4 Food Safety

4.1 Introduction

Food safety has become one of the biggest consumer issues of recent years. From the public perception that food additives are harmful, to the high profile scares about Listeria, Salmonella and BSE (mad cow disease), there has been an increasing public feeling of distrust of the mass-market food industry. This is despite the fact that modern processing methods can now deliver a range of high quality foods at unprecedented levels of production. Nevertheless, these same production methods bring with them a responsibility to ensure that the processed foods can be stored and used safely in the home. Yet despite public concerns about issues such as genetic modified foods, pesticides, fertilisers and animal feeds, one of the biggest threats to food safety remains food poisoning bacteria.

The challenge for the food industry is to use methods of preparation and processing that destroy pathogens and prevent recontamination of food. Given the variety of food poisoning organisms and how they can thrive, this is by no means a small challenge.

There are several bacteria that pose a significant threat to food safety. Most can be killed by cooking and re-infection can be avoided by preventing cross contamination and by appropriate cold storage. The bacterium *Bacillus cereus* is found on virtually every agricultural commodity, but generally at levels too low to cause illness. Eating foods on which the organism has grown and formed toxins, however, will result in food poisoning. Toxins are responsible for illness, causing diarrhoea and vomiting. These can be very resistant to heat and extremes in pH. In mild cases, full recovery may be within 24 hours.

Only in the past decade or so has *Campylobacter* bacteria been recognised as the cause of enteritis. Many cases of infection have been associated with unchlorinated water and unpasteurised milk, but it is also often found raw poultry meat. The bacterium infects the intestinal tract, excreting toxins causing abdominal pain, fever, and diarrhoea and vomiting. The illness usually up to a week to materialise and full recovery can take a further week.

Occurring on almost all foods, the toxin produced by *Clostridium botulinum* bacterium is among the most toxic of all naturally occurring substances. The lethal dose may be as little as 0005mg. Fortunately, it is inactivated by heating at 90°C for just a few seconds. Symptoms of infection include weakness and fatigue followed by blurred vision and difficulty in swallowing. Death is usually the result of respiratory failure.

Through careful control, incidents of poisoning by *C. botulinum* from commercially processed foods are rare. Cooking a food container to ensure that its slowest heating point is exposed to temperatures equivalent to 121°C for three minutes (known as a Botulinum Cook) is generally sufficient to kill the organism.

Listeria monocytogenes can survive well for several weeks at -18°C in various foods. However, it does not normally survive commercial pasteurisation. Most *L. monocytogenes* cases occur in people predisposed to the infection such as those with illness. Not all strains of *L. monocytogenes* are pathogenic but those that are, are haemolyphic in that they destroy red blood cells. Infection usually occurs via the intestine.

There are over two thousand identifiable strains of Salmonella. The two strains of concern in Europe are *S. enteritidis* and *S. typhimurium*. Salmonellae invade the small, and sometimes the large intestine, where they may overcome body defences to reach the bloodstream and give rise to abscesses on various tissues. Invasive strains pass into the lymphatic system and are engulfed by phagocytes. These bacteria re-enter the bloodstream causing septicaemia. Since low numbers of salmonellae can cause illness it is important to ensure their absence from ready-to-eat foods. Salmonellae are also often associated with raw eggs and poultry products.

Staphylacoccus aureus occurs widely on the skin and mucous membranes of warm-blooded animals, including humans. Food can be contaminated through poor hygiene and storage, allowing food poisoning enterotoxins to form. *S aureus* cells are easily destroyed by heat, but the toxin is heat resistant and will survive some sterilisation processes. Symptoms of enterotoxins include nausea, abdominal cramps and diarrhoea. In severe cases headache and collapse may occur. Recovery is usually rapid.

There are ten species of *Vibrio* which have food-borne pathogenic potential. Found in seafood, the bacteria prefers to grow in the presence of salt and is easily destroyed by drying. Food poisoning is thought to be associated with the production of a heat resistant haemolysin causing the destruction of red blood cells. The symptoms are therefore similar to those for salmonellosis.

There four types of pathogenic *Escherichia coli* bacteria that have been associated with food-borne disease. The most notorious of these is *E. coli* 0157. Though often associated with undercooked meat, *E. coli* 0157 has been found on many uncooked foods, and has caused many food poisoning cases during the past decade, some of which have been fatal.

