Food System Strategic Assessment: Trends and issues impacted by technology innovation in the food system

Figure 8: Issues and trends impacted by technology innovation and estimated timeline to impact as highlighted by experts consulted for this study. Most relevant issues and trends with regard to the FSA remit are discussed in this section.

Novel technologies are key drivers and potential solutions for the future transformation of the food system, as has been the case in the past. It was technology that enabled modern food production methods, which have led to historically unprecedented current levels of food and feed supply for mankind. However, it is now also clear what the negative impacts of the current technologies on the environment and human health are, and hence further innovation is urgently needed to create a more sustainable food system while supplying food for more people in the future.

5.1 Driver: technology innovation, status March 2023

Technology innovation: innovation slowing over the next five years, particularly in areas of higher commercial risk.

Technology innovation in the food system has in the past often been associated with technology innovations around resource optimisation, novel means of production enabling novel foods and ingredients, as well as with increased use of data analytics in all aspects of food production, distribution and consumption. These trends have been highlighted by recent studies and media reporting, such as the rise of technologies for the production of proteins from alternative sources and the increase of various online food market places and platforms to sell and deliver food (Short et al., 2021, 2022a, 2022b). Given the current UK and global economic context the pace of implementation of such innovations may slow down as other issues around more fundamental innovation need to be addressed first by actors within the food system.

While the overall pace of innovation has continuously increased over the past decades and in the food sector large players have been driving the implementation of innovative technologies, food industry experts consulted for this study have confirmed that current economic and supply chain pressures impact investment decisions for the near to mid-term future. This is particularly the case for SMEs, which make up 97% of the food and drinks sector.

In addition, there is a perception by industry experts consulted for this study that recent government regulation will introduce costs that industry players are aiming to pre-emptively address, and that government action is not considering the operating realities of the industry. Examples given were the UK plastic tax and Extended Producer Responsibility (EPR), with difficulties in sourcing sufficient recycled input plastics as recycling systems across the UK are very different and not sufficient to cover required input amounts, and more generally recycling infrastructure not being ready for the requirements for EPR. In addition, health and food safety concerns were raised regarding some recycled materials (for example residual mineral oil in recycled cardboard fibre, although not a new issue).

Overall, it is perceived by experts consulted for this study that the food industry will not make major decisions for innovative change in the near future as they wait for more regulatory clarity on future sustainability requirements and economic pressures to ease before investing in novel technology or processes. Hence, while innovations around online sales and distribution of food as well as data capture may continue at pace, innovation in production, processing and manufacturing that require high capital investment over the near future may not be as rapid as previously anticipated, as SMEs need to catch up and consolidate, and large players target investments to lower risk innovation.

A number of technologies were highlighted by experts consulted for this study for their potential to impact the food system in the future. These are presented in the following sections. Technologies that were considered of overall importance, but do not fall within the FSA remit are reported on only briefly in terms of what they are but without going into technical or impact related details.

5.2 Improved agricultural production methods

This overarching category was assigned high priority and high future impact by experts consulted for this study, given the well-documented systemic negative impacts that current industrial farming practices have on the environment, global warming and in part on human health. The following individual technologies were most frequently mentioned associated with improvements in primary production methods. As most of these technologies are outside of the regulatory remit of the FSA only a brief overview of key insights is given in this section.

- Precision agriculture
- Regenerative agriculture
- Integrated pest management
- High tech horticultural production
- Glasshouses / indoor farming
- Vertical farming
- Hydroponics
- Drones
- Reduction and collection of methane & carbon sequestration
- Marine and land based aquaculture

“Sustainable energy input is key to successful food production systems. Innovation, automation and robotics will lead the way. Closed production systems will lead to

improved control of food safety and security." Expert, Food Industry

5.2.1 Precision agriculture, regenerative agriculture, and integrated pest management

These practices use mostly established (or even ancient) as well as some novel technologies to reduce negative environmental impact, agrichemicals and overall inputs while increasing soil health, sustainability, and the efficiencies of processes. This includes more data captured by sensors, and analysis with digital technologies. The UK government has recently updated several support schemes for farmers to support these farming practices directly or indirectly, such as through the Sustainable Farming Incentive (SFI), the Farming Innovation Programme, a collaboration between Defra and UKRI, or the Environmental Land Management Scheme (ELMS) (Defra, 2021a, 2021b, 2022c; Hughes, 2023).

