations and great advancements have been made in supplying safe food and maintaining quality standards (Grosso 2024), commercial decisions are also made that may not always take sufficient consideration of consumer health. This may include 'overprocessing' of food, i.e. processing food over and beyond what is necessary for safety, at the expense of health and nutrition. Similarly, food regulators and consumers often differ in their perception of what is considered an acceptable risk in food processing and formulation, and this should be considered when communicating the potential for these risks to cause harm to consumers.

While some food processing techniques have been used for decades (Siegrist & Hartmann 2020) and may be more familiar to consumers (e.g. pasteurisation) (EUFIC 2016), food technology has evolved, consisting of both more traditional and emerging technologies (Knorr *et al.* 2020). The participants suggested that there may have been a failure by food technologists to inform consumers with respect to advances in technology and production, including processing techniques and the function of specific ingredients. After their UK survey, EUFIC considered that more information about processing methods would help to reassure and build consumer trust in the food chain (EUFIC 2016). There may be a role for this to build understanding and reduce fear stemming from a lack of familiarity e.g. with 'chemical' sounding names of additives that consumers may assume are present for nefarious reasons (Henson 2024), yet are sometimes crucial for food safety and quality. Overall, the concept of UPF may have created the stimulus for food technologists to communicate the benefits of processing more effectively, and an opportunity for consumers to ask more questions about the processes and composition of the foods they choose, thus placing the onus back on food manufacturers to respond and make improvements where necessary.

Communication to consumers about the 'healthiness' of food

While the Nova system is widely used and supporters view it as fit-for-purpose (Lawrence 2022; Monteiro *et al.* 2024), with work also carried out to aid its use (Khandpur *et al.* 2021; Martinez-Steele *et al.* 2023; Sneed *et al.* 2023; Steele *et al.* 2023), the classification system is not universally accepted (The Lancet Gastroenterology 2025; Tosun 2024; Grosso 2024). The roundtable participants expressed the view that the Nova system can be difficult to interpret and apply consistently, as well as highlighting that some foods classified as Nova 4 (e.g. pre-packaged wholemeal bread), make important contributions to nutrient intakes. The group expressed concern that demonising all UPF similarly could have unintended consequences, leading to the removal of healthier UPF from diets and therefore have a net negative effect on population health. In relation to some foods, the Nova approach is inconsistent with current messaging depicted in the UK's healthy eating model, the Eatwell Guide, which typically defines less healthy foods/drinks as those that are high in fats, sugars or salt (PHE 2018; SACN 2023). A large number of UK consumers report actively avoiding UPF, even though their ability to correctly identify them may be low (Robinson *et al.* 2024). Furthermore, it has been argued that it is not guaranteed that consumers who avoid UPF will necessarily select more nutritious options in an effort to decrease their intake of processed foods (Hess *et al.* 2024).

The fact that Nova group 4 is broad, encompassing products for individuals with particular nutritional needs, including infant formula, milk substitutes, enteral nutrition, products for athletes and vulnerable populations such as older adults and individuals with specific dietary requirements, such as allergies, was also raised. This could result in essential specialist foods and supplements being considered in a negative light, resulting in risk of reduced acceptability of these types of products. In addition, whether artisanal varieties of similar products are in fact demonstrably healthier versus UPF varieties, remains unclear. Yet the potential implications of messaging that imply such products are a better choice could be large in relation to consumer understanding and effects on cost, food waste and accessibility.