4.2 HACCP

The emphasis on food safety within the industry around the globe is based on the principles of prevention rather than cure. There has been universal adoption of the Hazard Analysis Critical Control Point (HACCP) principles for identifying hazards and putting in control procedures to minimise risk. Testing is now seen as a means of verifying the HACCP system, rather than checking on the safety of food.

Originally developed by NASA for the prevention of contamination in space, HACCP was designed to be a system and set of procedures for prevention. Applied to the food industry, it means that all elements of contamination risk in a food operation are checked thoroughly and is a systematic method of assessing and minimising or, if possible, eradicating risk.

The globalisation of the food industry means that foods may be comprised of components which are harvested, processed and shipped from many countries. Improper storage or handling at any point or place can result in the overall food being contaminated from unidentifiable sources. Under HACCP the food processor is required to develop and follow a HACCP plan that identifies the possible hazards, the steps at which controls must be applied to prevent the hazards from occurring, the safety limits that apply to the control point, and the monitoring and record-keeping necessary to document and verify that the control has been applied.

An example of a control point is a cooking step in which the food must be subjected to temperatures sufficient to kill any harmful organisms. The HACCP plan would include the temperature that the cooking must attain, and also the means of monitoring that temperature, the type of record used for documenting the reading; the corrective action steps to take if the required cooking temperature is not met; and procedures for verifying that the plan is being properly implemented.

A likely source of microbial hazards to be controlled under HACCP is cross-contamination. Personal hygiene of food handlers is the main source of cross-contamination, but pests such as rodents, birds, flies and cockroaches can also cross-contaminate food during processing. Sanitation programmes must include pest controls to prevent live, mobile pests from cross-contaminating food during processing and storage. These controls are the basis for good manufacturing practices.

Under HACCP, these sanitation programmes are called prerequisite programmes because they provide the foundation for the HACCP controls and must be properly applied if the HACCP controls are to be effective. They should not introduce additional hazards. The challenge is therefore to identify all hazards and develop and implement a HACCP plan that is able to control all food safety hazards.

HACCP applies to every food handling site and also includes cafés, restaurants, bakeries and other food handling sites, including abattoirs. Whatever the operation, there must be a practical system in operation, ensuring that the highest standards of hygiene and food safety are maintained for the benefit of the public. If a site, company or organisation does not have an HACCP procedure, severe penalties can be imposed including fines, closure, and recall of all foods sold to the public. A breach of major severity may lead to a custodial prison sentence.

The HACCP consists of seven distinct steps:

1. Assess the hazards
2. Identify critical control points
3. Set up control procedures and standards for critical control points
4. Monitor the critical control points
5. Take any corrective actions
6. Establish effective record keeping
7. Verify that the system is working

For food handling sites HACCP monitors the minimum number of critical points necessary to ensure a safe product. Decisions about the existence of critical points are based on scientific facts and statistics. A well-run HACCP system can control each critical point to eliminate occurrence of hazards.

4.3 Hygienic Design

The design of process equipment and plant should ensure that the food being processed can be processed safely without the risk of contamination either through expose to contaminated air, liquids or surfaces. Contamination may also be due to food process operators. Equipment should therefore be manufactured from approved food-grade materials and be designed such that the equipment can either be disassembled and cleaned manually or cleaned automatically in place. There should be no dead spots and cleaning programmes designed to remove chemically and physically any material which may have adhered to the surface. The cleaning agents should also be thoroughly washed from the equipment after cleaning.

From raw ingredients to the finished product, a food processing facility may have areas consisting of warehousing, dispatch, raw ingredient storage, cold storage, chillers, ingredient mixing, production, packaging, utensil and equipment wash, laboratories, plant rooms, mezzanine decks, staff changing rooms, toilets and offices. Each area has its own particular requirements for design.

It is essential that floor finishes satisfy all legislation. In high-risk zones the floor finish is required to be seamless, hygienic, durable and easy-to-clean and maintain. The flooring must also be able to withstand all, or a combination of chemical resistance, thermal shock, impact, abrasion resistance, flexibility on mezzanine decks. All facilities require a floor finish to be slip-resistant, hygienic and easy to maintain. Floor materials should be able to withstand aggressive and abrasive cleaning as well as steam cleaning processes that are essential for maintaining hygiene. The floor is likely to have to impact resistance and well as resistance to chemical attack and high temperatures. Careful planning is needed in the replacement or refurbishment of existing floors, to make maximum use of downtime, to keep lost production to a minimum and to avoid any risk of odour contamination.