Key insights

While most farmers are aware of the above-mentioned funding schemes, 27% of farmers say lack of funding is their main concern for not wanting to risk new approaches and 28% say they lack knowledge to implement such practices. Moreover, only 7% of farmers currently fully understand Defra's vision of the ELMS and although the great majority of farmers are supportive of improved farming practices, 68% believe that the recent changes to schemes and regulation will not lead to a successful future for UK farming (Swire, 2022). Given current economic conditions putting pressure on farmers due to high input costs, it seems very likely that implementation rates of such practices will slow down for the short- to medium-term future. Other issues adversely impacting the uptake of precision farming approaches at present relate to a lack of technology skills and required infrastructure in rural areas, such as good wireless connectivity.

As a result of this, promoting overall food sustainability goals will remain difficult in times when farming cannot invest in the required technologies to achieve them. This also impacts the health aspect of foods, as new farming practices can contribute to healthier foods.

In the longer term, once novel farming practices are implemented more widely, novel food safety issues need to be considered from areas such as the use of waste streams or novel active substances used as pesticides.

5.2.2 High tech horticultural production, glasshouses/vertical farming

These are high intensity farming approaches, also summarised as Controlled Environment Agriculture (CEA) growing mostly vegetables such as tomatoes, peppers, cucumbers, berries, and lettuce, and to some extent courgettes, chillies, aubergines and herbs. The sector is relatively small, and including unheated polythene tunnels represents approximately 2% of productive horticultural land in the UK, and represents around 10% by tonnage and around 20% by market value of UK vegetable production (Defra, 2021e, 2022a).

Key insights

Both high-tech glasshouses and vertical farming have been increasingly suffering over the past three years from high energy prices and in the glasshouse sector from acute labour shortages. As a result many glasshouse growers have not planted over the last two seasons, and will not have done so for this season, or have closed down operations altogether. The CEA sector is currently considered by some to be in an acute crisis due to energy prices and labour shortages and is predicted to contract further in the near future (Lawless, 2022; NFU, 2022). Energy input costs define economic viability of CEA in the UK. Given current energy prices this will remain a challenge for the near future with the sector very likely contracting further.

Hence, overall potential of these intensive farming approaches to contribute to a transformation of the UK food system in the future will remain uncertain, even though often perceived as solutions to increase food security through shortened supply chains and increased local production.

More recently, some concerns have been voiced that potential food safety issues with nutrient solutions used in vertical farming and hydroponic systems, or the fact that plants are in close contact with plastic materials all the time (piping, growing scaffolds) need to be better understood. Moreover, there is a lack of evidence about nutritional differences between soil-grown versus CEA grown plants (using mostly soil-free hydroponic systems and nutrient solutions) (Short et al., 2021).

“It is difficult (for businesses) to invest in infrastructure because food trends change and investing in premises or equipment then becomes obsolete. If fermented proteins and controlled environment agriculture are seen as future trends this will require significant upfront investment and also there will be significant upfront carbon impact." Expert, Academia

5.2.3 Marine and land-based aquaculture

Marine and land based aquaculture has been reported to be one of the fastest growing food production methods globally with an increase of 600% between 1990 and 2020, an annual growth rate of 6.7% and reaching an all-time high of 122.6 million tonnes of live weight in 2020 (Seafish, 2023). Aquaculture is often viewed in the UK as a ‘local’ production method that may increasingly supply more proteins to the country in the future. However, experts consulted for this study reported a slowdown of the growth of the sector over the past two years, likely due to the Covid pandemic and high input prices, alongside a backdrop of generally declining seafood consumption in the UK.