The participants speculated as to whether more discriminatory classification systems could be developed, which may be more relevant to societies that are already at an advanced stage in the common usage of foods described as UPF and discussed the value of information about processing in the communication of the healthiness of foods to consumers. The UK multiple traffic light front-of-pack labelling scheme focuses on nutrients of concern in addition to energy (Department of Health 2016), providing useful at-a-glance information for consumers (Department of Health and Social Care 2020) rather than representing all aspects of dietary advice. For example, some healthier foods such as plain nuts, oily fish and reduced fat cheese would display 'red' for some nutrients, and fibre and micronutrient content are not communicated. Nutrient content alone is unlikely to fully explain the interaction of foods with the body once ingested and systems based solely on nutritional composition can be viewed as overly reductive. However, communicating information about foods in this way is arguably simple (e.g. 'red', 'amber', 'green' labelling). Likewise, Nova may be viewed as simple because it places all food and drink items into four categories, which are often further reduced to a binary 'UPF'/'non-UPF', despite Nova detailing differing ideal consumption patterns for foods categorised as Nova 1, 2 and 3 (Monteiro *et al.* 2019a). One of the conclusions from the authors of a UK analysis was that it is unclear whether Nova, multiple traffic light labels or both, were most valuable for identifying micronutrient-dense products, questioning the value of adding information related to the degree of processing to current dietary guidance (Dicken *et al.* 2025a). A recent review has highlighted the current lack of 'real world' evidence to support the effectiveness of front-of-pack labelling approaches in re-shaping population purchase and consumption patterns, with well-designed, longer-term studies needed (Braesco & Drewnowski 2023). It was argued that most of the nutritional labelling systems currently employed would benefit from greater emphasis on consumer education. At present in the UK, while the National Curriculum mentions 'the principles of a healthy and varied diet', neither the multiple traffic light labelling system nor the Eatwell Guide, that provides guidance around label use, is specifically referenced (Department for Education 2013a; Department for Education 2013b). Information is, however available for consumers online (FSA 2020; NHS 2022). There is a significant gap between UK dietary reference values for fibre and average intakes in all age groups (OHID 2025b). Some of the participants commented on the potential for the development of a fibre score to communicate the variety of different fibre types present in foods, underpinned by a robust classification system of fibre functionality *in vivo.* It has been suggested that consuming a diverse variety of fibre types may be beneficial for health due to their differing biological activities (McKeown *et al.* 2022; Whelan & Staudacher 2022). The fact that some foods that would be classified as UPF are high in fibre and/or wholegrains has been highlighted in the literature (Vadiveloo & Gardner 2023; Price *et al.* 2024; Kesaite *et al.* 2025).

Appropriate ways to define and communicate healthiness of foods will likely continue to be debated due to its multiple dimensions. For example, the impact of macro- and microstructures on nutrient absorption, glycaemia and impacts on the gut microbiota (Aguilera 2019), and the significance of this to health may be less-well established than nutrient-health relationships and therefore requiring more research before incorporation into current systems. Likewise, defining the need to consider formulation and processing as separate factors in food classification has been discussed in the literature (Levine & Ubbink 2023), and addressed more recently by the Task Force on Food Processing for Nutrition, Diet and Health established by the International Union of Food Science and Technology (IUFoST), which aims to take a holistic approach by additionally including other key attributes such as safety, sustainability, palatability, affordability and convenience of food products (Ahrné *et al.* 2025). Messaging around more complex aspects such as these are likely to be more relevant to industry, scientists and regulators, but unlikely to be suitable for all consumers. Distilling all aspects of food into a simple metric is undoubtedly challenging, and a perfect system is unlikely to exist. However, scaling of the extent of food processing is fundamental in any processing-related food classification, but it is missing from most.

Some participants discussed recent media headlines regarding additives and health (The Guardian 2023; The Telegraph 2024; Women's Health 2024), particularly emulsifiers (or other additives such as thickeners), which are used across many categories of commercially available foods in the UK (Sandall *et al.* 2023). These headlines may contribute to consumer concern (Robinson *et al.* 2024). While it is undoubtedly important to continue monitoring safety, including investigating hypotheses generated by observational studies indicating increased chronic disease risk experimentally (Sellem *et al.* 2024) and how additives might interact, for example in the intestinal tract (Bancil *et al.* 2021; Whelan *et al.* 2024; FAO 2025), there was concern around scaremongering, with participants questioning whether the media should be consumers' primary source of messaging about food and health. In particular, it was suggested that news stories around processed foods that lack balance could be read by time-poor teachers leading to misleading information being incorporated into lessons for school children especially when balanced information is more difficult to find. The important role of nutrition and food scientists, including those working in and with the food industry to try to drive healthier and more sustainable solutions, in aiding understanding among journalists around the complexity of a given issue was highlighted. This could include communicating the nature and strength of the evidence, regulatory aspects and process (where relevant) and any additional research that is currently underway or may be needed. Overall, there is a need to encourage a more nuanced approach to reporting of topics within nutrition science. UPF is reportedly the second biggest food-related concern among UK consumers, after food prices, with 73% concerned about ingredients and additives in particular (FSA & YouGov 2025). The roles of the FSA and EFSA in regulating additives have been recently highlighted (EFSA 2024; FSA 2024b; FSA 2025b).

