International Journal of Food Science + Technology

Viewpoint

The role of food science and technology in navigating the health issues of ultra-processed foods

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(Received 9 March 2024; Accepted in revised form 18 March 2024)

Summary Food processing is seen as a double-edged sword. It is argued to have helped to provide a stable and safe food supply to urbanised societies, however with NOVA definition of ultra-processed foods it has now been linked to disease. Food science and technology has arguably been a major contributor to both. These potential harms are not a deliberate act, they simply meet the legal and market obligations placed on food businesses to be successful. So how food science and technology be pivoted back to improve health needs exploration, which will need to be consider within other issues including sustainability. Additionally, the increasing demand for plant-based meat alternatives and the role of fortification along with sustainable packaging and logistics to either enhance the physical properties and nutritional value of foods alongside minimising the need to process to transport them from farm to plate are further challenges. Finally, it will be considered how our food system might be supported to go through its next scientific and technological revolution to deliver a food environment and supply that has its primary objective of supporting human and planetary health, but in a way that is economically successful for all members of society.

Keywords Food policy, food processing aspects, food system, food use, ultra-processed food.

Modern humans and our world born out of food technology

Our modern food system seems to have given us both benefits with respect to a relatively stable food supply in many countries which has reduced food spoilage and risk of food-borne disease. This along with other societal measures linked primarily to clear water and sewerage along with vaccinations has increased life expectancy (Office for National Statistics, 2015). However, our food environment more recently become more of a risk factor, this can be seen with increasing number of publications associating ultra-processing and risk of disease (Lane *et al.*, 2024).

This tilting of views about food processing is interesting, as it has been argued and generally accepted that human evolution itself was at least in part driven by early food processing innovations (Wollstonecroft, 2011). The process and act of cooking of meat and other foods had the effect to enhance nutrient bioavailability and reduce risk of food-borne illness. However, changes to food production supported by innovations in science and technology some would argue (Monteiro *et al.*, 2019) may have taken this too far, so that calorie availability and palatability has been enhanced to a level which appears to be contributing to increasing levels of obesity and cardiometabolic disease. This has led considerable debate about the role of food processing and given the role of food science and technology in food production, distribution, storage, and preparation it is important to consider how this can help improve human health as well as providing a safe and palatable food supply.

When considering what modern society requires from its food system, which requires underpinning scientific and technological support, food safety can often be taken for granted and overlooked. Given the increasing urbanisation of many societies, the shift from food production being largely subsistence and localised this has changed to it being global and market driven. This has resulted in the growth of multiple actors within the food system from producers to intermediaries and through to multi-national food manufacturers and retailers before it reaches local markets and consumers. With the majority of this food system only developing very rapidly in the past century. It is important to consider the role of our food system in this holistic way, as it has the potential to highlight

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doi:10.1111/ijfs.17126

why some of these unintended consequences that are being reported. In the case of ultra-processed foods, these have been associated with increased risk of type 2 diabetes, cardiovascular diseases and cancer (Fiolet *et al*., 2018; Srour *et al*., 2020; Lane *et al*., 2024). It is then possible to deconstruct our current food system to explore how an innovative approach to food, including applications of food science can be developed to design a food system which is economically viable, ecologically sustainable and optimal to support human health at a population and individual level. This would then allow for opportunities to develop in logistics, packaging and food production, to focus on delivering healthy, tasty and accessible foods to consumers.

It is important to consider whether in recent history the result of food processing tipped over from being mostly beneficial to human health in terms of supporting the availability of safe and accessible foods within an increasingly urbanised society to one which appears to have negative health impacts. This time point might be difficult to pinpoint but given shortages in food supply leading to rationing and famine during the Second World War, and then societal changing in working practices and household structure after, which led to a demand to change our food supply, to provide adequate food and calories with an increasing drive for convenience. This has led to food and agricultural policies and subsides particularly in Europe which have changed our food supply and system (Lencucha *et al*., 2020). This has taken place at a time in our history when there has also been a shift in disease burden from infectious disease and injuries to long-term conditions, with the latter being more associated with environmental and especially diet-related risk factors. Additionally societal changes, especially the role of food in the home and time spent at work, thus reducing time for food preparation in initially western society, but increasingly this is being seen as nutrition transition on a global level. So, a combination of innovation, industrialisation and capitalism-based economy has led to the evolution of our current food system, which due to corporate obligations to be profitable produce foods which are popular and economically successful.

