SALMONELLA (NON TYPHOIDAL)
IN HIGH LIPID FOODS MADE FROM
SESAME SEEDS, PEANUTS OR
COCOA BEANS

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EXECUTIVE SUMMARY

The purpose of a Risk Profile is to provide information relevant to a food/hazard combination so that risk managers can make decisions and, if necessary, take further action. Risk Profiles include elements of a qualitative risk assessment, as well as providing information relevant to risk management.

This Risk Profile concerns *Salmonella* spp. (non-typhoidal) in high lipid foods, specifically sesame seed-based foods (sesame paste, tahini, sesame-based halva), peanut-based products (i.e. peanut butter) and cocoa beans/chocolate. These foods have been the source of salmonellosis outbreaks overseas. Tahini caused a salmonellosis outbreak in New Zealand in 2003, involving ten people, and may have been the cause of a further five New Zealand outbreaks. There are no reported salmonellosis outbreaks in New Zealand caused by peanut-based products or chocolate.

New Zealand supplies of sesame paste, tahini and halva are largely imported and only small amounts of peanut butter are manufactured in New Zealand. Chocolate is both imported and manufactured in New Zealand.

Tahini, halva, peanut butter and chocolate all have a low water activity that prevents microbial growth, but the composition of such foods allows *Salmonella* spp. to survive for long periods. These high lipid foods have a long shelf life and are usually consumed without further heat treatment by the consumer after purchase.

A roasting process is included in the manufacture of tahini, peanut butter, and chocolate and this should inactivate any *Salmonella* spp. on the raw sesame seeds, peanuts or cocoa beans. While the dry heat involved in roasting is less efficient at killing bacteria than moist heat (Farkas, 2001), the times and temperatures found for roasting of cocoa beans, sesame seeds and peanuts suggest that *Salmonella* spp. reductions should be substantial. This has been supported by a study using peanuts (Doyle, 2009), but no studies of the effect of roasting on *Salmonella* spp. on sesame seeds or cocoa beans were identified. There are only a few overseas salmonellosis outbreak investigations where the cause of contamination was identified, but those that do suggest that post-heat treatment contamination is the most likely source of *Salmonella* spp. in these high lipid foods (CDC, 2007a, 2007b; Elson, 2008; Gill *et al.*, 1983; Ng *et al.*, 1996; Powell, 2009; Scheil *et al.*, 1998). Nevertheless, the survival of *Salmonella* spp. through sesame seed processing (including roasting) has been postulated, based on the results of a survey in Germany (Brockmann *et al.*, 2004) and outbreak investigations (Unicomb *et al.*, 2005). In the absence of studies on the effect of roasting on *Salmonella* spp. in sesame seeds, it is unclear whether this might result from inadequate processing, or normal processing being insufficient.

Tahini produced from unroasted sesame seeds has been recalled by US manufacturers because of the possibility of *Salmonella* contamination. If tahini is produced without the roasting step there is greater opportunity for any *Salmonella* present on the raw sesame seeds to be carried through into the final product. It is not known whether any tahini imported into New Zealand is manufactured from unroasted sesame seeds. New Zealand import testing and outbreak surveillance have only reported contaminated tahini from the Seychelles and Middle Eastern countries. The available literature indicates that Middle Eastern countries manufacture tahini from roasted sesame seeds. Larger volumes of sesame paste are

apparently imported into New Zealand from Asian countries, and information on the production process for this material was not located. However, no *Salmonella* contamination of these products has been found from import testing. Neither have these products been linked to outbreaks.

Chocolate and peanut butter are consumed by approximately 20-30% of the population on a daily basis, based on national surveys in 1997 and 2002. Data collected by these surveys also indicate that <1% of New Zealanders consume hummus or tahini on a daily basis, although consumption of these foods may have risen subsequently.

The serving sizes for these foods are modest. Normally, this would translate into low exposures on an individual basis and ameliorate any risk of infection. However, there have been salmonellosis outbreaks involving these high lipid foods in which comparatively low concentrations of cells have caused illness. This may be due to a high prevalence of exposure to low numbers of cells causing illness in a small proportion of those exposed. In addition, lipids in the foods may protect bacterial cells from the acid in the stomach thus increasing the probability of infection.

Consequently, a more important factor in estimating risk is prevalence of contamination, rather than concentration. The one relevant survey in New Zealand, of sesame seed products, did not detect *Salmonella* contamination. No surveys of the prevalence of *Salmonella* in chocolate or peanut butter in the New Zealand were located. Import testing has detected *Salmonella* contamination in ten consignments of tahini/halva and two consignments of peanut butter twelve consignments between 2004 and 2009. This suggests that contamination is sporadic, and further surveys are unlikely to have much value.

