

Milk products can be derived from raw milk that may contain traces of antibiotics, pesticides and hormones, heavy metals or aflatoxin M1 (Fischer *et al.*, 2011).

To evaluate the likelihood of occurrence of chemical contaminants in incoming ingredients, knowledge on the origin of raw material is important, for example, country of origin, soil type and local climate where relevant as well as the existence and enforcement of regulatory measures. Moreover, information on storage conditions at farm and at supplier level, availability and price of agrochemicals used for ingredients of agricultural origin, as well as the supplier history and confidence level, are all key factors to be analysed when determining which contaminants might occur and at what level. An appropriate monitoring plan for the most relevant contaminants will help develop understanding and build confidence in the supply chain.

25.5.2 Chemical hazards occurring during processing

Contamination of chocolate with chemicals can also occur during manufacture and processing. Cross-contamination linked to the use of chemicals for cleaning confectionery equipment can easily happen. An example is sodium hydroxide solution, which is used to clean equipment such as caramel cookers – to avoid causing contamination; it must be used in the correct concentrations, effectively rinsed off afterwards and properly segregated or stored. Other chemicals, used for treatment of water in heating and cooling systems, or for boiler treatment, may also potentially contaminate the product through inadvertent leakage.

Oils and greases, which are necessary to many items of processing equipment, may potentially cross-contaminate confectionery products. Therefore it is essential that food-grade oils and greases be used where there is any possibility that they may come into contact with food materials.

Other chemicals required for maintenance and upkeep of the production environment, such as paints and sealants, must be of food safe composition when they may come into contact with food. They should be correctly stored and adequate precautions should be taken when using them, including the protection of production lines and ensuring good ventilation.

25.6 Microbiological hazards

25.6.1 *Salmonella*

The key microbiological hazard during chocolate manufacture and use is *Salmonella*. Although chocolate is a relatively dry product, with a low water activity typically around 0.2–0.4, it is proven that, although it cannot grow in these conditions, *Salmonella* can survive in chocolate products for longer periods of time than in other food matrices; in fact, periods of several years have been reported (Cordier, 1994).

There have been a number of food poisoning outbreaks that have been associated with the presence of *Salmonella* in chocolate, for example the recall of chocolate products in 2006 in the United Kingdom due to contamination with *Salmonella* Montevideo (Harker *et al.*, 2013). Food poisoning from chocolate products is often caused by a surprisingly low number of cells. It is hypothesised that the fatty matrix of chocolate actually protects the *Salmonella* cells from the acidic environment of the stomach, allowing them to colonise the lower gastrointestinal tract, producing clinical symptoms (D'Aoust, 1977).

The outbreaks shown in Table 25.1 demonstrate the small number of *Salmonella* that may be sufficient to cause illness in a large number of people, often children. With exporting of chocolate products to other countries now being commonplace, outbreaks could become very widespread in nature.

Symptoms of salmonellosis are diarrhoea, vomiting, fever and abdominal pain, lasting up to seven days. Although rarely so, it can be fatal, with higher mortality rates amongst “high risk” groups – the very young, elderly, and those who are ill, convalescing or with a weakened immune system (Engel *et al.*, 2001).

Salmonella may be introduced into the chocolate process through incoming raw materials, or through inadequate hygiene practices at the factory.

25.6.2 *Salmonella* in raw materials

The primary origin of *Salmonella* is the intestinal tracts and faeces of humans or animals (Engel *et al.*, 2001), therefore the raw materials that are most likely to become contaminated are those of an agricultural origin that may have been exposed to such conditions.

25.6.2.1 Cocoa beans

Cocoa beans are a known potential source of *Salmonella*, due to poor hygiene conditions during bean harvesting, fermenting and drying. The pulp and beans are contaminated during and after breaking of the pod by many sources, including hands and tools of harvesters, soil, leaves, re-used wooden containers, insects and animals (Lund *et al.*, 2000).

After harvesting, beans undergo a fermentation process, during which a succession of different micro-organisms can be identified. At the start, yeasts are predominant, declining by around the third day in favour of lactic acid bacteria and acetic acid bacteria (see Chapters 2 and 8). The last phase of fermentation favours the development of thermophilic spore-forming bacteria, and the microflora of fermented beans predominantly consists of members of the genus *Bacillus* (Barrile *et al.*, 1971). After fermenting, beans are dried, commonly in the sun. During the drying process there may be little environmental control and further microbial contaminants can access the beans. As a consequence of the fermentation and drying processes, raw cocoa beans have high microbial levels and the presence of *Salmonella* is a well recognised hazard (Bell and Kyriakides, 2002).