The rise of ultra-processed foods

With the near exponential rise in publications reporting about ultra-processed foods and particularly the health risks associated with consuming them, it is hard to ignore that there could be a problem with our food system and how it might negatively affect human health. The last decade has seen a threefold increase in publications according to PubMed (2024). This does not necessarily infer scientific validity, but it is suggestive at least of scientific interest with the NOVA classification being the primary way ultra-processed foods are classified (Monteiro *et al*., 2019). This is not universally accepted, but was acknowledged, despite limitations to be the most applicable when assessing population data (SACN, 2023). The NOVA system consists of four categories starting with unprocessed and minimally processed foods, food ingredients, processed foods (made from minimally processed ingredients) and foods made from processed ingredients being classed as ultra-processed (Monteiro *et al*., 2019).

With the growth in data about ultra-processed foods linked to negative health outcomes, there has been a mixture of reactions from calls to legislate or restrict marketing or supply of these manufactured food items in favour of minimally processed foods. This creates challenges as minimally processed foods with the exception of dried pulses, grains, nuts and seeds have a limited shelf life. Which given our increasingly urbanised society creates challenges. This is before considering the issue of food waste which has its own economic and ecological impacts.

Alongside the debate about ultra-processed foods, there has been interest about what components or aspects of these foods might be associated with poor health outcomes (Cordova *et al*., 2023). This is simultaneously going alongside the debate about whether the most commonly applied definition of ultra-processed foods by Monteiro *et al*. (2019) is appropriate for dietary patterns outside of Brazil. This is based on although foods classified as ultra-processed foods such as sweetened soft drinks and processed red meats have been well described as being linked to morbidity and mortality, others such as some breads and cereals, which are more typical of a European diet are generally linked to neutral or even positive health outcomes, especially if consumed in wholegrain form (Cordova *et al*., 2023). Additionally, these foods can be good sources of micronutrients, with due to their natural occurrence in these foods or because of fortification.

One theory why negative health outcomes are associated with ultra-processed foods is their energy density. Many ultra-processed foods are also considered to be high in fat, salt and sugar (Dicken *et al*., 2024) which can mean that they are also low in macronutrients. An alternative theory, evidenced by one of the very few interventional studies exploring the effects of ultra-processed foods (Hall *et al*., 2019) is that ultra-processed foods can result in increased energy intake and associated weight gain when offered in ad libitum feeding studies. This has led to the theory that they might be hyper-palatable and have greater calorie bioavailability. This has been linked to the reduced structural matrix in these foods and perhaps lower fibre and micronutrient density.

Therefore, it seems to some commentators that food science and technology in the period since 1950s has sort to make food more palatable and accessible. But may have resulted in a calorie-rich and in many countries a calorie oversupply but a nutrient-poor or even deficient food supply. Therefore, if this thesis is thought to hold some truth, it is important to consider how food science and technology may help to resolve some of the issues of diet-related disease, based on this approach, this viewpoint will focus on micronutrients, both retention in foods and fortification and the food matrix itself and how structure may influence the healthy nature of a food product.

It has been suggested that part of a route to a more sustainable diet is to consume less meat and more plant-based foods. This has led to a rapid expansion in the availability of meat analogues, which although they aim to be texture and flavour matched to meat. A feat that requires significant technological input to develop texture and appearance of meat analogues. This has led to increasing interest in the nutritional composition of these products which appear not to match the origin meat products (Melville *et al.*, 2023). This is further complicated by a lack of requirement to try and achieve a comparable nutritional composition, in particular its protein, iron, zinc and vitamin B12 content.

