6. Appraisal of food and feed safety risks

In this guide

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This is a time of rapid alterations to primary production systems, so the present situation is very fluid. Food businesses and retailers are pressing ahead with their plans to contribute to net zero carbon targets while governments at national, regional and local levels are still determining their detailed policies.

Against this mixed and rapidly evolving background, the relative food safety risks associated with the production systems described above have been appraised. The evidence available to make this assessment was largely obtained from published reports, 'grey' literature and interviews with informed people in the relevant businesses and areas of production. Although not exhaustive, the

following key potential food safety risks have been identified and are summarised in Table 2.

6.1 Areas where new risks might emerge

Although no new food safety risks arising from transition to net zero carbon have been specifically identified, there are changes to production practices that are big enough to have the potential to produce new risks in future. The areas for particular vigilance are:

6.1.1 Animal and fish feeds

The introduction of new plant components into animal and fish feeds is unlikely to cause food safety risks but the use of animal products and food by-products in feed has a long history of problems. The use of animal products from ‘waste’ streams to augment feeds can lead to zoonoses and microbiological and prion contamination of animal foods. However, there is now tight regulatory oversight of animal feed manufacture with the benefits of a highly standardized animal feed industry in the UK.

6.1.2 Vertical farms

These recently introduced production systems are potentially ‘clean’ and with minimal food safety risks. However, because the systems are novel, there is little experience of what will happen as the systems age. Microbiological safety risks could arise from the establishment of biofilms in plastic tubing and filters and from dirt and dust on surfaces. The recycling of water might also provide a source of contaminants to plant products especially leaf crops. New entrants may have little previous experience of food production so there is a risk that aspects of good hygiene standards are unintentionally overlooked and may not be built into business practices. This is more important for small businesses selling into local markets because any producer supplying large retailers will be subject, additionally, to assurance schemes.

6.1.3 Alternative protein sources

Legumes (peas and beans) are traditional sources of protein (so strictly neither new nor novel) but increasingly promoted as sustainable replacements for animal protein in human diets. Food safety issues are generally well understood. For example, the pyrimidine glycosides vicine and convicine present in faba beans

can lead to life-threatening favism in individuals with G6PD deficiency but these have been substantially reduced by conventional breeding. The presence of raffinose series oligosaccharides in most peas and beans (needed for seed germination) produces flatulence in humans – not a safety issue but a limiter of consumption. Legumes present a risk of cross-reactive allergy,` although processing (hydrolysing) the protein can reduce pea allergy substantially.

Insect farming is developing rapidly with the main market currently expected to be pet food. Future market growth is likely to be for the aquaculture sector and then for the production of pigs and chickens; the trajectory for human consumption is uncertain. Insects typically consist of 60% protein with 20-30% fat and efficiently concentrate the protein in their feeds, although the choice of insect substrate has a major influence on this. Insects vary in their food sources and metabolism, so that different food safety concerns may arise for specific insects. For example, heavy metals in feed will accumulate in black soldier fly larvae but be excreted by mealworm. Similarly, house fly larvae can break down *E.coli* in feed while mealworm can break down mycotoxins. To date, no pathogens have been found in black soldier fly production facilities. The main human food safety concerns that can arise are allergenicity (to both ingested proteins and chitin; those with allergies to crustaceans can produce an allergic reaction), chemical contamination with heavy metals (from the insect feed), carry over of any pathogens from any manures used in the feed and potential accumulation of nanoplastics. The widespread pathogen *Bacillus cytotoxicus* (causing diarrhoea) has been found in foods containing an unnamed insect flour (Cairo *et al*., 2022).

Red seaweeds can contain up to 45% protein although this varies seasonally. Human food safety issues are largely centred around heavy metal accumulation because they can rapidly accumulate elevated concentrations of metals such as arsenic, cadmium and copper when grown in contaminated coastal waters. Brown and red seaweed production for ruminant animal feed is increasing because it has been shown to reduce methane emissions, although carcinogenic bromoforms in red seaweed are a safety concern in feed.

