Risk analysis for biological and chemical hazards in meat production

by Dr Bob Mitchell, consultant to the food sector, UK.

Different people can perceive risks in vastly different ways and so this creates the need for an agreed scientific approach based on authoritative sources of information to provide a transparent evidence based food safety system.

Table 1 describes the salient differences between biological and chemical hazards.

Biological hazards

Bacterial infections

Live organisms invade and multiply to cause disease in the host. To initiate a foodborne infection, sufficient viable organisms (viruses, bacteria or parasites) must be ingested in the food.

Foodborne infections that are confined to the gastro-intestinal tract mostly present as diarrhoeal disease together with vomiting and abdominal pain. Examples include:

- Salmonella.
- Campylobacter.
- Escherichia coli (VTEC).
- Yersinia enterocolitica.
- Clostridium perfringens.

Some pathogens cause disease by spreading outside the gastrointestinal tract (extra-intestinal infections) into the blood or other organs in the body. Bacterial examples include:

- Listeria monocytogenes.
- Brucella.
- Mycobacterium.

Bacterial intoxications

Intoxications are diseases caused by the consumption of preformed toxins in the food. They are generally formed as a result of growth of the organisms in processed foods during inappropriate storage of the food, generally involving some degree of temperature abuse.

- Neurotoxins of Clostridium botulinum.
- Enterotoxins of Staphylococcus aureus.
- Emetic toxins of Bacillus cereus.

Parasites and waterborne infections

Live organisms invade and multiply to cause disease in the host. To initiate a foodborne infection, sufficient viable organisms must be ingested in the food. These are fully destroyed by cooking so are generally associated with meats eaten raw.

Control options include inspection to remove diseased animals from the food chain, cooking and freezing.

Examples include:

- Toxoplasma, Trichinella, Taenia (tapeworm).
- Cryptosporidium.
- Sarcocystis.

Prion proteins

Transmissible Spongiform Encephalopathies (TSEs) are a family of untreatable fatal diseases caused by the build-up of abnormal prion proteins in the brain and nervous system. In humans the TSE is Creutzfeldt-Jakob Disease (CJD and vCJD), in cattle it is called Bovine Spongiform Encephalopathy (BSE), or Mad Cow disease.

A similar TSE in sheep, scrapie, is not thought to be harmful to humans. There is another variant in sheep and goats, atypical scrapie, but there is no scientific evidence that it is of any risk to humans.

Prion proteins are particularly stable in chemical terms and so are resistant to denaturation by chemical and physical agents, making their destruction and disposal difficult. Control is by the removal of

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Table 1. Comparison of biological and chemical hazards.

Biological hazard	Chemical hazard
Hazards can enter foods at many points from production to consumption	Hazards usually enter foods in the raw food or ingredients, or through certain processing
The prevalence and concentration of hazard changes markedly at different points along the food production chain	The level of hazard present in a food after the point of introduction often does not significantly change
Health risks are usually acute and result from a single edible portion of food	Health risks may be acute but are generally chronic
Individuals show a wide variability in health response to different levels of hazard	Types of toxic effects are generally similar from person to person, but individual sensitivity may differ

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infected animals and contaminated materials from the food supply.

Viruses

Viruses are intracellular pathogens that cannot multiply outside host cells. Viruses implicated in foodborne diseases all have their niche in the human gastro-intestinal tract and their presence in food is a consequence of poor hygiene through water being contaminated with sewage or products being contaminated by the food handler.

The diseases caused by human enteric viruses fall into two major categories:

- Viral gastroenteritis: Norovirus.
- Viral hepatitis: Hepatitis A virus.

Other viruses of potential concern include:

Avian influenza

Avian influenza, also known as bird flu, is a disease of birds caused by type A influenza viruses which are closely related to human influenza viruses. Transmission to humans in close contact with poultry or other birds occurs rarely and only with some strains.

The potential for transformation of avian influenza into a form that both causes severe disease in humans and spreads easily from person to person is a great concern for world health.

In the most recent worldwide outbreak of avian influenza, 539 human cases and 318 deaths due to H5N1 have been reported from 15 countries which have reported outbreaks of H5N1 in poultry flocks.

To date, no epidemiological data suggest that the disease can be transmitted to humans through properly cooked food. However, in a few instances, cases have been linked to the consumption of dishes made of raw contaminated poultry blood.

Pandemic (H1N1) 2009 virus (Swine Flu)

The pandemic (H1N1) 2009 virus has not been shown to be transmissible to people through eating properly handled and prepared pork (pig meat) or other products derived from pigs. The pandemic influenza virus is killed by cooking temperatures of 70°C, corresponding to the general guidance for the preparation of pork and other meat.

