Table 25.1 Summary of published chocolate outbreaks due to *Salmonella* contamination (compiled from Werber, 2005: CDR-HPA, 2006; Elson, 2006).

Year	Country	Serovar[a]	Vehicle	Source of contamination	CFU/g[b]	No. of affected persons	Age of cases (years)
1970	Sweden	*S. durham*	Chocolate products	Cocoa powder	–	110	53% ≤15
1973 to 1974	USA, Canada	*S. eastbourne*	Chocolate balls from Canada	Cocoa beans	2.5	200	3 (median)
1982	England, Wales	*S. napoli*	Chocolate bars from Italy	Unknown	2–25	272	58% ≤15
1985 to 1986	Canada	*S. nima*	Chocolate coins from Belgium	Unknown	–	–	?
1987	Norway, Finland	*S. typhimurium*	Chocolate products from Norway	Avian contamination speculated	≤1	349	6 (median)
2001 to 2002	Germany, other European countries	*S. Orianenburg*	Two chocolate brands from Germany	Unknown	1.1–2.8	439	15years (median)
2006	UK	*S. Montevideo*	Chocolate confectionery	Leaking waste water pipe that dripped into milk chocolate crumb during processing	Unknown	37	3 children

[a] Type or strain.

[b] Colony forming units per gram

Roasting of beans or nibs is an essential step in the destruction of *Salmonella* and other vegetative bacteria. It is therefore very important that appropriate controls are applied at the roasting step to ensure that sufficient temperatures and roasting times are achieved and that no under-roasted material can pass into the subsequent process. It is considered that the traditional roasting process, (typically temperatures of 105–150 °C (220–300 °F) for 15 min to 2 h) is sufficient to destroy vegetative micro-organisms, including pathogens such as *Salmonella* (ICMSF, 2000). The most effective process in reducing microbial levels is one that combines a steam pretreatment, or "debacterisation" step; lower thermal death rates can be expected from a dry roasting process. Roasting processes should be validated to ensure that they are capable of inactivating expected levels of *Salmonella*.

A recent trend is the consumption of "raw chocolate", which is typically not exposed to temperatures exceeding 42 °C during processing. Due to the lack of a validated heat treatment step, there is concern that such products may present a health hazard from *Salmonella*. (National Confectioners Association's Chocolate Council, 2011).

After the roasting step, there are no further processing stages in the manufacture of chocolate products that will effectively destroy *Salmonella*, as the low water activity and high fat content lead to significantly increased heat resistance of *Salmonella* in the chocolate matrix (Cordier, 1994). Temperatures of 70–80 °C (158–176 °F) attained during milling, refining or conching are not sufficient to destroy small numbers of *Salmonella* (Lund et al., 2000; Krapf and Gantenbein-Demarchi, 2009). Therefore hygienic processes and working practices are essential as preventive measures to avoid *Salmonella* cross-contamination.

Correct hygienic zoning of the cocoa bean process is required to ensure that there is no possibility of cross contamination from the raw beans to subsequent, post-roasting steps. Raw bean storage and handling areas must be well segregated. Personnel and equipment should be dedicated to these areas and movement between the raw bean and post-roasting departments must be minimised. Hygiene barriers between these areas must be robust, incorporating shoe and overall changing for workers and complete separation of the buildings and equipment. The airflow as well as personnel and vehicle movement must be designed to prevent any chance of the ingress of raw cocoa bean dust into the post-roasting process. Air, including that used for cooling the beans after roasting, must not be drawn from the environment in which raw beans are present (Bell and Kyriakides, 2002). All air introduced directly into products or in an exposed product environment should be suitably filtered (IOCCC, 1991).

25.6.2.2 Other raw materials

The hazard of *Salmonella* must also be controlled during the production processes of other sensitive chocolate ingredients. Milk powder has been implicated in a large number of Salmonellosis outbreaks (Bell and Kyriakides, 2002) and heat