6.1.4 Cellular agriculture

Two types of products are produced through cellular agriculture. The first are cellular products (usually proteins) made naturally by unicellular organisms or plant and animal cells, and the second are acellular products such as milk and egg proteins, plant proteins, food enzymes and food additives. Acellular products are normally the result of genetic modification of a bacterium or yeast from which

the desired molecule is extracted and purified. This is standard practice in the development of lab-produced enzymes for yoghurt and cheese making (e.g., recombinant chymosin) and the food safety issues are well known and managed.

Animal muscle cells, cultured by adding hormones and growth factors to promote cell growth, are used to produce cultured meat (now also being referred to as ‘cultivated meat’) and there are some food safety concerns about them (FSA, 2022a). Although the products are generally grown in sterile conditions without the use of antimicrobials, the latter may be used when cleaning equipment between batches. If the meat is grown on plastic surfaces, then plastics containing endocrine disrupting chemicals should be avoided. The source of animal cell lines raises ethical issues for some religious groups.

6.1.5 Packaging

Food packaging is a major means of reducing food waste and thus can contribute towards achieving net zero carbon. However, the desire to reduce consumption of fossil fuels and production of food waste simultaneously is leading to the development of new packaging approaches including bio-based packaging, active and intelligent packaging, nanotechnology packaging films, and reusable and zero packaging.

Business operators have the responsibility to ensure that no food safety issues arise as a result of the packaging approach that they adopt. There are potential safety concerns arising from the use of some nanomaterials (especially metals) and the migration of nanoparticles into food and thence into the human bloodstream. There are food safety risks, too, in replacing plastics with biopolymers because they typically have reduced barrier or mechanical properties. This may increase the risk of contamination and reduce food shelf life. Some processed biopolymers could also retain original proteins leading to potential allergenicity concerns due to incomplete purification.

Increased use of re-useable containers and minimal/zero packaging on food products can lead to inadvertent cross-contamination by consumers, as well as the absence of safe ‘use by’ dates on products in the home.

6.1.6 Use of food by-products (wastes)

Processing of waste materials via composting and anaerobic digesters is already well regulated and food safety risks are understood. However, as collection of domestic food waste is introduced in parts of the UK, there is a possibility of

pathogens (known or unknown) surviving thermal processing. Processing conditions should therefore be validated against the likely pathogens present.

As pressure to increase the recycling of all materials increases, the complexity of waste and compost regulations and associated codes of practice may inadvertently compromise food safety if producers do not comply with them. Moves to change the regulatory framework for wastes from process-based to product-based may assist in reducing the complexity, but in the short-term, vigilance for new pathogens and sources of chemical contamination is required.

6.2 Known food safety risks in new backgrounds

6.2.1 Regenerative/mixed/rewilded farming

Farming systems in which the production of crops and animals are closely integrated on the same farm are fundamental to mixed farming and are especially favoured by regenerative farming approaches. The food safety risks arising from animal wastes in close proximity to food crops (e.g., *E. coli* and other microorganisms such as *Listeria monocytogenes*, salmonella, clostridia and cryptosporidia) are well known but may be amplified by an increase in regenerative farming practices, particularly when adopted by new entrants. Similarly, crop diversification to produce maize silage for animal feed can increase levels of *Aspergillus flavus* in soil increasing the risk of aflatoxin production in subsequent wheat crops.

6.2.2 Agroforestry

Agroforestry has the prospect of being a major contributor to achieving net zero carbon in the UK. The choice of agroforestry system has a big effect on whether food safety risks are likely. Orchards combining fruit trees, pasture and sheep were common in the recent past but have largely disappeared. A return to grazed orchard means that fruit must be protected from faecal contamination, with windfalls eliminated from the fruit intended for human consumption. Planting trees in alleys between crops could result in more tree pollen allergenicity if the pollen is deposited, for example, on grains. Similarly, trees producing nuts (e.g., hazel and walnut) could contaminate harvested crops if they were broken or crushed and therefore not removed by usual sifting procedures. Fortunately, both of these occurrences are likely to be low risk because the timing of tree flowering

and nut maturity does not generally coincide with cycles of crop development. Nevertheless, producers should be made aware of the risks.