Practicalities of consuming a healthy, sustainable diet

The participants discussed food behaviours in the context of modern lifestyles. Adults in Great Britain reportedly only spend a total of 48 minutes making foods or drinks (including cooking) and 67 minutes eating, on average, across the day (ONS 2024). It was suggested that a diet consisting of largely unprocessed foods is likely to require a significant amount of food preparation time and skill. Some processed foods and ingredients can play a role in home cooking, acting as culinary aids (e.g. sauces, stock cubes) creating flavour and facilitating intake of nutrient dense minimally processed foods such as vegetables in those that are less able to cook entirely from scratch (Brasington *et al.* 2023). While improving cooking skills can improve diet quality (Mills *et al.* 2017; Sprake *et al.* 2018; Lavelle 2023), it was pointed out that declining and fragmented food education (including on healthy diets) is evident in schools in the UK and so improvements are clearly needed (Jamie Oliver Food Foundation 2017; British Nutrition Foundation 2022; McKendrick *et al.* 2023). Additionally, in the UK, UPF intake is higher among those with lower social class occupations (Rauber *et al.* 2020) who may be more likely to face barriers to cooking e.g. lack of time, cooking and food handling skills, confidence and equipment; inhibitory fuel costs; living in food deserts and food insecurity (Select Committee on Food 2020; Brasington *et al.* 2023). Differences between home cooked and pre-prepared foods and meals in relation to aspects including nutritional composition, energy density, cost and cooking-related greenhouse gas emissions have been explored somewhat in the literature. Recipes of foods produced in both settings can arguably vary greatly in their attributes (e.g. ranging from healthier to more indulgent options) and results of comparisons of ready meals vs. home cooked dishes differ in terms of reported superiority (Aceves-Martins *et al.* 2023; Tharrey *et al.* 2020). With respect to neoformed substances such as acrylamide that forms during heat treatment of starchy foods, it has been pointed out that the generation of these is not exclusive to industrially produced foods. While concentrations within foods varies, these have been noted to be present in lower, equal, and even higher quantities in some cases when comparing home cooked equivalents to industrially produced foods (Göncüoğlu Taş *et al.* 2022; Pellegrini *et al.* 2025). Legislation and guidance exists for food businesses in the UK aiming to ensure that acrylamide levels are as low as can be reasonably achieved (FSA 2021), as well as advice for consumers on how to reduce acrylamide in foods at home and information detailing action being taken by the FSA (FSA 2024a).

Is the concept of UPF helpful in promoting increased production of environmentally sustainable foods/drinks?

Food systems

Concerns have been raised about the environmental impact of UPF, with various issues highlighted ranging from the production of their ingredients to packaging (Seferidi *et al.* 2020; Anastasiou *et al.* 2022), though the picture may be complex (Fardet & Rock 2020; Kesse-Guyot *et al.* 2023). It is estimated that much of the world's food comes from a small number of plants (FAO 2018; FAO 2019). Some of the participants discussed the issue of increasing the variety of crops that are grown and used for human consumption that are acceptable and would be sustainable, something that has been highlighted in the context of the UPF debate (Monteiro *et al.* 2018; Fardet & Rock 2020; Leite *et al.* 2022). While there have been efforts to promote underutilised crops (Gregory *et al.* 2019; WWF 2019; Wimalasiri *et al.* 2023; IFT 2024), including work to assess acceptance among UK consumers (Yang *et al.* 2020), it has been suggested that using alternative crops will require extensive efforts and multidisciplinary collaboration (FAO 2012). A recent UK report suggests that while industry concern and focus within the topic of sustainability may be narrow, NGOs are acting to highlight the full range of issues to companies, including biodiversity (FSA 2022a). Several examples of the potential role of emerging technologies in sustainable food production were highlighted during the roundtable, including precision fermentation (e.g. to produce products of animal origin and other foods such as soybean oil) (Graham & Ledesma-Amaro 2023; IFT 2023b), microalgae (Araújo *et al.* 2021; Williamson *et al.* 2024) and selective breeding (e.g. to create easy-cook British-grown beans (UKRI 2024)). Interestingly, a two-year regulatory programme for cell-cultivated products was recently launched in the UK (FSA 2025a). Underutilised crops that are already growing in the UK (such as fava beans (Jones & Cottee 2024)) could potentially have a positive impact in a shorter timeframe than emerging technologies, so a combined approach will likely be needed.