Key insights

With regards to overall evolution of the market for seafood as a source of protein, it is anticipated by experts consulted for this study that most fish and seafood will continue to increase in price and will undergo further premiumisation into the luxury food segment at a time when consumers would want to consume cheaper seafood options (e.g. frozen and packaged). Overall seafood consumption has been in decline for over a decade in the UK, mainly through decline of home consumption, and only briefly increased during the Covid-19 pandemic (Garrett et al., 2023; Seafish, 2023). Against this background, the trend towards premiumisation is known to have motivated seafood labelling fraud in the past, often in the catering sector, where cheaper sorts of fish are labelled as more expensive ones, or line-caught, or organic while they are not, as indicated by experts consulted for this study and academic literature (Lawrence et al., 2022). Nevertheless, despite economic pressures and exposure to the grey labour market, no increase of food crime is currently detected in the seafood industry according to experts consulted for this study.

Given these factors, the role of UK aquaculture in contributing to protein supply for human food is very likely to remain modest for the short- to mid-term future given current trends.

5.3 Digital technologies, AI and robotics

These technologies are often perceived as providing transformative technology solutions to current problems that will influence and shape anticipated future developments. With respect to helping transform the food system, experts consulted for this study included under this heading additional terms such as Industry 4.0, (the fourth industrial revolution), and Big Data, with blockchain highlighted (Ghobakhloo, 2020). These technologies are expected to impact all levels of the food value chain from production and processing to supply chain and distribution enabling improved tracing and transparency as well as improved consumer insights and better data driven predictive decision making.

Moreover, digital technologies have enabled new business models and more networked, or digital platform-based modes of interaction between consumers and different parts of the food system changing linear supply chain models into food system interaction networks, which create not only a much more dynamic food system, but also novel risks that can emerge very rapidly impacting wider parts of the system. This requires a much more responsive and flexible way of dealing with such risks (Short et al., 2022a). In figure 9 the emerging digitally enabled interactions between consumers and various players in the food value network are shown with their potential food safety risk impacts.

Figure 9: Representation of the dominant future value interaction network of the food system enabled by digital technologies, replacing linear interaction models. Colours indicate potential food safety and authenticity risks. Relative size of circles represents a qualitative estimate of their future role in the food system.

Source: (Short et al., 2022a).

While most digital technologies and robotics have improved efficiencies along the value chain for a long time, they are increasingly seen as solutions to improve processes as well as reducing GHG emissions and generally negative environmental impact by improving resource and energy efficiency and by reducing waste. Over the past two decades tracking and tracing applications have helped to improve food safety and authenticity standards in most parts of the world.

Key insights

Intuitively the contributions of these technologies to improvements in the food system are often perceived as straightforward and on a continuous forward trajectory. However, the specifics of the food sector may make achieving any large gains in the short- to medium-term future less likely than is hoped for due to a much slower and less integrated technology uptake than media reporting may imply. A recent survey of food industry stakeholders showed that 40% of respondents do not use any sophisticated digital technologies at all, while only 33% reported using digital technologies in manufacturing processes, quality control and oversight, indicating a much lower implementation rate than one might expect. The majority of respondents (65%) stated that the main hurdle for technology adoption is selection of the right technology that is fit for purpose, followed by high capital investment, complexity of technology and lack of necessary skills particularly affecting SMEs which make up most of the food and drinks sector (Lotfian et al., 2022).

