

5. What food and feed safety risks have been identified?

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At the time of writing, no published material on potential food safety risks arising from changes in production practices aimed at achieving net zero carbon was identified. This means that the potential food safety risks arising from changes in primary production described below have been inferred from the known hazards, the likelihood of risks associated with production techniques, and expert knowledge.

While no previously unknown safety hazard specific to changes to achieve net zero carbon has been identified, the degree and balance of known risks will change as actions to achieve net zero carbon are implemented. As the changes to

practices become established, the existing systems in place (e.g., codes of agricultural practice, Hazard Analysis and Critical Control Point (HACCP) principles and the procurement requirements of major retailers and food service businesses) to mitigate risks are likely to evolve and the risk be managed accordingly. The awareness of new or evolving risks may be influenced by the nature of the innovation (e.g. breakthrough or incremental) and the maturity (e.g. established food business or start-up) and scale of enterprises.

5.1 Climate change and food safety risks

While it is not the purpose of this report to examine in detail the likely effects of climate change on food safety, some of the potential risks associated with measures to achieve net zero carbon, described below, will be similar to those associated with climate change. Unlike the food safety consequences arising from changes aimed at achieving net zero carbon, those arising from climate change are relatively well understood. Several studies on climate change and food safety have been published (e.g., EFSA, 2020; FAO, 2022; IPCC, 2022). These highlight the multiple pathways by which climate change may affect food safety including:

- Changes in temperature and precipitation
- Increased frequency and intensity of extreme weather events
- Ocean warming and acidification
- Changes in transport pathways of contaminants

Of particular concern are the possible effects on foodborne diseases including zoonoses, microbial agents especially mycotoxins and algal blooms, environmental contaminants and chemical residues (EFSA, 2020; FAO, 2022).

The IPCC (2022) concluded its global analysis with high confidence that, in addition to climate-related extremes affecting the productivity of all agricultural and fishery sectors with negative consequences for food security and livelihoods, climate-related food safety risks are increasing globally in agriculture and fisheries. Examples cited include:

- High temperatures and humidity increasing toxigenic fungi on many food crops (very high confidence).
- Algal blooms and water-borne diseases threaten food security of many coastal communities (high confidence).
- Increasing ocean warming and acidification are enhancing movement and bioaccumulation of toxins and contaminants into marine food webs (medium confidence).

The report found that 'climate-related food safety risks have increased globally (high confidence)' with particular concerns about increased:

- Salmonella, campylobacter and cryptosporidium infections (medium confidence).
- Mycotoxins associated with cancer and stunting in children (high confidence).
- Seafood contamination with marine toxins and pathogens (high confidence).

IPCC (2022) highlights that climate change will compromise food safety through multiple pathways (high confidence) and that the pressures on marine systems are complex.

Medina et al. (2017) drew particular attention to the food safety risks caused by mycotoxin contamination, especially aflatoxins, which disproportionately affect low- and medium-income countries. The projected impact of climate change on mycotoxin contamination is complex, with marked geographical differences probable. For example, northern Europe may be less affected than the Mediterranean region. Despite the uncertainty, there is currently a dearth of research data available to ensure the adequacy of current risk management measures in response to climate change.

The Working Group's specific focus has been on the potential food and animal feed safety risks associated with changed systems of primary production in the UK which are intended to contribute to net zero carbon goals. These will be experienced in addition to those associated with climate change. The following hazards and potential food and feed safety risks associated with different production systems were identified and are described below.

