4. Changes underway in UK primary food and feed production

In this guide

Changes to primary production practices in the UK are being influenced by a variety of interacting and sometimes competing, technical, social, political and commercial interests. For example, many of the practices linked to reduced GHG emissions such as conserving soil carbon were established in the context of biodiversity and good land stewardship. Similarly, there has been a long-standing interest in reducing fishmeal as a component of fish feed in aquaculture driven by the need to conserve wild fish stocks, and in reducing the soya bean content of animal feed to reduce dependency on a single protein source (Fiorella *et al*., 2021; Wilkinson and Young, 2020). Most recently, the incentive to reduce energy consumption in the UK has been driven by the rising costs of energy rather than

net zero carbon goals. This means that many of the changes currently being researched and implemented were prioritised primarily for purposes other than the specific achievement of net zero carbon. If carbon reduction targets are supported by such developments, this may sustain or even accelerate their adoption. Thus, any assessment of the possible impact of carbon reduction measures should include the additional impact of those enabling technologies.

4.1 Technological changes already underway

Technological changes in primary food production have been summarised in the FSA's Rapid Evidence Assessment of emerging technologies impacting the UK food system (FSA, 2021) and are also evident in projects supported by Innovate UK. Boxes 1 – 3 highlight some features of three developing areas of technology (vertical farming, aquaculture, and alternative and novel proteins) chosen because of the contrasting potential food safety issues they raise. Vertical farming includes a variety of technologies used in indoor food production; aquaculture encompasses marine and freshwater cultivation and multi-trophic systems; alternative and novel proteins are diverse and produced using many different production systems.

Box 1 Vertical Farming

Vertical farming, where crops are produced indoors with the use of LED lighting systems, has received significant private equity investment over the last five years (van Gerrewey *et al*., 2022). The majority of crops produced are salads, leafy greens and herbs with a growing interest in the production of soft fruits including strawberries. Vertical farms are often promoted on the basis of claims about their sustainability which suggest food can be produced locally, including in urban settings, with reduced use of pesticides and water. These advantages have to be offset against their need for electricity to power LED and air conditioning systems, plus overall capital costs. Crops are typically grown in a hydro or aeroponic system and can use large buildings and cellars in urban areas. Vertical farms with multiple horizontal layers can produce as much as 10-20 times biomass per unit area as conventional field-based farming. They have the potential to deliver high-quality fresh produce into urban areas with minimal transport costs with associated contribution to net zero carbon. The environment within each farm is controlled and developers suggest that there is a significant reduction in crop water use. A controlled environment reduces the risk of food contamination from, for example, pathogens, contamination from birds and soil microorganisms, but the materials used to provide the controlled environment and how they are maintained may bring other risks. Warm, high-humidity production environments may be conducive to the formation of biofilms on equipment and building surfaces that may harbour pathogenic organisms (Chiaranunt and White, 2023). Dust and nutrients in solution can support the growth of such organisms.

Box 2 Aquaculture

Aquaculture is the cultivation of aquatic organisms. It is not a new technology, but practices are changing to accommodate net zero carbon. The two biggest production issues for fish cultivation worldwide are the ingredients for feed mixes and the control of fish death in pens. The raw materials in feed mixes account for 65% of the GHG footprint of the value chain. Big changes have already occurred to fish (principally salmon) feeds in the last 30 years, with calories now coming mainly from vegetable oils (rape and soya bean), with fish oil as a source of long-chain omega 3 acids; progress towards net zero carbon is likely to see these trends continue. While the UK farmed salmon industry is using about the same amount of fish meal and oil as 30 years ago, it is producing 10 times as much product. Two recent changes in the production process have reduced food safety risks. First, the move of salmon farms further offshore has reduced the risk of exposure to contaminated water leading to higher quality fish and less exposure to pollutants; and second, new materials such as copper alloys are being used to construct fish nets leading to less use of toxic cleaning materials and lower safety risks due to contamination. The use of cleaner fish such as wrasse and lumpfish in pens has also reduced sea lice infections, salmon death and the use of chemicals to control the lice (Skiftesvik *et al*., 2014). While new systems of fish production are being explored internationally (e.g., recirculation systems, submersible crates and integrated multi-trophic aquaculture), these have currently only been deployed in a very limited way in the UK. Integrated multi-trophic aquaculture (IMTA) systems permit the simultaneous cultivation of multiple products with by-products (e.g., uneaten feed or nutrients in faeces) from one aquatic species used as inputs for another (e.g. sea bream (fed organism) and molluscs or seaweed (extractive organism); Rossi *et al*., 2021). However, it is important to prevent contamination of finished products.