Another important aspect of technology implementation is the fact that it often requires a change of operating practices, business culture and business models which are perceived as risky to change, particularly at times of increased economic and regulatory uncertainty. Misconceptions about how certain technologies actually work in an industry setting also make implementation more difficult. For example, of overall investment in AI applications in food manufacturing, such as in machine vision, predictive maintenance, Internet of Things, e-nose fingerprint technology for detection of volatile compounds in food (food safety and quality application) only 10% are spent on AI algorithms, 20% on enabling technologies and 70% on embedding AI applications into specific business processes and agile ways of working (Boston Consulting Group, 2022). Similar issues apply to the implementation of advanced AI supported robotics in sectors where automation has only just started, such as the industrial horticulture sector, where acute labour shortages have intensified momentum to implement harvesting robots. At current maturity levels horticulture experts agree that a significant replacement of human labour in the horticulture sector is still not very likely over the next decade (Defra, 2022b).

Given the cost and complexities of implementation it is apparent that large, often multinational businesses are leading innovation in these technology areas with SMEs lagging behind, and a delay of investments in these technologies is expected in the near to mid-term future due to economic pressures.

With regards to dynamic developments in digital consumer interactions with various actors in the food system, food safety and authenticity issues may arise very rapidly requiring novel enforcement tools and guidelines for online operators. The FSA has already started engaging with this sector providing guidance for digital food distribution platform operators (FSA, 2022e).

5.4 Alternative sources of protein

Technology-enabled food production methods for proteins were viewed as highly important by experts consulted for this study for their potential to positively impact the future evolution of the food system. This is mainly based on the argument that meat and dairy products are a main source of protein in many parts of the world and current livestock farming methods have a large negative impact on the environment. The following protein production technologies were highlighted by experts consulted for this study (not in order of perceived importance):

- alternative single cell proteins (cellular agriculture)
- cultured meat
- fermentation and precision fermentation
- plant-based proteins for foods such as plant based meat alternatives
- insect proteins (covered separately in section 5.7)

Technologies used for the production of alternative proteins utilise the following cellular mechanisms:

- conversion of organic or inorganic carbon atoms into biomass, proteins, carbohydrates, lipids, and other nutrients.
- fermentation with the help of (sometimes genetically modified) microorganisms such as bacteria and fungi, to produce high-value macromolecules that are extracted via biotechnological and biochemical methods from the fermentation culture for use as ingredients in food products.
- in-vitro production of multi-cellular aggregates using laboratory technologies (for example, lab-grown meat).

The end products of these processes can either be used directly in food products, such as in the case of traditional Japanese tempeh or miso, or for further taste and texture processing into finished products such as in meat alternatives like Quorn and many others based on fungal biomass production. Alternatively, proteins generated by cells in these processes are extracted, purified and reformulated by various biotechnological and biochemical processes and then used as ingredients in a finished food product. In the past decade many of the required applied biotechnology methods have been up-scaled for medium to large-scale production and many large food manufacturers as well as SMEs have invested in these kinds of technologies to produce proteins for a large variety of food items. This has also contributed to an acceleration in food manufacturing innovation for the production of a great variety of meat alternative products as competition between manufacturers increasingly requires differentiation, although the price for these products is still high due to high processing costs (Short et al., 2022b). For a discussion of current consumer trends relating to some of these products see section 3.

Key insights

Plant-based meat substitutes are presented by manufacturers as sustainable and healthy alternatives to meat, and most consumers perceive them that way. However, they are not equivalent to a standard vegetarian diet. While many products on the market can be very similar to meat in terms of nutrient density and are often fortified with added nutrients, they are highly processed foods often high in salts, sugars and additives. Moreover, although some products have environmental benefits, for example in terms of reduced GHG emissions and land use, often production requires high energy inputs and ingredients which have themselves negative health or environmental impacts. At present, the health implications of long-term consumption of such products are still unknown. Hence health and sustainability claims and labelling of these products need to be better regulated to ensure consumers can make informed choices, which is currently still a challenge as science based metrics for health and sustainability labelling are at a very early stage for these products.