The fact that each part of the world has its own challenges and context with respect to dietary patterns, agriculture and sustainability was emphasised, therefore setting is important when considering the suitability of different solutions for sustainable food production. The complexity of these issues and the need for an adequate, holistic, longer-term funding strategy for multi-partner, transdisciplinary research (e.g. including sustainability, food technology, food safety and nutrition science) which takes a food systems approach rather than studying parts of the system in isolation (akin to the Transforming UK Food Systems Strategic Priorities Fund) was raised by many of the roundtable participants. This would require significant time investment and collaborative effort from all interested parties, though with the crucial aim of helping to improve the food chain for years to come. A guide to support those interested or engaged in convening, implementing, facilitating or supporting a multi-stakeholder initiative that contributes to the sustainable transformation of food systems was published in 2023 (UN Environment Programme FAO and UN Development Programme 2023).

Environmental sustainability in food processing

Caution was expressed around potential unintended consequences (with respect to food safety) of changes made by the food industry due to the narrative around sustainability, particularly SMEs who may lack sufficient expertise, yet attempt to modify existing processing techniques that have been used for decades (e.g. switching to alternative energies). While there may be potential for such change in the future, including techniques that use less energy and water (IFT 2023b) and use of alternative 'green' solvents for extraction (Chemat *et al.* 2019), it was suggested that more research is needed. At present, products that are more environmentally sustainable tend to be more expensive or require a greater level of in-home input, creating more premium products only accessible to more affluent consumers (that may not necessarily be healthier).

The participants discussed 'minimal-processing technologies', which have been defined as 'modern techniques that provide sufficient shelf life to foods to allow their transport and distribution, while also meeting the consumer demands for convenience and fresh-like quality' (Ohlsson 1994). Examples include modified-atmosphere packaging and high-pressure treatment, aiming to reduce the degradation of nutrients (e.g. vitamins) during production and storage, thus retaining or increasing nutritional quality (Knorr & Watzke 2019). However, many techniques come with disadvantages, including a need for more packaging to reduce the impact of reduced shelf life or requiring the use of more energy. The application of technological advances such as AI, machine learning and data analytics in food production was also referenced. These technologies have the potential to optimise processing, reduce its environmental impact (e.g. by reducing temperatures used, which may also reduce thermal effects of cooking) and improve hygiene monitoring (Huang *et al.* 2025). Collaborative work in this area is taking place in the UK via the BBSRC-funded network AIBIO (aibio.ac.uk), and in the Netherlands via the Top Sector Knowledge Institute Agri & Food Scheme (topsectoragrifood.nl).

There is increasing interest in work to retain the natural structure of raw materials creating ingredients that are closer to the original source both structurally and nutritionally (Aguilera 2025; Warner 2024). This has the potential to make products harder to digest, which may reduce caloric value of products due to decreased bioaccessibility of macronutrients (Holland *et al.* 2020). While this may work for some types of foods, there are likely to be a number of other trade-offs (Warner 2024). A new research project is investigating the use of mild processing techniques such as dry separation and fractionation processes or mild preservation technologies, which have lower energy and water usage. Impact on the food matrix, macronutrient digestion, metabolic responses and nutrient bioavailability, compared to conventional processing techniques, will be measured (Next Food Collective 2025).

The role of meat alternatives

The participants discussed the role of food technology in helping reduce consumption of animal source protein in favour of more plant-based alternatives, an approach that is increasingly recommended for the sake of planetary health (Willett *et al.* 2019; Climate Change Committee 2022; UN Environment Programme 2022; Halevy & Trewern 2023). In particular, they highlighted increasing research interest in, and development of, meat alternatives (Jafarzadeh *et al.* 2024; Mintel 2024). Meat alternative products typically require high amounts of processing, since raw materials need to be extracted. While pulses are a possible alternative that are encouraged within the Eatwell Guide, UK average intake of pulses is estimated to be only around half of what it should be according to modelling work (Scarborough *et al.* 2016) and many barriers to their consumption have been identified (Onwezen *et al.* 2021; Henn *et al.* 2022). A recent report comparing meat alternatives to meat concluded that while pulses and grains offer the greatest number of co-benefits of the alternatives considered (e.g. lower cost, better nutritional profile), processed plant-based meat alternatives can be a useful stepping stone for encouraging consumers to shift their diets (The Food Foundation 2024). All categories of meat alternatives analysed led to much smaller greenhouse gas emissions compared to meat. However, higher salt content and a lack of micronutrient fortification were identified as issues for some 'new generation' products (The Food Foundation 2024) , as highlighted elsewhere (Nolden & Forde 2023; Lindberg *et al.* 2024; Zhang *et al.* 2024).