5.2 Evolution of production systems for specific ends (and markets)

5.2.1 Crop and animal production

The wide range of farming objectives currently being pursued (e.g. sustainable intensification to rewilding and conventional to organic) mean that any food and animal feed safety risks are likely to be specific to particular production systems. Nevertheless, the general trend towards land being actively managed for multiple ecosystem services (food production, water filtration, biodiversity and carbon) is likely to increase. The current energy crisis is also likely to provoke reassessment

of farm inputs with consequences for use of fossil-fuel based products (e.g., nitrogen (N) fertilisers). The innovations in production systems highlighted above (Section 4) will affect the following risk scenarios:

- The quantity of animal manures may decrease in line with changes in land use to meet net zero carbon targets (more forests and less meat consumption; UKCCC, 2020) but, conversely, more intensive systems may limit the area available for spreading and concentrate potential sources of pollution. It is also likely that there will be increased applications of domestic sewage, council green waste and industrial waste to farmland as landfill declines. Existing codes of practice and statutory controls protecting against the transmission of pathogenic organisms (such as *Escherichia coli* and *Clostridium botulinum*) and/or contamination with toxic elements should be validated against future changes in production systems.
- Recycled water and/or brown water use can increase the risk of transmission of many pathogens (e.g. *Cryptosporidium* spp.) especially to leafy vegetables.
- Wildlife contact with farm animals can increase the risk of exposure to zoonoses (e.g., avian flu).
- Modified crop rotations, coupled with climate change, may lead to new or increased levels of fungal diseases and mycotoxins (e.g., if growing wheat shortly after maize on the same land).
- There is a rapid pace of change in the development of novel animal feed formulations including the use of feed additives to inhibit methane production in ruminants (e.g., the potential inclusion of 3-Nitroxypropanol (3-NOP) in feed for dairy cows). Other approaches may entail changing feed composition and introduction of natural ingredients requiring case-by-case safety evaluation.
- Traditional plant breeding is being complemented with genetic modification and gene editing techniques. Each approach requires a tailored safety evaluation of any potential allergens, contaminants and toxicants in the crops produced.
- Changed land use (e.g., afforestation) and tillage practices may alter the amount and/or timing of runoff and leaching affecting the development of toxic algal blooms in watercourses. Upstream events in watercourses can affect risks for food produced downstream as well as the direct local effects on fish and other organisms used as food.

5.2.2 Aquaculture and ocean farming

The following changes have the potential to affect risks:

- Inclusion of more animal (including insect products that have regulatory approval) and plant by-products in fish feeds could reduce carbon footprints, although industry sources suggested that UK consumers might be averse to their use for farmed salmon. Such feeds are already being used for sea bass and bream farmed in the Mediterranean and imported into the UK. Reducing the fish oil component of feeds will also reduce exposure to persistent organic pollutants (POPs).
- Cultivation of seaweed and fish can support the goal of net zero carbon via multiple routes but contamination of sea water with heavy metals, algal and other biotoxins from runoff and dumping can result in poor quality fish, crustaceans and seaweed which pose food safety risks if consumed. Growing seaweed for food risks contamination with crustaceans or molluscs, for example, with the potential to provoke allergic reactions.
- Consumer behaviour which may be aligned with sustainability and net zero carbon goals, such as local harvesting of wild foods, may carry food safety risks. For example, serious water pollution incidents in England increased by 63% between 2017 and 2021 (OEP, 2023) with several documented warnings issued to the public not to harvest shellfish from estuaries or forage from the seashore. Similarly, seafood harvested from estuaries and close to shore may be at risk of contamination with chemical and biological hazards (Banach *et al.*, 2020; EFSA, 2019; Mudadu *et al.*, 2022).

5.2.3 Interactions of the circular economy with food production

A wide range of pressures including consumer environmental concerns, limiting disposal of wastes to landfill sites and the current energy crisis is fuelling the recycling and re-purposing of materials previously regarded as waste. The likely increased use of diverse nutrient sources, via wastes applied to land or through the introduction of food by-products into the food chain, raises the possibility of increased risks to food and feed safety and the need to segregate food, feed and non-food crops:

- Recycling and waste product utilisation in food production systems will be increasingly necessary to minimise carbon costs. Such practices will require the development of validated safe practices, industry standards and guidelines, and regulatory instruments.