While production of dairy proteins such as milk and egg protein by precision fermentation is a rapidly increasing field and considered to have the potential to reduce the current high environmental impact of dairy farming, their price is still multiple times above production from conventional sources (Short et al., 2022b).

Cultured (lab-grown) meat, despite the amount of media attention, is still an emerging technology with high production and input costs that mean products are not competitive with conventional meat production. While proponents of cultured meat advertise the technology for its potential to reduce negative environmental impacts of livestock meat production, it is at present not well understood in terms of measurable environmental benefits. Lab-grown meat has high energy inputs and uses ingredients such as growth media, and biologically active substances (such as hormones and transcription factors) that are not fully understood in terms of their metrics and Life Cycle Assessment (LCA). Moreover, impacts on human health after long-term consumption are currently unknown. As mentioned in section 3, consumer acceptance for trying cultured meat can reach around 30% when asked in surveys. Actual acceptance will only be known when products are tested in bigger markets at a realistic price point. A recent meta-study on the consumer acceptance of cultured meat highlights that besides food neophobia impacting acceptance, food safety and naturalness are major concerns for consumers. In addition, consumers wanting to make ethical decisions regarding sustainability and animal welfare would prefer to pay a premium price for plant-based products rather than cultured meat (Pakseresht et al., 2022).

However, lab-based meat producers are currently supported by a wave of investor interest from the past five years and are about to enter first consumer test markets. Lab-grown meat products have so far been approved for human consumption in Singapore, and in November 2022 by the FDA in the US. Both products were chicken nuggets (Douglas, 2022). Currently, a number of US, Israeli, and European companies are applying for their lab-grown meat products for approval in the US. In the UK, many products made with proteins from novel sources may require authorisation under the Novel Foods regulatory framework, which is currently being reviewed, and would also need to consider lab-grown meats.

As many future products using alternative protein sources will fall under the UK Novel Foods regulation, a balanced approach between maintaining food safety and authenticity standards and being supportive of innovation in a complex and rapidly evolving technology area will be required for the sector to grow.

In addition, assessment frameworks for nutritional value, health and sustainability standards of these alternative protein products need to be established and linked to a clear labelling system to support consumers in making informed choices. As our understanding of the longer-term health impacts of these products is currently limited, building the scientific knowledge base around these products would be necessary to build trust with consumers in this kind of novel products that may have health and sustainability benefits.

5.5 Novel food processing technologies

Recent innovations in food processing technologies have been driven by consumers wanting healthier, ‘fresher’ or fresh-like products with less chemical preservatives and processing steps compromising texture, natural ingredients, and flavour. Of particular interest is replacing standard food preservation technologies involving heat treatments, such as pasteurisation that can impact nutritional value by damaging proteins, enzymes, and flavour molecules among others, with novel approaches. Experts consulted for this study mentioned a number of so called non-thermal, or low temperature processing technologies that have been tested and implemented over the past decades to varying degrees, for inactivating microorganisms. These include:

- high pressure processing,
- ionising radiation,
- Ultrasonics,
- UV radiation,
- Ohmic heating
- high voltage arc discharge,
- pulsed electric fields,
- pulsed light,
- dense phase carbon dioxide,
- cold plasma

Key insights

While some of these technologies are well established, such as UV light for antimicrobial surface treatment, most other mentioned technologies are still at a stage where additional antimicrobial technologies/measures need to be applied to make food products safe. Many high-energy radiation technologies need to be carefully adapted to each food type to avoid unwanted side effects at the molecular level that might impact taste or texture. Some of the technologies while working on food surfaces and a few millimetres inside the product, have issues penetrating deeper into the food item or liquids. Moreover, while indeed some of the technologies allow antimicrobial effects at lower temperatures enabling better preservation, issues with reaching all parts of the product still remain, depending on complexity of shape or microstructure, making additional antimicrobial technologies necessary in combination.