6.2.3 Aquaculture

Harvested seaweed can be contaminated with crustaceans raising allergenicity concerns in some humans.

Development of large-scale recirculation systems, aquaponics and integrated multi-trophic aquaculture (IMTA) is occurring internationally but has not yet been adopted in the UK. The food safety risks in open net pens are well understood, but these newer systems may give rise to greater opportunities for incidents of contamination. For example, IMTA uses waste from fish to feed shellfish so that chemicals used to treat the fish might be transferred to other trophic levels (i.e. shellfish).

6.3 Known risks for which guidance exists

6.3.1 Water

Water is ubiquitous in primary production both as a component of the food produced and as a cleaning agent for surfaces and equipment used during the production process. Changes to land and energy use to move towards net zero carbon may affect the amount of water available for primary production and as competition for fresh water increases, there may be pressures for agriculture to use more ‘brown water’ especially in peri-urban areas. Clean water is an essential component of a safe food system, with water contaminated with heavy metals and/or sewage posing numerous food safety risks requiring meticulous management. For example, the on-farm washing of salad products has previously led to outbreaks of cryptosporidiosis in humans; these risks may increase if pressure to conserve water use increases as a response to net zero carbon measures. Current regulations are intended to minimise safety risks, but incidents of pollution of river and coastal waters have resulted in documented cases of food contamination.

6.3.2 Manure, sludge and compost

Good manure management is key to the effective operation of many agricultural systems and the delivery of safe food. Farm manure contains many microorganisms that pose a risk to food safety and these need to be managed by,

for example, allowing a minimum of six months between manure application and seed drilling (FSA, 2009). Similarly, guidance exists for the application of sewage sludge and compost. If farmers do not apply these organic fertilisers according to the guidance, then this could lead to an increased risk of contaminated food. Ready to eat crops (e.g., baby leaf spinach, salads, some fruits) provide the highest potential food safety risk because contaminated irrigation water downstream of the site of organic fertiliser application may be used unknowingly. Similarly, water polluted with slurry and solid manure poses food safety risks for fish, shellfish and seaweed via multiple pathways. Active pharmaceutical ingredients originating from human and animal waste have been detected in the environment, water and edible plants (Cunningham *et al*., 2009; Hafner *et al*., 2023). While such reports have resulted in media attention, there is no evidence of direct risks to human health (Cunningham *et al*., 2009). Research publications are available on the behaviour of microplastics in sludge and compost (Mahon *et al*., 2023). However, there is a scarcity of data on appropriate treatment options to protect agricultural systems.

It should be noted that processes to remove residues also have a carbon footprint and, therefore, a risk-based approach is essential.

Table 2. Key food safety risks arising from net zero carbon changes to food and feed production practices;

Recognised risk	RR
Potential risk	PR
No identified risk	NIR

Risk category	Production system or input to system	**Food safety risk**: Allergenicity	**Food safety risk**: Chemical contamination	**Food safety risk**: Biological contamination
Areas where new risks might emerge	Animal and fish feeds	NIR	PR	RR
Areas where new risks might emerge	Vertical farms	NIR	RR	RR
Areas where new risks might emerge	New protein sources	RR	PR	NIR
Areas where new risks might emerge	Cellular agriculture	NIR	PR	PR
Areas where new risks might emerge	Packaging	PR	RR	RR
Areas where new risks might emerge	Use of wastes	NIR	PR	RR

Known food safety risks in new backgrounds	Regenerative/mixed/rewilded farming	NIR	NIR	RR
Known food safety risks in new backgrounds	Agroforestry	PR	NIR	PR
Known food safety risks in new backgrounds	Aquaculture	PR	RR	NIR
Known risks for which guidance exists	Water	NIR	RR	RR
Known risks for which guidance exists	Manure, sludge and compost	NIR	PR	RR