Although there is a wide variety of flooring materials available only a few are suitable for the food industry. Seamless resin compounds and slip-resistant heavy duty vinyl flooring materials are the most popular for high risk zones and can satisfy most or all of the requirements of food manufacture and retail. Resin flooring systems range from high solid content coatings for low-traffic areas to heavy-duty screeds for high-risk zones, such as ingredient mixing and blending, production, warehousing, freezers and chillers. There are many resin systems available, including acrylics, polymers, polyesters, epoxy and polyurethane. Modern resin systems such as polyurethane screeds are at the forefront of resin development and constructed for the harsh environment of food processing and manufacturing offering excellent chemical resistance. In less demanding low-risk areas of laboratories, staff changing rooms and toilets, epoxy resin systems or slip-resistant vinyl materials offer a wide range of finishes, thickness and a firm grip underfoot.

Good housekeeping and maintaining general tidiness is essential to ensure risks are reduced to a minimum and the avoidance of contamination. This can be improved by installing trays for the collection of waste. Sweeping, shovelling or vacuuming of spilt material rather than hosing it down the drain should be used. Procedures for manual cleaning processes should also ensure that hoses and water lances use trigger controls to minimise the amount of wash down water. High pressure, low volume water systems are preferable.

In using cleaning chemicals, operators should be trained in the handling, making up of working solutions and their application. The concentration of the chemical agent should not be too high and the overuse of chemicals avoided, particularly where manual dosing is used.

In the design of Cleaning-in-Place (CIP) systems, remnants of dry product should be expelled or removed before the start of the wash cycle by gravity draining, pigging or air blowdown. A pre-rinse is then used to enable remaining product to be recovered for re-use or disposal. Turbidity detectors can be used to maximise product recovery.

A CIP programme should be optimised for the plant or vessel size and soiling type to ensure that the automatic dosing of chemicals are set at the correct concentrations (see Table 4.1). The programme should include internal recycling of water and chemicals, a recycle control on conductivity rather than time with a continuous cleaning of re-circulated solutions.

Processing equipment and production facilities are cleaned and sanitised periodically, with the frequency varying according to products and processes. The aim of cleaning and sanitation is to remove product remnants from the foregoing process and remove other contaminants and microbes.

Manual cleaning means that the equipment to be cleaned is taken apart and manually cleaned (brushed) in a cleaning solution. Only mild conditions, with regard to temperature and cleaning agents, can be used.

Cleaning in place (CIP) is used especially for closed process equipment and tanks. The cleaning solution is pumped through the equipment and is sometimes distributed by sprayers. The cleaning programme is mostly run automatically and includes a pre-rinse with water, circulation with a cleaning solution, and intermediate rinse, disinfection and a final rinse with water. In automatic CIP systems the final rinse water is often reused for pre-rinsing. Typical cleaning temperatures are around 90°C and used together with strong cleaning agents.

In high-pressure jet-cleaning, water is sprayed at the surface to be cleaned at a pressure of about 40 to 65 bar. Cleaning agents are injected in the water and temperatures up to 60°C are used. An important aspect of the cleaning action is due to the mechanical effect of cleaning. There are, however, hygiene implications of over-splash and aerosols.

In foam cleaning, a foaming cleaning solution is sprayed on the surface to be cleaned. The foam adheres to the surface and remains on the surface before being rinsed away. High-pressure jet-cleaning and foam cleaning is generally applied for open equipment, walls and floors.

Cleaning agents used in food and drink industry include alkalis such as sodium and potassium hydroxide, sodium carbonate, acids such as nitric acid, phosphoric acid, citric acid and gluconic acid. Formulated cleaning agents containing chelating agents include EDTA, NTA, phosphates, polyphosphates, phosphonates as well as and surface active agents.