At present the technology readiness level of many of the mentioned non-thermal technologies, although often in development for decades, does not yet allow commercially viable up-scaling for mass production applications. In addition, they are mostly considerably more expensive and complex compared to conventional heat treatment technologies, which makes them more suitable at present for niche applications. Hence, such technologies can be found in the premium foods segment for the production of functional foods and supplements, and with further growth of this market, further improvements, up-scaling and wider adoption is expected in the mid- to long-term future (Chacha et al., 2021; Short et al., 2021).

5.6 Gene Editing (GE) / Precision Breeding (PB) technologies

The development of the CRISPR/Cas9 gene editing methodology, introduced in 2013, now implied when using the term Gene Editing (GE) or Precision Breeding (PB), enables a much more precise and much faster manipulation of DNA sequences to produce favourable traits in plants and animals. In recent public and legal definitions gene edited organisms, or Precision Bred Organisms (PBOs) are often described as organisms that have genetic changes that could have been achieved through traditional breeding or which could occur naturally" (Defra, 2021c).

The rapid evolution of gene editing technology in basic research over the past decade has put considerable pressure on regulators to clarify whether GE/PB is treated in regulatory terms equally to genetic modification (GM) or differently. Over the past five years some countries have responded quickly by creating guidelines for the permitted use of GE/PB, while other countries maintain that GE/PB is to be treated like GM. This lack of harmonisation has considerable impact on the plant breeding industry and trade between countries. From a systemic perspective, it is hoped that the GE/PB production of novel plant and animal varieties can in the future help alleviate some of the pressures on the food system with regards to productivity, sustainability, and resilience (Hundleby & Harwood, 2022). To realise this potential at a global scale requires however urgent international harmonisation of regulatory systems to reap wider benefits from GE plants and organisms. An overview of the current state of the global regulatory landscape with regards to approval of GE organisms is shown in figure 10.

Figure 10: Regulatory status of gene-edited crops (when no foreign DNA is inserted). Dark green = regulated as conventional crops. Pale green = draft regulations suggest they will be regulated as conventional crops. Red = GE is treated like GMO. Yellow = favourable legislation passed in March 2023 (UK).

Source: (Hundleby & Harwood, 2022).

Key insights

While most experts consulted in this study view GE/PB positively, and anticipate no negative impacts on human health and no novel food safety concerns, several issues were highlighted where the FSA might have a role in shaping public debate around the technology.

GE/PB crops, animal feed, and food were regulated in line with EU regulation as GMO until very recently, but this can now change with the royal assent of the Precision Breeding Act in March 2023. After approval in the UK, experts estimated that imported GE/PB crops, animals and foods might reach the UK market within the next two years.

A recent consumer survey by the FSA has shown that 75% of respondents have not heard of precision breeding and only 8% have before polling. Once respondents understood the technology, 50% supported the sales of GE/PB foods and products in the UK and 29% objected (FSA, 2023). Should consumers be enabled to make informed choices on whether to choose GE/PB foods or not, for example via a labelling scheme, then difficulties in detecting potential mislabelling fraud could arise as authenticating food that is precision bred would be extremely difficult by current standard sampling methods.

Access to this new technology (CRISPR/Gene Editing) could result in significant improvements to (plant/crop) traits … However, it is not yet clear how quickly the science can deliver on this potential nor how quickly the regulatory system can cope, how much this will cost and crucially how consumers will react. Expert, Food Industry

Most of the potential of GE/PB is currently seen in specific plant traits playing a role in resistance to climate conditions, water uptake, pest resistance, and the production of novel or improved nutrients. While these are well studied in academic research laboratories and some successful field trials were performed in the UK, experts expect that it may take at least 5-10 years until novel GE/PB crops can be rolled out at scale, or other benefits of the technologies be reaped in the UK (Raffan et al., 2023). This is due in part to scientific complexities, for example the part epigenetic mechanisms play in plant phenotype independent of DNA changes, and the time required to field test and produce seeds at scale for farmers, assuming that farmers do not reject the technology. Hence, despite being a much faster technology to produce genetic variation, its potential for the UK may take a decade to unlock.