The participants noted that current meat alternative products may lack sufficient sensory appeal (Appiani *et al.* 2023; Mintel 2024) and so further innovation may be required to convince consumers to switch to these products (Marangoni & Panescu 2025). While acknowledging that such products will not interest all consumers, the participants discussed the tension between the UPF definition and meat alternatives (Coffey *et al.* 2023; Estévez *et al.* 2024; Lee *et al.* 2024; van Hensbergen 2024; Messina & Messina 2025), suggesting that this represented an impediment to the production of sustainable products that are acceptable. Indeed, consumers reportedly view 'highly processed'/ 'artificial' meat alternatives as off-putting (Onwezen *et al.* 2021), opinions that may have been fuelled by the UPF concept (Mintel 2024; EIT Food 2024). It was suggested that it seems unlikely that current challenges in reducing meat consumption can be met without food processing and technology and potentially novel foods and methodologies (Salter & Lopez-Viso 2021). Examples include edible insects and lab-grown meat, for which safety and trust in regulation are reported as key for persuading UK consumers to try them (FSA 2022b)) and so general mistrust in food technology can create a communication challenge to shifting diets. Importantly, any meat alternative products need to have a healthy nutritional profile and be genuinely more sustainable than meat.

Potential unintended consequences of moving entirely from animal-source to plant-source proteins with respect to nutritional adequacy, along with the fact that processing impacts (e.g. on bioavailability) are not fully understood, were also raised. Therefore food, nutrition and sustainability need to be considered together as a holistic issue (Leonard & Kiely 2024; Food Standards Scotland 2024a). The role of hybrid/blended products (e.g. burgers/mince containing both meat and pulses/vegetables) was highlighted, with research indicating consumer acceptability and willingness to try these (Neville *et al.* 2017; Grasso *et al.* 2022a; Grasso *et al.* 2022b), though success in convincing UK consumers to purchase these appears to have been limited (Grasso 2024; The Grocer 2025). The utility of food technology in making use of edible byproducts generated from the production of meat alternatives and other foods, thus reducing waste and contributing towards the creation of a circular/spherical economy, was also pointed out (IFT 2023a). It was suggested that there is a role for academics in demonstrating the importance of such links with respect to food production and sustainability, including to research funders.

What are food technologists working on now, or might do in the future, that can aid the development of healthier and more sustainable foods/drinks? What changes in technology, regulatory nutritional guidelines (and consumer responses to them), will be needed to achieve improved health and environmental sustainability?

Responses to the final question posed during the roundtable are summarised in Table 1. Points raised clustered into four themes: target areas and considerations for innovation and reformulation that can be suggested based on current or future capability; potential definitions/targets that industry can work towards to improve the healthiness of products and related evidence needs; greater transdisciplinary working -development of cross-sector, food systems approaches; consumer-related issues and potential policy/regulatory changes, as well as some other comments.

As detailed in Table 1, the importance of funding for research dedicated to transforming food systems to improve diets and ultimately health in the context of competition for research funding in the UK was stressed by the participants. There was particular emphasis on the need for adequate resource allocation to inform mechanistic understanding around observed adverse associations between higher UPF consumption and health. As well as more general research recommendations around the topic, particular aspects have been highlighted within reports from scientific advisory committees as worthy of further investigation. These include whether the formulation of UPF and the circumstances in which they are consumed (e.g. fast-food restaurants, in front of a screen, on the move, etc.) promote excessive food intake; neoformed substances such as acrylamide or advanced glycation end-products (ANSES 2024); food additives or other processing methods (SACN 2023); foods containing particular ingredients listed within Nova (e.g. hydrogenated and inter-esterified oils, hydrolysed proteins) (AESAN Scientific Committee 2020) and the lack of information within current food composition databases indicating the presence of particular ingredients has been highlighted (SACN 2023; DGAC 2024). The challenges in designing and conducting studies to test some of the proposed mechanisms of action have been highlighted (Government Office for Science 2024).