- Domestic and industrial wastes applied to a more limited area of agricultural land (see 5.2.1) requires vigilance to ensure that toxins and contaminants are controlled and do not enter food and feed chains. Because domestic sewage may contain pathogens, runoff and leaching can lead to polluted water being applied to crops downstream as irrigation, and also directly affect the food safety of fish and other aquatic organisms.
- Frass from insects (a mix of faeces, exoskeletons and uneaten feed) is currently treated as a manure. Insect farming is rapidly evolving and the use of sanitised frass as fertiliser is being investigated to ensure that no additional microbiological risks to food are involved (Smink and Huulgaard, 2022).
- Treated sewage is also applied to agricultural land posing potential risks to food from heavy metals, toxins and pharmaceuticals (especially antimicrobials). To address these hazards, standards for heavy metal concentrations and microbial content, coupled with a code of practice, have been introduced under the Biosolids Assurance Scheme launched by the UK Water Industry in 2021.
- Digestate from anaerobic digesters is spread on land but the regulatory regime is complex, with food and crop wastes treated differently. The quantity of digestate from food waste has declined as the food industry reduces its waste, but with domestic food waste to be collected separately in the next few years, this source may increase again. No specific food safety risks have been associated with digestate, but any pathogens shown to survive the digestion process could pose a risk if they were able to enter the food system (e.g. on salad crop leaves).
- Common to all of these 'wastes' is the inclusion of plastics from bags and microplastics. The fate of plastics entering soil and their possible entry into the food system is largely unknown. This is an area of considerable concern.
- Inclusion of food and other by-products into food packaging can increase potential food safety risks. For example, chitin derived from crustacean or insect exoskeletons needs to be processed into chitosan for commercial use. While there is currently no evidence that levels of allergenic proteins in biobased packaging materials would increase the risk of allergic reactions in vulnerable individuals, the issue has still to be fully addressed for food contact materials (COT, 2021).

5.3 Novel or major changes to existing production systems

5.3.1 New technology farming

Controlled environments, of which vertical farms are the most recent innovation (see Box 1), have factory microbiomes which are different from conventional, outdoor, production facilities; this brings different food safety risks:

- The controlled environment system may help to prevent contamination with organisms associated with the complexity of conventional, outdoor production but will also generate unique hazards that will require targeted risk management measures using processes such as HACCP.
- Although the environment (temperature, nutrients, water and light) in a controlled system is optimised to promote crop growth, these same conditions might also accelerate the growth of pathogens.
- With more automation, recycling of nutrient solutions and substrates, and less human interaction with the crops, disease, moulds, or other unexpected events may not be noticed as quickly and could enter the food system. Vigilance and a HACCP is required for each facility with separate standards and food safety management plans (Lubna *et al.* 2022).
- So far there is limited experience of how the new systems will age, with dust or other matter such as biofilms accumulating over time. Many of the growing systems are made of plastics from which chemical migrants (e.g., endocrine-disrupting chemicals) may be released into foods. There are also concerns that products produced in this way may lack the microbial flora that play a role in the development of the human immune system and a healthy and robust gut flora.
- Some production systems are commercialised by new entrants to the food industry, with limited experience of food production, who may need additional support to identify and manage food safety risks. New, small-scale producers may require assistance to meet food safety and standard regulations.

5.3.2 Novel sources of protein

Novel protein sources are a subset of the alternative protein sources described in Box 3. For the UK they include non-traditional materials such as insects, seaweeds, microalgae, bacteria and jellyfish; cultured meat is both new and novel. Because they have not been widely consumed in the UK and cultured meat involves a novel process, they are regarded from a regulatory viewpoint as novel. Emerging concerns include the following:

- Insects can be produced in vertical factories on brown-field sites. Insect protein has implications for both human nutrition (macro- and micronutrient intake will change if existing meat sources are replaced) and health (because insect proteins have the potential to trigger food hypersensitivity). The long-term consequences for human health are little understood (Galecki and Sokól, 2019).
- Novel sources of proteins from plants and microalgae have the potential to cause allergic reactions in sensitive individuals.
- Production of cultured meat in bioreactors is still mainly at pre-production scale with beef, chicken, fish and milk being actively researched. There are some concerns that the risk of contamination of cell cultures, growth media and final products at industrial scale without antimicrobials is high. Interactions of growth-promoting chemicals and hormones used to facilitate cell growth is not well understood and plastic surfaces on which the cells are grown may release harmful contaminants (FSA, 2022a).
- Labelling of the food products from these new processes needs to include both safety (e.g., allergy) and consumer interest statements (e.g. composition, source of cultured cells, origin declarations).