"It should not be assumed that gene editing is necessarily a solution for food shortages, authorities need to be vigilant on this." Expert, Government

5.7 Insects in food and feed

While insects have always been consumed in some parts of the world, they are a novel source of protein in the West. Insects such as crickets, black soldier fly, grasshoppers and mealworms which are currently commercialised and explored for large scale production are high in proteins, fats, and are a source of some vitamins and micronutrients such as Iron or Calcium, as an increasing body of scientific literature has shown (de Castro et al., 2018). The benefits of insect proteins lie in their reduced feed inputs (around a sixth of the feed of cattle, and around half the feed compared with chicken and pigs) to produce the same amount of protein. Insects can be grown in factories requiring substantially less land and water than livestock, can be fed on organic waste streams, and have a much lower GHG and ammonia footprint (IPIFF, 2022; World Wide Fund for Nature - UK, 2021).

The number of product categories using insects has increased significantly over the past decade increasing significantly in the past five years, to include: processed whole insects, animal feed and pet feed, and processed insect powders used as an ingredient in various foods such as snack bars, drinks, or baked goods.

Currently, insects for use in poultry and pig feed are already approved by the EU as well as insect powders for human consumption since January 2023, while in the UK insect feed for animals used for human consumption is not permitted (with the exception of insect meal as feed in aquaculture).

Key insights

While the biggest impact of using insects for feed and food is seen in their reduced environmental impact compared to many other animal protein sources, it is also clear that the quantities needed to enable substantial environmental benefits would require a rapid growth of the insect production industry with associated input streams and (preferably sustainable) energy sources (mainly for heating). One particularly large protein replacement segment would be soy for animal feed, which currently accounts for 75% of global soy production, to free up land for crops for human consumption and re-forestation. Another often seen role for insects is as processors of organic waste streams as part of circular agricultural production systems and a number of successful pilot operations are currently being tested in EU countries.

It is estimated that around 240,000 tonnes of insect meal could be sourced from UK insect producers, but the growth of the industry is clearly lagging behind Europe and the US. When compared to the required amount needed to substantially contribute to animal feed, output will remain marginal for some time. Even the predicted demand of 540,000 tonnes by 2050 for insect meal in the poultry, pig, and farmed salmon sectors in the UK, is modest (World Wide Fund for Nature - UK, 2021). Despite insect meal being permitted in UK aquaculture, its price is still too high to be commercially viable due to low levels of supply, preventing uptake.

"Insect-based food and feed could be a sustainable alternative protein source, but if not well-regulated and produced, it could pose food safety risk" Expert, Food Industry

In addition, feed streams for insects need to be regulated with regards to possible contaminants and allergens and relevant UK legislation is currently under review. Moreover, a lack of scientific information about the longer-term health impacts of insect proteins on animals and humans, including sensitisation to novel insect allergens needs to be addressed, to fully understand the nutritional potential of insect proteins in human food and animal feed.

Despite a lot of media attention regarding insect products for human consumption, any evolving human market in the UK will be small for some time into the future, given that the global market size was estimated at only USD 0.65b in 2020, and longer-term consumer uptake is still unclear (Grand View Research, 2019). Hence, overall, growth of insect production is expected to remain modest in the UK with tangible contributions to the animal feed market beyond 10 years from now, and with much less certainty around the development of the market for human consumption.

5.8 Improved packaging / alternatives to single use plastics

Reducing or replacing plastic packaging was highlighted as important by many experts consulted for this study and is also increasingly supported by consumers over the past five years who understand this as a way to reduce negative impacts on the environment (Which?, 2021)

Single-use plastic (SUP) packaging has, since the 1960s and 70s, transformed and shaped economies and the food system on a global scale, and enabled many advancements in food safety, production, supply chain logistics, and consumer convenience. SUP packaging for food has also become an integral part of supply chains, production processes, commercial pathways, as well as regulatory requirements and food safety standards, as many decades of research on different types of plastics used as food contact materials had established their use as safe for consumers. In addition, industrial innovations in plastic packaging production technologies have made fossil fuel-based SUP the most cost effective form of packaging in the food sector to date (Dey et al., 2021).