There are several ongoing trials exploring biological and health effects of consuming UPF. For example, in a follow-up study by Dr. Kevin Hall and colleagues, subjects will consume 4 x 7-day UPF/minimally processed diets, that will vary in non-beverage energy density and the amount of foods defined as hyper-palatable (ClinicalTrials.gov ID: NCT05290064). Outcome measures include energy metabolism and intake, eating rate, palatability and bodyweight. The impact of sensory and material properties of food on daily energy intake over a 14-day UPF-diet intervention will be explored within the Restructure trial (ClinicalTrials.gov ID: NCT06113146), which also aims to investigate interactions with factors such as metabolite production, metabolic (including endocrine) responses, satiation and the gut microbiome (Lasschuijt *et al.* 2025). With respect to additives, the ADDapt trial (ClinicalTrials.gov ID: NCT04046913) focuses on individuals with mildly active, stable Crohn's disease to compare the effects of consuming a diet low in emulsifiers with a normal UK diet on outcomes including Crohn's disease activity and gut bacteria, permeability and inflammation (Bancil *et al.* 2025). Once published, the results of these studies (and others) hope to shed more light on particular aspects of this topic. With particular relevance to the UK, results from a study comparing the effects of consuming 8-week minimally processed/UPF diets that both follow Eatwell Guide advice have recently been published (Dicken *et al.* 2025b), showing weight loss and metabolic improvements on both arms (though weight loss was significantly greater on the UPF diet). Pre-prepared meals and snacks were delivered to participants by supermarkets and catering companies (Dicken *et al.* 2024a). There were fewer dropouts on the UPF arm and the UPF diet was rated higher in terms of flavour and taste, though the diets were rated the same overall by the participants.

Concluding remarks

UPF specifically are not currently the focus of regulation in the UK, rather the definition applied within policies targeting less healthy food is HFSS. However, UKRI has funded a public dialogue to explore consumer views on UPF, and it is reported that the results will help UKRI identify and address gaps in existing knowledge and develop future research priorities (UKRI 2025). Current information and advice for UK consumers highlights correlations between consuming a lot of UPF and poorer health and points to ongoing research but states that while some (but not all) UPF are high in calories, saturated fat, sugar and salt, not all processed and ultra-processed foods are unhealthy and some may have a lot of nutritional value and can be included in a healthy diet (NHS 2023; Food Standards Scotland 2024b; FSA 2025b). The Eatwell Guide depicts a plant-rich healthy, balanced and varied diet encouraging meals based on wholegrain and higher fibre varieties of starchy foods and including plenty of fruits and vegetables; some protein, encouraging more plant-based sources (with pulses being particularly highlighted) and advice to include at least two portions of fish per week; some reduced fat dairy foods or fortified dairy alternatives and small amounts of unsaturated oils and spreads. When choosing pre-packaged foods, the Eatwell Guide encourages the use of food labels to help select those that are lower in energy, fat, saturated fat, sugar and salt and contains advice to limit (red and) processed meat consumption (PHE 2018). Importantly, the UK's healthy eating model emphasises that food/drinks such as chocolate, cakes, biscuits, full-sugar soft drinks, butter and ice-cream are not needed in the diet. Globally, The International Agency for Research on Cancer (IARC) has placed UPF consumption on its monograph high priority list (ready for evaluation in 2026) (IARC 2024) and following on from its 2024 statement 'What are healthy diets?' (WHO 2024), the WHO has communicated a roadmap for work in this area, with the potential for the development of recommendations for acceptable intakes of UPF (Whittall 2024; WHO 2025).