Fortification a benefit of processing?

Fortification of food, be that mandated or voluntary is seen as a way that food technology can be used to support public health. This can be seen in the case of flour fortification with folate to reduce risk of neural tube defects (DHSC, 2021) and salt with iodine (FSANZ, 2021). The approaches to fortification vary from country to country with Australia and New Zealand having clear codes, but in other countries such as the UK, this is less clear. In the case of flour, in the UK prior to it entering (and leaving the EU) white flour had to be legally fortified to the level of wholemeal flour with thiamine, niacin, iron and calcium, with the recent addition of folic acid (ref). However, the benefits of fortification are not universally accepted with some bread campaigners likening this to 'legally enforced adulteration' (Real Bread Campaign, 2024). This viewpoint perhaps is exaggerated by regulation which prohibit organic food products from being fortified in the EU, a policy which has been retained in the UK.

However, fortification is not always possible unless mandated by law, organic food cannot in UK and EU be labelled as organic if they contain any voluntarily fortified nutrients (Soil Association, 2018). Meaning plant-based alternatives to milks cannot be fortified to be comparable to cows' milk with respect to vitamin D, calcium and iodine. Meaning that these processed foods despite attempting to demonstrate environmental and a 'cleaner label' product may be nutritionally inferior to the non-organic variety. Perhaps this is regulatory issue, rather than being a technological one.

Despite the challenges of some jurisdiction's organic food regulation, it is perhaps around the area of fortification, particularly with the increase in plant-based alternatives to meat products food science could play a role in the future. Although there are some concerns that fortification is likely to lead to a product being classified as ultra-processed foods, a combination of good science communication, changes in legislation and public health policy alongside technological advances. The need for more sustainable food products and interest in plant-based or meat-free alternatives has led to a rapid growth in food products in this sector.

Perhaps a better way technology can support human health is to go beyond simply fortifying with nutrients that foods are deplete in (especially in the case of meat analogues or plant-based alternatives). Given the challenge which food processing may have created to our dietary patterns, of a nutrient-poor, hyper-palatable and high biologically available calories it could offer opportunities to resolve this by developing solutions in terms of mimicking naturally occurring food matrices, with biologically available micronutrients but restricted or delayed availability of calories.

Iron is a technological challenge with respect to its chemistry being a transitional metal cation, meaning it can alter its redox state between Fe^{2+} and Fe^{3+} states. This can result in oxidation of food stuffs which can reduce shelf life and potentially if ingested increased risk of oxidative stress along with low bioavailability. One solution might be to develop alternatives to haemoglobin to provide a more bioavailable iron than the inorganic iron which is typically used to fortified foods (Shubham *et al.*, 2020). A potential solution would be alternative to haemoglobin in the form of soy legume haemoglobin or leghaemoglobin, this is a soy root derived protein, this can be synthesised by the *Pichia pastoris* species of yeast (Ahmad *et al.*, 2023). Leghaemoglobin has been going through regulatory review as it presents a number of issues. Firstly, what is its primary purpose in foods, alongside it being a bioavailable source of iron it is also has the ability to function as both a flavour and colour additive could add to the regulator complexity in identifying its primary reason for use in foods. In Australia and New Zealand, it has approval linked to Beyond Meat as a way of adding iron to meat analogues (FSANZ, 2021), however in the US it is approved as a colour additive and in Europe it is considered to be under the remit of the genetically modified organism panel before being passed to the food additives and flavouring panel while in the UK it is being considered as a flavouring. This perhaps highlights some of the issues with respect to the role of science and technology in the production of what could be healthier processed food products. As it is unclear on how it is being presented to global food regulators if leghaemoglobin is a vehicle for nutrient food fortification, colour or flavour additive potentially this could add to further public distrust and confusion with respect to industrially produced foods.