Box 3 Alternative and novel proteins

Current major sources of protein in the UK include beef, pork, lamb, chicken, fish, egg, dairy products, pulses and nuts, with meat providing most dietary protein (34%). Although animal protein sources are generally of superior nutritional quality and digestibility to plant proteins, meat production systems are being challenged from several directions because of their associated GHG emissions (UKCCC, 2020; IPCC, 2022) and research is underway to diversify protein sources and reduce consumption of red meat, in particular. Considerable investment is funding the development of alternatives that can be used in human, animal and pet food products. These include plant-based meat substitutes, novel protein sources such as insects and microalgae, proteins and biomass synthesised by microbes and cultured meat (FSA, 2022a). Each production system has its own food and feed safety issues. For example, plant-based meat substitutes typically contain at least one known allergen such as soya bean or wheat gluten. While pulses such as peas and beans have a long history of production in the UK with known food safety risks, commercial production of insects is new and potential food safety risks arise from contamination of both substrates (insect feed) and the production system, and species dependent factors (see section 6.1.3). With the exception of cultured meat, most of the novel protein sources being explored are not new to parts of the world (although new to the UK) so health and food safety risks are generally known elsewhere and well understood. However, experience of industrial scale production of these proteins is very limited with vigilance essential.

Many changes to primary production systems are occurring very rapidly in the UK with potential impacts on food safety, although it is important to note that such impacts may have positive as well as negative outcomes. Table 1 shows projected growth in selected production systems covering several of the technological innovations highlighted by Innovate UK and the FSA's Rapid Evidence Review (2021) of emerging technologies that will impact on the UK food system. Precision farming includes the use of sensors, data and artificial intelligence to direct inputs to sites where they can be most effective. Vertical farming is an indoor production system for high value crops and food waste management includes the production of by-products from waste. The growth estimates vary between analysts, but the values cited are indicative of the anticipated rates for the different production systems and types of food.

Table 1. Global market trends for some primary food production technologies; CAGR is Cumulative Annual Growth Rate. Sources are reports from Markets and Markets (e.g. https://www.researchandmarkets.com/tag/vertical-farming?ac=true with information sourced on 02/11/2022) and the FSA Rapid Evidence Review (2021).

Technology	Start	Value	Finish	Value	Source
Precision farming (global) CAGR 7.9%	2022	$US 8.5 billion	2030	$US 15.6 billion	Markets and Markets
Vertical farming (global) CAGR 25%	2021	$US 3.1 billion	2026 2030	$US 9.7 $US 20 – 30 Billion	Markets and Markets
Edible insects (global) CAGR 24.4%	2019	Not stated	2030	$US 8 billion	FSA Rapid Evidence Review
Food waste management (global) CAGR 5.4%	2019	$US 34.2 billion	2027	$US 49.4 billion	FSA Rapid Evidence Review
Cultured meat (global) CAGR 15.7%	2025	$US 214 million	2032	$US 593 million	Markets and Markets

4.2 The policy context

The policy context underpinning changes in UK primary production is complex and includes several related, but separate, policy-related elements which include the UK Government's Food Strategy (Defra, 2022), the report of the UK Committee on Climate Change (UKCCC, 2020) and a possible, forthcoming land use framework from the Government. These contextual aspects and more details of the technological changes under development are described in Annex 2.

The UKCCC (UKCCC, 2020) has suggested that, without radical changes in land use, GHG emissions from agriculture will not be reduced substantially and that the UK will be unlikely to approach net zero carbon by 2050. Although the actions suggested by UKCCC (2020) will not be fully implemented for 25 years, some of these changes are expected to occur in the next decade and the implications for food and feed safety require consideration now.

4.3 Categorisation of changes to primary food and feed production

In the Science Council's interim report to the FSA (FSA, 2022c), three categories of changes in primary production related to the delivery of net zero carbon were identified which might have implications for food safety. The selection of these three groups remains unchanged, although there has been some revision to take account of further research. They are as follows:

1. **Evolution of production systems for specific ends (and markets)** – agriculture in the UK is currently subject to multiple influences with producers (and food sellers) employing a range of adjectives to describe their mode of production. Precision, sustainable, organic, conventional, sustainably intensive, rewilded, regenerative, climate smart and low carbon are all in play. In this complex milieu, change from one production system to another may either increase or decrease food safety concerns, or even introduce new ones, depending on the circumstances. The experience and skills of the producer and the standards required by the proposed market can have substantial consequences on food safety risks.
2. **Novel or major changes to existing production systems** – vertical farming, climate-controlled animal and plant production systems, and large-scale recirculation systems and integrated multi-trophic systems in aquaculture are all technologies either adopted or under development for use in the UK. Known food safety risks are dealt with using existing protocols, but experience of such systems to date is limited. There is no evidence that food produced by such means is more, or less safe. However, as with any new technology, vigilance is needed to respond to a changing production environment.
3. **New products developed in anticipation of consumer/market demands** – many consumers wish to purchase food products which are perceived to be beneficial for the environment and/or health, or which meet ethical or religious requirements. For example, this might be a plant-based

diet or seafood that is ‘friendly’ to dolphins. These descriptions may encompass the practices of primary food producers, and the impact of anticipated consumer behaviour is, therefore, included in this review. Some elements of consumer choices in response to climate change are discussed in a report of the FSA Advisory Committee for Social Science (FSA, 2022b).