On average, many UK dietary recommendations are not being met, with the population currently consuming too much saturated fat, free sugars and salt and not enough fibre, fruit and vegetables and oily fish (Public Health England 2020; OHID 2025b). Rates of obesity and type 2 diabetes are increasing (OHID 2025a) and the current food environment is undoubtedly a key part of the problem (Butland *et al.* 2007). There is an urgent need to improve the nation's diet for the sake of human and planetary health. Yet, neither health nor sustainability are a high priority for many consumers when selecting their diet, with less than 1% of UK consumers meeting Eatwell Guide recommendations (Scheelbeek *et al.* 2020) and ~43% of energy intake deriving from foods high in fat, sugars or salt (Kesaite *et al.* 2024). An estimated 65% of UK energy intake from foods that would be classified as processed or ultra-processed (Madruga *et al.* 2022), therefore the onus falls on manufacturers to improve the healthiness of foods while ensuring price parity and sustaining consumer appeal. There is also likely to be a role for retailers in helping to raise the profile of health. Recent plans from the UK government to tackle obesity laid out as part of the 10 Year Health Plan for England include mandatory reporting on healthy food sales for all large companies and consideration of reforms to the soft drinks industry levy to drive more reformulation (UK Government 2025). Furthermore, a new government food strategy has been proposed, aiming for a food system with a thriving UK food sector that supports access to and sales of healthier food and more sustainable and resilient production and supply at its heart, as well as the development of a supportive policy environment or 'good food cycle' (DEFRA 2025). Metrics, indicators and implementation plans are awaited.

During the roundtable, it was argued that due to the large contribution of UPF to dietary intake in the UK, more favourable ways to process and reformulate food need to be found in order to inform industry. Continuing and exciting developments within food science and technology may offer solutions. Indeed, a proposal for the development of "Good Processing Practices", standards within the food industry to optimise the nutritional quality and consumer acceptability of foods while conserving water and energy use, has been proposed (IFT 2023b). It is imperative that any changes to the food supply result in products that are genuinely healthier and not inadvertently less healthy due to misplaced reformulation efforts motivated by perceived ideals, including the demand for clean label products (Chen *et al.* 2022; Finnegan & Krzyzaniak 2024). Progress has been made in understanding the impact that some food characteristics can make on food intake and bodyweight (e.g. energy density, food structure) and these may have practical applications for industry (Chiu *et al.* 2015; Bolhuis & Forde 2020; Rolls *et al.* 2020; Stribiţcaia *et al.* 2020; Ren *et al.* 2021). However, in relation to processing *per se*, it has been suggested that the net effect of the combination of chemical and mechanical changes occurring during food processing on digestion, absorption and utilisation of nutrients in foods is yet to be untangled (Capozzi *et al.* 2021; Government Office for Science 2024; Aguilera 2025). What is underpinned by a wealth of evidence however, is the relationships between excess consumption of nutrients of concern and poor health outcomes (SACN 2003; SACN 2015; SACN 2019) and the benefit of consuming sufficient fibre (SACN 2015).

In terms of gaining more information related to food processing techniques and health, the multidisciplinary and innovative approach of "enginomics" (engineering + omics) has been put forward; the integration of the effects of food processing and structure design on nutrient bioavailability (host/microbiome) and omics (e.g. metabolomics, microbiomics). This places a holistic focus on health within the context of an environmentally sustainable and socially responsible model (Saguy & Taoukis 2017). It has been suggested that consumers can influence agrifood systems through their purchasing decisions by choosing products that are sustainably produced and healthy and that interventions including financial incentives, information and educational programmes and regulations can support changes needed (FAO 2024). Yet with considerable pressures affecting food purchasing decisions, the healthy, sustainable choice needs to be the easiest choice and so the weight of responsibility on the food industry and potential to self-evaluate, prioritise the healthiness of food and make improvements through technological expertise should not be ignored. Further research helping to identify additional factors relevant to reformulation beyond nutrients, such as food texture, structure and speed of eating will likely be important to monitor and consider. As the largest private sector employer, employing more than 4 million people and representing 7% of the economy, the UK food industry has been described as a powerhouse of innovation, playing a crucial role in shaping the economy and the nation's future (IGD 2024). It is important that technological advances in improving the health and sustainability attributes of food are not stifled due to framing around food processing and health.

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Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

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Author contributions

The event was conceived by the British Nutrition Foundation and chaired by C.W. with presentations from M.A. and C.G.F given during the event. S.L. wrote up the first draft of the manuscript based on the information presented and discussed at the roundtable meeting (consisting of inputs from all authors) and review of relevant literature, with critical inputs from C.W. and C.G.F. that helped shape the manuscript. All listed authors reviewed and provided comments on the manuscript and agree to be accountable for all aspects of the final manuscript.