Changing the structure of food

With the respect to food matrix, there are two potential aspects where technological advances could assist with respect to human health. One can be demonstrated by moving away from modifying carbohydrates in ways that have been suggested to be negative towards human health, in the form of modified starches which may be more rapidly digested or in the case of chemically modified celluloses these may negatively impact the gut microbiome (Cox *et al.*, 2013). An alternative to this, dependent on the physical properties might be to consider how microbial exopolysaccharides produced in foods which are fermented might be incorporated into a wider range of foods. These polysaccharides seem to have a prebiotic potential and may enhance diversity in the colonic microbiome and be associated with linked health effects (Muninathan *et al.*, 2022; Oz *et al.*, 2023). It may be more of a challenge to engineer foods which slow down eating rate, as the general effect of food preparation and processing is to breakdown or as some commentators suggest, pre-digest foods.

The future of food technology and science over the next 60 years, needs to operate in an economic system which prioritises human and planetary health first. This requires more of a geopolitical shift, as currently our food system is obliged to be profitable, this could be delivered through changes in how food industry and production is regulated. This could be through the use of taxation and levies which could build on the model seen with the UK's Soft Drinks Industry Levy, which led to significant technological development and change in product formulation over the course of 2 years. Although, seen by many as a tax, its true success seems to be how it has incentivised manufactures to reduce sugar content of products. This has not been achieved without some unintended consequences, as not all beverage products only require sugar as a sweetener, in the case of frozen slush drinks it also has a physical property. The technological solution was to replace sugar with glycerol, which still functions physically the same way to suppress the freezing point of water by disrupting the formation of hydrogen bonds restricting the formation of ice crystals allowing a consistent slush to form. However, although glycerine is generally recognised as safe and approved for use in US, Europe and UK, there have been a number of cases of hospitalisation of young children following the consumption of glycerol containing slushies linked to its ability to expand plasma and have an osmotic effect on cerebral spinal fluid resulting in nausea, headache and even loss of consciousness. Therefore, legislation to improve our food supply needs to be carefully designed to maximise public health benefit and minimise the risk of unintended risk and harms.

Although scientific and technologically advances have enabled a more consistent food supply to an increasingly urbanised society. In part as a response to a market that regulates based on need to supply food that is safe primarily from an acute toxicity and food-borne illness perspective there is little investment to support innovation to improve human health.

Conclusion

It is time that all members of the food community from public health and policy makes, through the industry, nutritionists and food science and technology should come together. There ultimately is not a desire to make food that may make people ill, after all solutions provided through previous food science and technology revolutions has developed ways to reduce incidence of borne diseases including brucellosis, ergotism and salmonella. Innovation in food science seeking to add health function to foods, such as reducing cholesterol (Ilyas *et al.*, 2023) or through application of biologically active compounds such as phenolics (Oluwole *et al.*, 2022) could be one approach. This could be part of a positive action approach that will best serve society, as too often in the past mistakes have been made by seeking simplistic substitution approaches, for example reducing fat or sugar without considering the health implications of such changes. Perhaps, the concept of ultra-process foods and NOVA classification offers an opportunity. Not necessarily in the details and limitations of the classification system, but to re-engineer our food system through the next technological and scientific food revolution. This will have to consider environmental impact of foods (Brennan, 2024) as well as delivering optimal human health. This will increase the demand for novel foods and how they can be introduced to new communities (Lumanlan *et al.*, 2022) considering issues of risk of both toxicity and allergy.

Therefore, given the environment which supports innovation in health and collective working food science and technology can be the solution to the apparent health problems presented by ultra-processed foods. This can partly build on the nutrient profile of the next generation of foods developed, moving beyond simply considering its chemical composition, and be inclusive to consider its physical structural composition and matrix, given what is known about the effect of prebiotics on our microbiome. Success in future foods must be in the form of holistically designed foods which promote human health alongside considerations of economics and sustainability.

Author contributions

Duane Mellor: Conceptualization (equal); investigation (equal); visualization (equal); writing – original draft (equal); writing – review and editing (equal).

Peer review

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/ijfs.17126.

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