Compared with many other foods, the amounts of these products consumed by New Zealanders are low. Contamination is likely to be sporadic, but when it does occur the potential for illness is high, for the reasons described above. On the basis of the small number of outbreaks of salmonellosis attributed to these high lipid foods together with import controls at the borders and food safety programmes in place for New Zealand manufacturers, it seems likely that these foods represent a minor component of the overall foodborne risk of this illness to New Zealanders. However, an increase in popularity of foods such as tahini and hummus could increase the risk in future.

The data gaps identified in this Risk Profile are:

- Prevalence of *Salmonella* spp. in chocolate and peanut butter in New Zealand (although surveys are unlikely to detect the presence of sporadic contamination unless very high numbers of samples are taken).
- Sources and prevalence of contamination in tahini imported into New Zealand (more comprehensive data than that currently available from import testing).
- Information on the importation of unroasted sesame products, and emerging high lipid foodstuffs potentially contaminated with *Salmonella* spp. e.g. nut butters, blended snack foods including tahini or sesame paste (apart from hummus).
- The heat resistance of *Salmonella* spp. in tahini during the manufacture of halva and on sesame seeds and cocoa beans during roasting.
- The roasting temperatures and times used for the products that are manufactured in New Zealand or imported to New Zealand (including sesame products from Asia).

- Dose-response information specific for high lipid foods.
- Transmission routes for the majority of reported salmonellosis cases in New Zealand.

1   STATEMENT OF PURPOSE

The purpose of a Risk Profile is to provide information relevant to a food/hazard combination so that risk managers can make decisions and, if necessary, take further action. Risk Profiles are part of the Risk Management Framework (RMF) approach taken by the New Zealand Food Safety Authority (NZFSA) (NZFSA, 2010b). The Framework consists of a four step process, as shown in Figure 1.
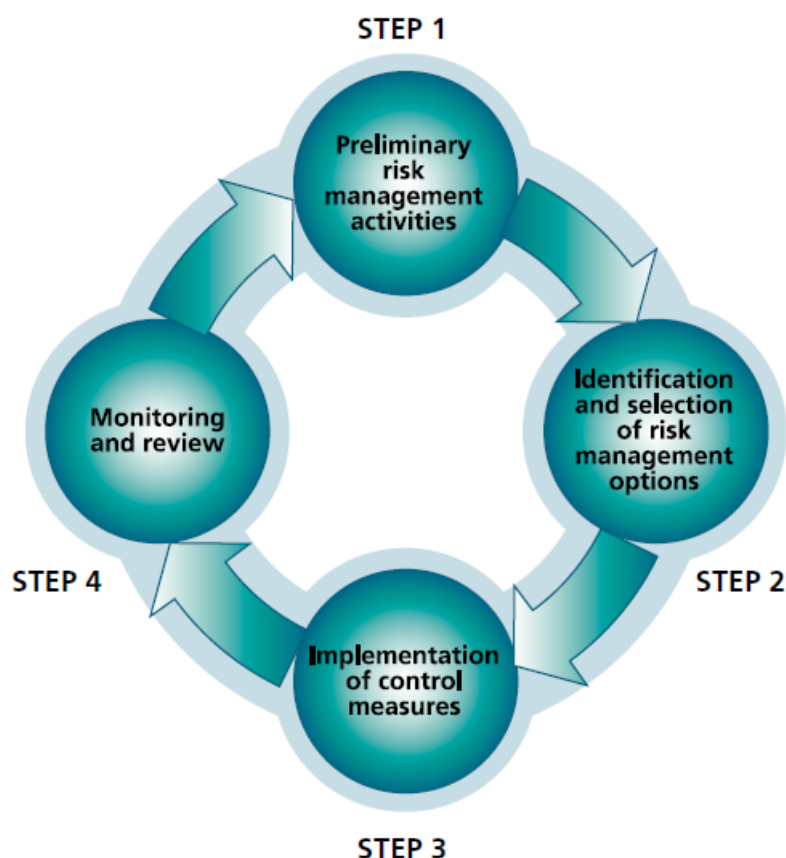
Figure 1:   The four steps of the Risk Management Framework

This initial step in the RMF, Preliminary Risk Management Activities, includes a number of tasks:

- Identification of food safety issues
- Risk profiling
- Establishing broad risk management goals
- Deciding on the need for a risk assessment
- If needed, setting risk assessment policy and commissioning of the risk assessment
- Considering the results of the risk assessment
- Ranking and prioritisation of the food safety issue for risk management action.

Risk profiling may be used directly by risk managers to guide identification and selection of risk management options, for example where:

- Rapid action is needed
- There is sufficient scientific information for action
- Embarking on a risk assessment is impractical.

1.1 Food/hazard Combination and Risk Management Questions

The food/hazard combination addressed by this Risk Profile is *Salmonella* (non-typhoidal) in high lipid foods, specifically high lipid foods made from sesame seeds, peanuts or cocoa beans. Such foods are diverse, but have the common characteristic of a low water activity that can protect *Salmonella* spp. against thermal treatments. In addition, the high lipid component provides protection for the salmonellae through the stomach acid barrier after consumption.