Table 1: Summary of responses to the question: 'What are food technologists working on now, or might do in the future, that can aid the development of healthier and more sustainable foods/drinks'

Target areas and considerations for innovation and reformulation that can be suggested based on current or future capability	**Potential definitions/targets that industry can work towards to improve the healthiness of products and related evidence needs**	**Greater transdisciplinary working - development of cross-sector, food systems approaches**	**Consumer-related issues and potential policy / regulatory changes - and other comments**
• 'Designer/functional foods' e.g. those targeting specific parts of the gastrointestinal tract to achieve a specific health outcome (pre-/pro-/synbiotics) or processing for controlled release of nutrients, or effective fortification to control delivery and release of fortificants. • The development of lower energy density products that are equally as acceptable as more energy dense equivalents. • Analysis of the impact of current processing techniques on physiological responses to food that may ultimately impact health (e.g. food structure, loss of the food microbiome) and sustainability (e.g. are some ingredients overrefined, wasting energy, water and money); acknowledgement of any shortcomings as risks of 'overprocessing'. • Evaluation and communication of current reformulation efforts to stimulate further impactful activity. • Decoupling food complexity, freshness and shelf life by learning from other cultures e.g. Korea and Japan have cuisines that have	• Agreed, measurable metrics are needed, underpinned by accepted science, alongside definitive guidance and/or accompanying standardised methodologies for quantification/testing and communication tools (e.g. labelling elements) to allow products to be compared, in order to inform, guide and motivate industry, that may be tailored by product category (e.g. in recognition that fat serves to deliver fat-soluble vitamins in some foods). • Are aspects of food such as texture, structure and energy density well-enough established and is the research exploring their relationships with health sufficiently indicative to inform reformulation efforts? • Could metrics around fibre scores be devised? • Well-designed human studies, requiring significant funding, will be essential to inform mechanistic understanding to explain the links between high consumption of ultra-processed foods and health, in order to pinpoint any particular 'ultra-processed' ingredients, packaging types or neo-formed substances that	• An industry-wide collaborative, transdisciplinary systems approach is needed to advance scientific understanding and generate practical solutions which may include new or improved farming practices, processes, supply chains and packaging. • Developing the next generation of scientists to make sure that they have the opportunity, exposure and training to think about issues such as food holistically, using a transdisciplinary approach (e.g. also including psychology, economics, and anthropology), rather than just looking at finer details (e.g. the UK Food Systems Centre for Doctoral Training Programme). • Research approaches need to move with the times in terms of the food environment and how food is produced and consumed (e.g. takeaways, dark kitchens). Less may be known about food derived from the out of home sector since ingredients are not always labelled and processes can be unknown.	• Government incentives to enable healthy and sustainable foods (which can include some processed foods) to be sold at a competitive price and made more easily available (e.g. through school meals) are needed so that people of all socioeconomic groups can access them, in order to narrow dietary inequalities. • Retailers could be required to report sales data so that it can be available for research purposes. • There is a need for education (in all types of schools) around food production, supply and sustainability, including food processing and the role of the food industry. • Education should focus on healthy, balanced diets rather than individual products. • Tools to influence consumer behaviour to improve diets likely need to be tailored for different cultures.

traditionally been plant-rich, with higher content of vegetables including fermented foods that may be viewed negatively in other cultures as ‘processed’. • Recognition that improving the food offering may require many small changes to a multitude of factors rather than one definitive answer (e.g. nutritional composition/eating rate/nutrient density/food structure/behavioural change).	may be problematic, in order to inform policy and subsequently industry. • Move away from classifying foods based on their ‘level’ of processing as a framing for the healthiness/sustainability attributes of food but critically examine and communicate about the beneficial and necessary aspects of food processing to reduce fear and confusion among consumers. • How can new knowledge and expertise for improving foods with respect to health or sustainability become accessible to SMEs that may lack funds and/or technical expertise? • There is a need for interested consumers to be better informed about the health attributes of foods with simplified systems (e.g. Nutri-Score, which communicates about nutrient density) rather than binary ‘healthy’/‘unhealthy’, ‘UPF’ vs. ‘not UPF’ systems. Currently implementation progress can be slow/use is limited due to disagreement.		

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