At the same time, plastic waste has become one of the major pollutants worldwide. Its degradation products in the form of micro-plastics can be detected in all ecosystems and throughout the global food chain. Micro-plastics have been shown more recently to be present in human blood and may pose various risks to human health which are currently not well understood (Allen et al., 2022; Leslie et al., 2022). Findings like these have led the Canadian government to add manufactured plastic items to the list of toxic substances under Schedule 1 of the Canadian Environmental Protection Act in 2021 (Walker, 2021).

Over the past decade, considerable efforts have been undertaken by legislators as well as through voluntary industry initiatives and NGOs internationally to reduce and find alternatives for SUP. Legislation to reduce SUP has come into effect over the past five years in many countries, in particular targeting the food sector. For example a number of SUP items have been banned in the EU since 2021, following the Single Use Plastics Directive 2019 and packaging producers in the EU will likely be mandated from 2023 to increase the percentage of packaging made from recycled plastics (currently ~5%), with specific targets for 2040 set as high as 40% for certain packaging types (European Commission, 2022; Taylor, 2022). The UK plastic tax that applies to businesses when 10 tonnes or more of packaging or packaging components containing less than 30% recycled plastic are produced or imported came into force on 1st of April 2022. In addition, a number of government initiatives are underway in the UK and the devolved administrations to reduce plastic use more generally.

These efforts mostly acknowledge that reduction of SUP is a complex issue that can only be achieved via multi-level approaches and simultaneous consideration of circular economy models and the implementation of 4R strategies (reduce, reuse, recycle, and recover) as well as wider sustainability and decarbonisation goals (Cruz et al., 2022).

However, recent reports have shown repeatedly that SUP reduction via recycling or reuse is currently not delivering at any significant scale, mainly due to issues around consumer behaviour and industry practices. In addition, innovations such as compostable and bio-degradable plastics after many years in use in parts of the food system are not delivering the environmental benefits they were designed to deliver (Greenpeace, 2020, 2022; Purkiss et al., 2022). Hence, developing novel materials with properties that match those of currently used plastics and are commercially viable at scale has become a matter of increasing urgency. Specific research initiatives and dedicated centres of excellence have been launched in the UK and elsewhere to find such alternative materials (two examples of many are the UKRI funded Smart Sustainable Plastic Packaging Challenge, SSPP, or the Sustainable Plastics Technology research unit at Wageningen University in the Netherlands).

Key insights

Despite more recent initiatives and decades of earlier research producing a great variety of plastic alternatives including “bio-plastics”, many successful small-scale trials and some level of consumer acceptance of such alternative materials, considerable challenges remain (Li et al., 2022; Melchor-Martínez et al., 2022). Some of these challenges include: lack of chemical and physical robustness to deliver properties required for current food safety standards, often blended complex composition, difficulties sourcing input materials at scale, production processes with unfavourable sustainability parameters, lack of studies on long term impact on consumer health, high costs of production at industrial scale, consumer acceptance and willingness to pay. These challenges also apply to recent novel food packaging concepts, such as active and intelligent packaging, or biodegradable and edible films for extending shelf life.

Several food industry experts consulted for this study voiced concerns about a lack of regulatory clarity about future policy trajectories relating to plastics and packaging and insufficient interaction between industry and government to innovate efficiently in this space. They also pointed out that while most large manufacturers are exploring some novel packaging technologies, regulatory uncertainties and lack of infrastructure make investments risky. Moreover, at present most novel packaging technologies are too expensive to be commercially viable.