NZFSA has recognised non-typhoidal *Salmonella* spp. as one of the three most important foodborne pathogens in New Zealand. The organisation is taking a strategic approach to *Salmonella* Risk Management, with the ultimate aim of achieving a 30% reduction in foodborne salmonellosis after five years (NZFSA, 2009d). Underpinning this strategy are a range of preliminary risk evaluation activities, including risk profiling to better understand the risk of *Salmonella* spp. attributable to a range of food types.

This food/hazard combination was chosen as the subject of a Risk Profile after a number of well-publicised outbreaks of illness overseas and detection of *Salmonella* spp. in imported products.

NZFSA has commissioned this Risk Profile in order to address the following specific risk management question:

- What is the risk of *Salmonella* spp. contamination and human exposure in New Zealand from high lipid foods made from sesame seeds, peanuts or chocolate?

2   HAZARD AND FOOD

2.1   *Salmonella*

The information in this section represents a summary of a microbiological data sheet relevant to this Risk Profile (ESR, 2001). Further details are presented in Appendix 1. These data sheets are prepared for the NZFSA by ESR.[1]

This group of organisms is comprised of two species: *Salmonella* enterica, which is divided into 6 subspecies (enterica, salamae, arizonae, diarizonae, houtanae and indica), and *Salmonella* bongori (Jay *et al.*, 2003). Most pathogenic isolates from humans and other mammals belong to subspecies I: *Salmonella* enterica subspecies enterica. Other *Salmonella* enterica subspecies and *Salmonella* bongori are more commonly isolated from cold blooded animals and the environment, and are of lower pathogenicity to humans and livestock.

Salmonella spp. typing is primarily performed using serological identification of somatic (O), flagella (H), and capsular (K) antigens. There are more than 2,400 different *Salmonella* serotypes.

Salmonella enterica serotypes are normally denoted in a shortened form that includes a non-italicised serotype name, e.g. *Salmonella* enterica subsp. enterica serotype Enteritidis becomes *Salmonella* Enteritidis. In older publications this may be represented as a full species name i.e. *Salmonella enteritidis*.

Further subtyping may be performed using susceptibility to bacteriophages. These types are denoted as phage type (PT) or definitive phage type (DT) numbers. These two terms are interchangeable and both are used in current literature.

Salmonella Typhi and *Salmonella* Paratyphi are serotypes which are particularly well adapted to invasion and survival in human tissue and cause a serious enteric fever. They have a particular antigen makeup and differing ecology to other serotypes of *Salmonella*. This Risk Profile does not address *S.* Typhi or *S.* Paratyphi.

2.2   Sources of *Salmonella*

Human: Person-to-person transmission of salmonellosis is well recognised, and secondary transmission of *Salmonella* spp. in outbreaks has been demonstrated (Loewenstein, 1975). Carriage in faeces in convalescent cases can be quite substantial, with numbers approximating 10^6-10^7/g persisting up to 10 days after initial diagnosis. Reduction in numbers with time is variable; most people will have counts of less than 100 salmonellae/g after 35 to 40 days, but a count of 6 x 10^3/g has been recorded in one patient 48 days post-illness (Pether and Scott, 1982).

Animal: *Salmonella* can be found in mammals, fish, reptiles, amphibians, insects and birds. Most *Salmonella* spp. infections in animals produce no clinical signs. Some serotypes are largely confined to particular animal reservoirs causing both systemic and enteric disease, for

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[1] A full set of the data sheets can be found at http://www.nzfsa.govt.nz/science/data-sheets/index.htm (accessed 20 June 2010). ESR originally prepared the data sheets for the Ministry of Health in 2001.

example *S*. Cholerae-suis is host restricted to pigs (Allison *et al.*, 1969). Other serotypes (for example *S*. Typhimurium) are associated with intestinal infections in a wide range of phylogenetically unrelated species (Paulin *et al.*, 2002). Animal feeds may be contaminated with salmonellae, although feeds that include animal products (e.g. meat and bone meal) should receive sufficient heat treatment to destroy the organism.

Food: Red and white meats, meat products, milk, cheese and eggs are considered the major food sources of human salmonellosis, although a wide variety of other foods has been associated with outbreaks (Jay *et al.*, 2003). On rare occasions, salmonellae may be internally present in meat tissue, but more commonly the bacteria reach meat surfaces from the cross-contamination of intestinal contents and faeces to carcasses during slaughter and processing. The *S*. Enteritidis types that are capable of transovarian transmission into eggs are not endemic in New Zealand so this food type is likely to be of lower risk here (Lake *et al.*, 2004a). Foods of non-animal origin which have been shown to be contaminated by *Salmonella* spp. include coconut, barley, cereal powder, yeast, cottonseed, chocolate, peanut butter, soybean sauce, cider, watermelon, white and black pepper and watercress. Tahini, a product made from crushed sesame seeds, has been contaminated with *Salmonella* spp. and caused a number of outbreaks worldwide, including New Zealand and Australia (Unicomb *et al.*, 2005).