Risk assessment example

A risk assessment is only a tool and can be as simple or as complex as the situation demands. Sometimes it can be as simple as 'Is the food high, medium or low risk' or it can be a complex multi-agency multi-national exercise looking at the risks to whole populations.

An example of the latter is the WHO Listeria monocytogenes in Ready to Eat Foods report. It provides an indication of the resources required to perform a formal qualitative risk assessment as well as the type of the outputs that can be expected. Note: this is the top of the range risk assessment and is the area in which governments and international bodies will operate.

- It was drafted by six scientists with assistance from seven research groups and many reviewers from over 20 countries.
- It took two years to complete and publish and is 153 pages long including appendices.

Hazard characterisation

Severe illness or death in three age-based populations were considered: prenatal/perinatal; the elderly; and an intermediate age population.

Dose-response relationships were estimated by using contamination and growth data to predict levels of L. monocytogenes at the time of consumption for all ready-to-eat foods. These data were combined with epidemiology data to derive a dose-response model for each population group.

Exposure assessment

Exposure assessments were based on estimates of the frequency of contamination of foods, the numbers of cells on ready-to-eat foods, the amount of growth before consumption, the amount of each food type consumed at a typical serving and the number of servings that were consumed per year. A survey of consumer practices, commissioned by the meat industry for hot dogs and delicatessen meats, found that:

- Most (1,300) contaminated servings of food per person per year contained less than one organism per serving.
- 19 servings contained between 1.0 and 1,000 cfu/g.
- 2.4 servings contained between 1,000 and 1,000,000 cfu/g.
- Less than one serving per person per year contained more than one million L. monocytogenes.

Risk characterisation

Individual food category data and the dose-response model were used to estimate the number of cases of illness per serving and per year for each food category and each population group. The ability of a food to support growth of L. monocytogenes to high numbers and the opportunity for growth is a key risk factor in foodborne listeriosis.

Table 2. E numbers.

E numbers	Functions
E100-E199	Colours
E200-E299	Preservatives
E300-E399	Antioxidants, acidity regulators
E400-E499	Thickeners, stabilisers, emulsifiers
E500-E599	Acidity regulators, anti-caking agents
E600-E699	Flavour enhancers
E700-E799	Antibiotics
E900-E999	Miscellaneous
E1000-E1999	Additional chemicals

Key findings

The model indicates that it is the few servings with very high levels of contamination that are responsible for most of the illnesses and deaths. The vast majority of cases of listeriosis are associated with the consumption of foods that do not meet the current standards for L. monocytogenes in foods, whether that standard is zero tolerance or 100 cfu/g.

Chemical hazards

Finding information on actual incidents involving chemical hazards is more difficult than for biological hazards because:

- The health effects are generally not acute and are not readily visible unless one is dealing with deliberate poisoning, for example arsenic in foods or exceptional incidents with very high levels of toxic compounds, for example mercury in fish.
- People are exposed over extended periods of time. The effects are chronic and so it can take a long time for them to appear, for example cancer; or they can be difficult to define, for example behavioural problems.
- People tend to be exposed to chemical hazards through their total diet and not just some specific commodities.
- Chemicals are not consumed in isolation but in combination with many others. The health ramifications of this 'cocktail effect' are difficult to determine and are still the subject of much scientific debate. These and other factors make detection of chemical incidents and their epidemiological investigation very difficult.

Hazard potential

All foods are composed entirely of chemicals. This article will consider only those chemicals that have the potential to produce a hazard to human health.

Generally, they will be present only at very low levels and will have been added to perform a specific function; will arise naturally in the food; or accidently contaminate it during production, processing, packaging or storage.

There are potentially thousands of additives and contaminants in foods. It is impossible to cover them all in this article. Instead the main generic types will be briefly touched upon with detail being reserved for those that have recently been associated with meat and poultry products. Basically, there are only two types of chemical hazard in food – additives and contaminants.

The distinction between them is simple – an additive is anything that is legally deliberately added to a food (usually to perform a specific function) while a contaminant is anything that is not.

Additives

Food additives are used to modify the colour, flavour, shelf life or other attributes of foods. Some additives have been used for centuries, generally to preserve otherwise perishable foods.

Strictly speaking, additives are not hazards if they are used in foods at the levels described in legislation.

They are subject to strict regulatory control and require some form of government approval determining the level they can be used and in which foods they are permitted.

Labelling regulations permit consumers to make an informed choice over whether they want to eat foods containing additives or not.

In the European Union every additive is assigned a unique identification number (E number) in order to permit regulatory control, assist labelling and allow consumers to make an informed choice (see Table 2).

Every food additive should have an E number, whether or not it is permitted for use.

The Codex General Standard for Food Additives is the de facto international standard for the safety of additives in food and their place in international trade.

Only those additives that are regarded as 'safe' are approved for use in foods in the EU.