Table 4.1 Cleaning-in-Place

Component	*Solubility*	*Removal*	*Difficulties*
Sugars	Water soluble	Easy	Caramelisation
Fats	Fat soluble	Difficult	Polymerisation
Proteins	Water insoluble	Very difficult	Denaturation
	Alkali soluble	Very difficult	Denaturation
Sugar & Protein	Alkali soluble	Very difficult	Denaturation
Mineral salts	Water soluble	Varies	Use hot water
	Acidity dependent	Varies	High temperature

4.4 Food Packaging

The function of food packaging is to provide protection from physical damage, chemical attack, environmental contamination and tampering and as well as forming good product utilisation. Food packaging is designed for each food product in order to make it easier or more convenient for a consumer to use. The packaging is also designed to provide good communication to the consumer or user. In particular, packaging should convey details of the product identity, the mount and number of servings, ingredient contents, nutritional content, preparation instructions, consumer service information and include coupons, recipes and any promotional offers.

Food packaging is required to be non-toxic, sanitary, durable, easy to use, economical, recyclable, designed to extend product shelf-life and provide a good barrier. Packaging may therefore be designed to be permeable, semi-permeable, or impermeable to water as a liquid or vapour, oxygen, carbon dioxide, volatiles and light. After use, packaging can be re-used, recycled, sent to landfill or incinerated.

4.4.1 Glass

Glass is fabricated from sand, soda ash, and limestone. Colorants and coatings may be added. Glass has the advantage of being inert, good optical qualities, easily recycled although is fragile, heavy and requires a lot of energy for its production.

4.4.2 Metal (Steel Cans)

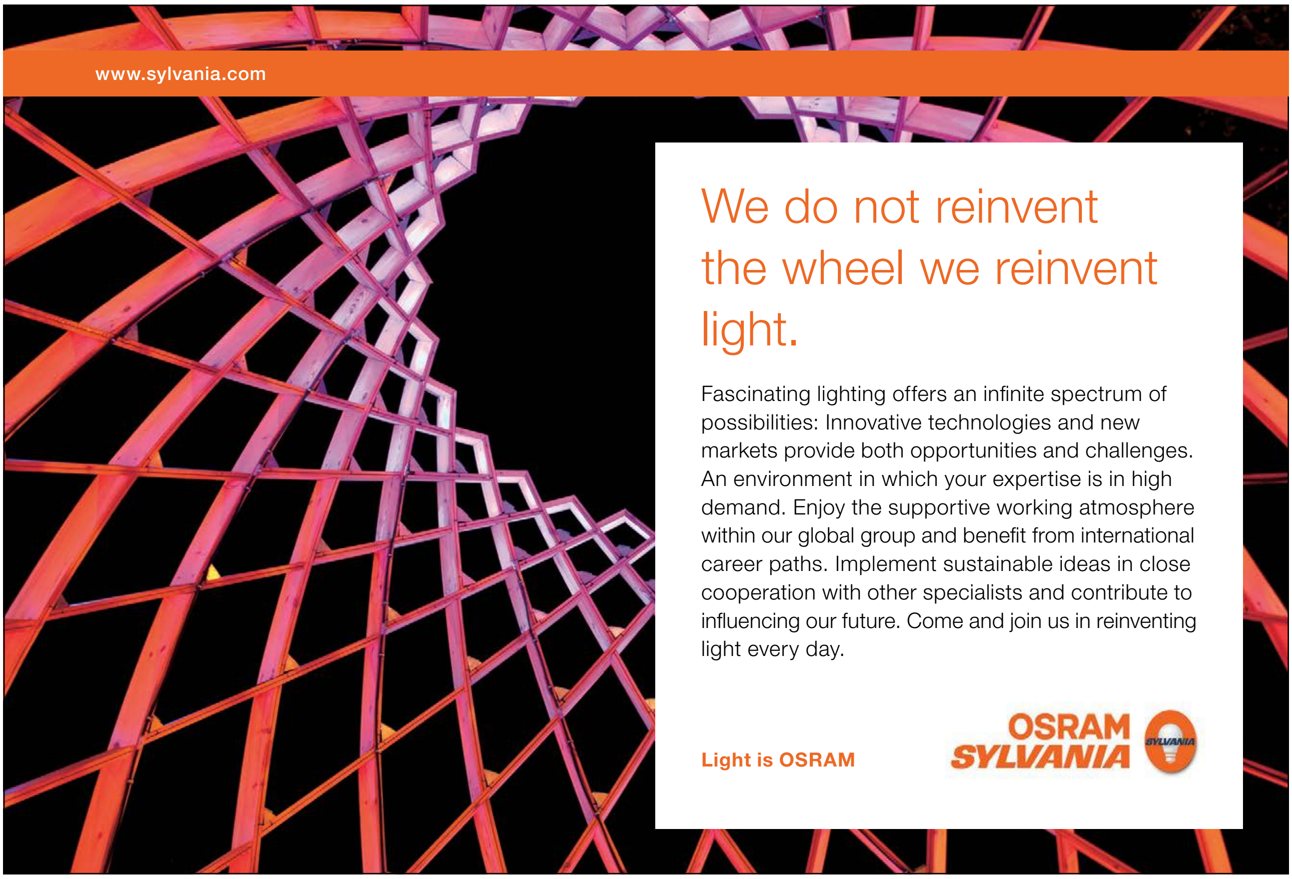
Fabricated from steel with a thin tin and/or polymer coating, coatings protect the steel and prevent electrochemical reactions (corrosion) between the container and the food. The advantage is that it is hermetically sealed, offers an impermeable barrier, has good heat transfer properties, is strong, can be made on site. However, it may react with food and unfilled cans dent easily and are heavy.