5.3.3 Changes to livestock and fish feeds

There are several new developments in animal and fish feeds which aim to reduce carbon footprints. These include replacement of soya bean in feeds with other protein sources, using food by-products in feed, and employing supplements to reduce methane from ruminants (see sections 5.2.1 and 5.2.2).

Issues noted in the current work are:

- Alternative proteins used to replace soya bean may affect animal health and ultimately the nutritional profile of meat produced. For example, lupin meal containing high levels of alkaloids has produced toxic effects in poultry and poor performance due to anti-nutritional non-starch polysaccharides. However, other protein sources could benefit the nutritional profile.
- The use of food waste as animal feed has a history of animal health problems such as BSE, Foot and Mouth and African Swine Fever.
- Given the speed of change for new animal feeds and supplements, all stakeholders will need to ensure that systems of scientific evaluation of evidence, risk assessment, policy development and functioning of the regulatory framework are sufficiently agile.

5.4 New products developed in anticipation of consumer/market demands

Although the focus of the present study is on changes to activities associated with primary food production, consumer choice and satisfying the expectation of consumer trends is a strong driver of change in the production system. The FSA's Advisory Committee on Social Science (ACSS) report (2022b) on the Impact of Climate Change on Consumer Food Behaviours drew attention to four behavioural trends namely: avoidance of food waste, increased use of alternative packaging such as biopolymers to reduce fossil fuel based plastic use, increased use of reusable containers to purchase food and drink, and the increased consumption of novel proteins. This section summarises the potential food safety issues arising from changes led by consumer choices.

5.4.1 Changes to the human diet

Plant-based and novel proteins produced to respond to trends for sustainable 'healthier' plant-based diets may introduce allergen and toxin-related hazards, as well as possible nutritional deficits, for example:

- Consumers may lack awareness of the nutritional choices being made, when, for example, plant-based protein is substituted for animal meat in the diet. Typically, plant-based meat substitutes are highly processed foods that are nutrient deficient (except for high levels of sodium) unless fortified with nutrient additives (FSA, 2022a) so may not have nutritional equivalence to foods they are replacing.
- Proteins in plant-based meat alternatives consumed instead of meat or dairy present additional complexity in terms of their nutritional profile and digestibility, and the need for appropriate processing technologies and formulation (Sridhar *et al.*, 2022)
- Plant proteins and some sources of insect protein may pose allergenicity risks. Most plant-based meat substitutes contain the known allergens found in soya bean and/or wheat. Although rare at present, allergic reactions due to chitin contamination of insect protein and potential cross-reactivity with allergens in house dust mites or crustaceans, might become more common if more chitin is consumed.

5.4.2 Demand for changes to packaging and labelling

Some consumers and the food industry are looking to move away from single use plastics in favour of alternative packaging solutions, and progress towards net zero carbon is likely to add to this trend. The FSA has already considered the food safety issues associated with alternatives to plastic food packaging (FSA, 2019, 2020) so these will not be repeated here. However, information about sustainability and allergenicity of novel proteins may require new labelling to inform consumers about:

- Risks from allergens in foods that are reformulated to reduce or remove animal products as part of net zero carbon strategies, for example, use of legumes/concentrated pea protein due to their allergenic potential.
- Allergen (and possibly toxin) risks from new proteins such as insect protein, which may be not obvious to consumers if used as an ingredient in powdered form, to boost the protein content of a product.
- The potential for misleading claims about the net zero carbon or sustainability credentials of foods; currently there is no consistent standard for sustainability claims or labelling for foods.