

(Allergen hazards are addressed later, in Section 25.7.) At high doses, the exposure to chemical contaminants can cause toxicity to the consumer, for example, acute poisoning from the ingestion of high levels of lead; at lower doses there are generally long-term adverse health consequences that will affect the consumer, such as kidney dysfunction, skeletal damage or reproductive deficiencies when cadmium builds up in the body for many years.

25.5.1 Chemical hazards in incoming ingredients

Raw materials of plant and animal origin are potentially affected by a number of environmental contaminants.

25.5.1.1 Heavy metals

Cadmium is a heavy metal that exists naturally in low concentrations and is absorbed from the soil by many plants, including cocoa beans. Levels of cadmium can vary by growing region, according to the type of soil: soils of volcanic origin, for example, tend to contain higher than average cadmium content. Regulatory limits for cadmium in cocoa products have been, or are being, introduced in a number of countries.

Lead is also widely present in the environment, due to both natural occurrence and human activities, such as the use of leaded petrol. Levels have reduced in food in recent years due to efforts to reduce lead emissions. Raw materials may become contaminated with lead if they are grown, stored or processed under conditions that could introduce larger than typical levels of lead in the food, such as crops grown in soil contaminated from prior use of leaded pesticides. Cocoa mass (liquor) is the principle source of lead in chocolate. As a consequence, lead levels in finished chocolate products tend to be higher in dark than milk chocolates, due to their higher cocoa mass content.

25.5.1.2 Mycotoxins

Mycotoxins are toxic substances produced by specific fungal moulds. Toxigenic fungi occur regularly in food supplies worldwide due to mould infestation of susceptible agricultural product such as grains, nuts and fruits (Murphy *et al.*, 2006). Ochratoxin A (OTA) is the major mycotoxin that threatens cocoa. OTA is produced by several species of *Aspergillus* and has been found to occur essentially between harvest and fermentation of cocoa beans, and under warm, humid transport or storage conditions (Copetti *et al.*, 2014). Good post-harvest practises are essential to prevent mould development and OTA contamination (Codex, 2013). Ochratoxin A can have serious health consequences, including kidney failure, and is classified as a probable human carcinogen by the International Agency for Research on Cancer (IARC). Research on Ochratoxin A levels in cocoa products showed the highest levels concentrated in the shell – hence the efficiency of the winnowing process is important in reducing the levels of contaminant – reducing to much lower levels in other cocoa products and finished chocolate products (Copetti *et al.*, 2014). The lowest levels are found in the fat fraction of cocoa products.

Aflatoxins are generated by a number of species of *Aspergillus*. They are carcinogenic and toxic to the liver (Engel *et al.*, 2001). Although most commonly associated with nuts, cereals, rice and dried fruits, Aflatoxin B1 has occasionally been identified in batches of cocoa beans (Doncheva and Dikova, 1992). This research showed levels tending to decrease with each cocoa bean processing step, until they were undetectable in cocoa butter.

25.5.1.3 Pesticides

Pesticides are a group of substances designed to kill pests and to protect crops and stored products. Some pesticides can accumulate in the environment and become increasingly concentrated as they move up the food chain (Engel *et al.*, 2001). The type of pesticide used varies by growing region of the cocoa bean. Consignments of West African cocoa have been known to have been rejected due to residues of lindane that was traditionally used to control mirids (sap-sucking insects; Mabbett, 2002).

Methyl bromide has for many years been used to fumigate cocoa beans in storage, particularly as a defence against the cocoa moth, which is a main agent of destruction of stored beans in tropical origin countries. However the use of this chemical has been phased out for environmental reasons to comply with the Montreal Protocol on Substances that deplete the ozone layer.

25.5.1.4 Mineral oils

Cocoa beans are traditionally shipped in bags or sacks, made of woven natural fibres, commonly jute. Jute has previously been impregnated with mineral hydrocarbons, which may subsequently contaminate the cocoa beans. As a consequence, the International Jute Organisation has put a limit of 1250mg/kg unsaponifiable matter present in jute bags (IJO, 2005). This problem can be avoided by the use of non-toxic vegetable oils for this purpose (Mabbett, 2002).

25.5.1.5 Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAH) are organic compounds, numerous of which are carcinogenic, that are generally a result of the incomplete combustion of organic material. In cocoa bean processing, the drying step has been identified as a potential source of these contaminants, especially certain artificial drying methods. (Misnawi, 2012). Regulatory limits for PAHs in cocoa bean-derived products have been, or are being, introduced in several countries.

25.5.1.6 Chemical hazards in other chocolate-making ingredients

In addition to the hazards described above, relating to cocoa products, chemical hazards in other chocolate making ingredients must also be considered, as these may all end up in the finished product. Other agricultural crops such as those used to produce vegetable oils, sugar or lecithin, may be similarly exposed to environmental contaminants such as heavy metals or to pesticide residues.