4.4.3 Metal (Aluminium Cans)

Aluminium cans are lightweight, resistant to corrosion, easily formed and recyclable. They are, however, fragile and must be pressurised up to 6 bar to offer appreciable strength.

4.4.4 Plastic

Plastic can be moulded and drawn into flexible films and used either with or without coatings. The advantage of plastic is that it lightweight and can easily be formed into shapes. It is, however, difficult to achieve desired barrier properties for some products particularly against gas diffusion.



4.4.5 Paper

A variety of strengths are available with or without coatings. Paper is not a good barrier and loses strength in high humidity environments.

4.4.6 Paperboard

This is made from carton stock with or without coatings. It can be heat stable and may be used for cooking in both conventional and microwave ovens.

4.4.7 Corrugated Cardboard

This is used to make shipping containers and is made from several layers of paper with internal flutes that provide strength to the material. The paper can be from a variety of grades, is inexpensive and easily recycled.

4.4.8 Composite packages

These comprise three layers with the outer layer being composed of polyester film that provides thermal resistance, strength, and printability, a layer of aluminium foil to provide barrier properties and an inner layer of polypropylene to provide heat seal integrity. They are lightweight, easy to open but expensive and not recyclable.

4.4.9 Food Labelling

Food labelling must comply with the EU food labelling requirements. Food labels provide information from the manufacturer to the consumer. They allow the consumer to know exactly what they are buying. They also provide instructions for storage and preparation, and allow the consumer to make dietary choices as well as judgement on value for money.

By law, most food products must include the following information, though some products may be exempt from one or more of these conditions.

Product name
Ingredients list (in descending order of weight)
Shelf-life (use-by or best-before date)
Storage instructions
Name and address of either the manufacturer, packer or EC seller
Country of origin
Weight (or volume)
Instructions for use

Although not a legal requirement, other labelling can also include:

Instructions for long term storage
Instructions for opening
Serving suggestions
Consumer advice details
Promotional details
By appointment
Logos and pictures
Recipes
Bar codes

Example:

The following label is taken from a pot of cottage cheese:

NUTRITION INFORMATION		
TYPICAL VALUES	PER 100g	PER POT
Energy	405kJ 96kcal	809kJ 192kcal
Protein	9.9g	19.8g
Carbohydrate	6.5g	13.0g
of which sugars	5.1g	10.2g
Fat	3.4g	6.8g
of which saturates	2.0g	4.0g
Fibre	1.0g	2.0g
Sodium	0.3g	0.6g

Confirm that the energy requirement is 809 kJ.

Solution:

In calculating the energy value on the label the following conversion factors are used:

1 g carbohydrate = 17 kJ (4 kcal)
1 g protein = 17 kJ (4kcal)
1 g fat = 37 kJ (9 kcal)
1 g ethanol = 29 kJ (7 kcal)
1 g organic acid = 13 kJ (3 kcal)

In this case:

Protein:	19.8 g x 17 kJ.g^{-1}	= 336.6 kJ
Carbohydrate:	13 g x 17 kJ.g^{-1}	= 221 kJ
Fat:	6.8 g x 37 kJ.g^{-1}	= 251.6 kJ
	Total	= 809.2 kJ