Therefore, for the purposes of risk assessment and risk management it is a reasonable assumption that any additive currently approved for use in foods by the EU is 'safe' for use in the foods and at the levels stated in the legislation.

In the European Union, additives have to fulfill a number of criteria before they can be approved for use in foods. These criteria are published in Commission Regulation (EU) No 1129/2011.

Contaminants

A contaminant is anything that is not deliberately added to the food (or is deliberately added illegally). It can arise from a range of sources:

- During cooking or processing.
- From the use of pesticides.
- From drugs used to treat the animal.
- From packaging materials in contact with the food.
- From natural toxins present in feed.
- From the environment due to industrial activity, the natural environment or from deliberate or accidental release of radioactive materials.
- Addition of an illegal substance for the purposes of fraud.

Council Regulation (EEC) No 315/93 lays down community procedures for the regulation of contaminants in food. Maximum levels for certain contaminants in foodstuffs are listed in Commission Regulation (EC) No 1881/2006.

The Codex General Standard for Contaminants and Toxins in Foods is the de facto international standard for the safety of these chemicals in food and their place in international trade.

Annexes are available that list which levels of chemicals are permitted in which foods.

Heavy metals

Heavy metals are found naturally in the Earth's crust. Excessive levels of heavy metals can be harmful to living organisms.

Examples include arsenic, cadmium, copper, lead, mercury and tin.

Dioxins

Dioxins are pervasive worldwide environmental pollutants found in soils, sediments and food, especially dairy products, meat, fish and shellfish.

They cause a wide variety of toxic effects and are carcinogenic in humans. Health effects can be observed for years after the initial exposure. Intoxications can be acute or chronic depending on the toxic dose ingested and the time of exposure.

In 2008, the European Food Safety Authority used Quantitative Risk Assessment to determine the risks for public health due to the presence of dioxins in pork from Ireland.

Radionuclides

A radionuclide is an atom with an unstable nucleus that undergoes radioactive decay and emits gamma rays and subatomic particles.

If radionuclides are released into the environment through accident or poor disposal they can potentially cause harmful effects of radioactive contamination.

Commission Regulation (Euratom) No. 770/90 lays down the maximum permitted levels of radioactive contamination of feedstuffs following a nuclear accident or any other cases of radiological emergency.

The regulations were drafted in response to the Chernobyl Incident of 1986, and apply equally well to the more recent nuclear station incident in Japan.

Veterinary residues

Veterinary residues arise in meats from medicines or other substances administered to the animal in order to treat or prevent disease, encourage growth or control fertility.

Commission Regulation 37/2010 lists Maximum Residual Limits for veterinary residues in foods as well as listing those which are banned.

The Codex Alimentarius Commission has a searchable database for veterinary residues in food.

Pesticide residues

Pesticides are used in agriculture to prevent weeds, insects or fungi adversely affecting the yield or quality of agricultural crops either during production or during storage.

Pesticides have the potential to appear in meat and meat products when animals have eaten animal feeds made from crops that contained them.

The Regulation (EC) No 396/2005 covers the maximum residue levels of pesticides in or on food and feed of plant and animal origin.

The EU has a searchable database for permitted levels of pesticides in food.

DDT

DDT is not metabolised very rapidly by animals; instead, it is deposited and stored in the fatty tissues.

The biological half-life of DDT is about eight years; that is, it takes about eight years for an animal to metabolise half of the amount it assimilates. If ingestion continues at a steady rate, DDT builds up within the animal over time.

The use of DDT was banned worldwide in 2004 apart from control of vectors such as malaria carrying mosquitoes.

Cooking and processing contaminants

These can occur via a number of pathways, often by accident. Examples include leakage of machine lubricants and coolants; misuse of cleaning fluids or other chemicals; and absorption from copper or aluminium utensils.

Many chemical contaminants are formed during the combustion of fuel both in the smoking and in the direct drying process. Examples include polycyclic aromatic hydrocarbons, dioxins, formaldehyde, nitrogen and sulphur oxides.

Mycotoxins

Mycotoxins are natural products synthesised by filamentous fungi that cause a toxic response when ingested. At least 20 mycotoxins occur naturally in foods and feeds at significant levels and frequency to be of a food safety concern.

Human intake of mycotoxins occurs mainly from plant-based foods and from animal-derived foods such as milk, cheese and certain fermented meat products.

Maximum levels for mycotoxins in foods are listed in Commission Regulation (EC) No 1881/2006.

Melamine

Melamine is a chemical compound that has a number of industrial uses but can be illegally added to inflate the apparent protein content of food products.

There are no approved direct food uses for melamine in any country. In 2010 the European Food Safety Authority published a detailed Quantitative Risk Assessment for melamine levels in food. ■

References and key sources for further study can be found on the author's website: www.bobmitchellfoodsafety.com