Environment: Salmonellae in sewage effluents or animal faeces can contaminate pasture, soil and water. They can remain viable for months in soil. The organism may also be dispersed in dust and aerosols generated during the handling and processing of animals. Contamination in the environment can act as a source of infection for other animals i.e. spreading by rodents or wild bird populations.

Transmission Routes: Salmonellae may be transmitted to humans via person-to-person transmission, contaminated food or water, animal contact or from a contaminated environment. The faecal-oral route is the most common.

2.3   The Food Supply in New Zealand: High lipid foods

2.3.1   Definitions

For the purposes of this Risk Profile, the specific high lipid foods included are:

- Sesame seed-based foods (sesame paste, tahini, halva)
- Peanut-based foods (i.e. peanut butter)
- Chocolate (from cocoa beans).

This section includes a brief description of these high lipid foods. Readers are invited to consult Appendix 1 for more detail.

2.3.1.1   *Sesame seed-based foods*

Tahini, or sesame paste, is a paste produced from ground sesame seeds (*Sesamum indicum*). Tahini is the name used for this product from the Middle East, while the product from Asia is just called sesame paste. The information available in the literature indicates that Middle Eastern tahini is made from hulled and roasted seeds. The sesame seeds are roasted to

produce a product with desirable flavour, colour and texture (Kahyaoglu and Kaya, 2006). Bozkir tahin is produced in Turkey from roasted unhulled seeds (Akbulut and Çoklar, 2008), and there is anecdotal information to suggest that unhulled seeds are also used in the production of Asian sesame pastes.[2]

Most of the information found for this report concerned production of tahini, while little information on the production of sesame paste in Asia was found. Occasional references were found to sesame seed oil extracted from unroasted seeds (e.g. Yamashita et al., 1992). However, we have assumed that sesame paste from Asia is also made from roasted seeds.

The seeds are cleaned and dehulled (using a water or mechanical process), then roasted and milled into a paste. Roasting of sesame seeds during tahini production has been reported to be performed at 120°C for one hour, and the temperature after milling reaches about 130°C (Brockmann et al., 2004; Elleuch et al., 2007). However, other times and temperatures have also been reported e.g. 120°C, 150°C or 180°C for up to 2 hours (Kahyaoglu and Kaya, 2006).

The fat content of sesame seeds and tahini is the same (58-59%) (Holland et al., 1991). In a survey of tahini from 14 producers, the average water activity (a_w) was 0.16 and the average pH was 5.9 (Yamani and Isa, 2006).

Halva is a confectionary that can be made from a number of different ingredients. This Risk Profile only considers sesame seed-based halva, which is made by mixing tahini and acidified, heated (120-140°C) glucose syrup. After adding flavour or other ingredients (e.g. pistachio) the hot mass is poured into jars or moulded and packaged (Brockmann et al., 2004; Kahraman et al., 2010). Halva has less than 3% moisture with a pH of 6 (Kahraman et al., 2010; Kotzekidou, 1998).

Tahini is also a common ingredient in hummus, a dip or spread made from cooked, mashed chickpeas, tahini, oil, lemon juice, salt and garlic, and is the base of tarator sauce (tahini, lemon juice and garlic) (Davidson, 2006). Tahini might also be added to other savoury dips such as baba ghanoush (made primarily from cooked, pureed aubergine). Hummus has a high water activity (>0.9) and neutral pH (5-7) (Al Holy et al., 2006).

2.3.1.2 Peanut butter

Peanut butter is principally made from roasted (180-240°C) ground nuts (*Arachis hypogaea*) and salt. Other ingredients, such as sugar or emulsifiers, may be added. The water activity of commercial peanut butters in a study from the United States ranged from 0.20 to 0.33, the fat content was approximately 55%, the water content was 0.5-2%, and the pH was 6.1-6.4 (Burnett et al., 2000).

2.3.1.3 Chocolate

Chocolate is the generic name for a homogenous product obtained from cocoa materials which may be combined with milk products, sugars and/or sweeteners, and other additives.

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[2] Source: http://en.wikipedia.org/wiki/Tahini. Accessed 23 July 2010.

Cocoa beans are fermented after harvesting to remove a pulp that covers the beans and allow the chocolate flavour to begin to develop. After fermentation and drying, cocoa beans are roasted (105-150 °C, up to 2 hours), and then cracked and de-shelled into bean pieces called nibs by a winnower machine. Alternatively, the beans are first deshelled and only the nibs are roasted. The nibs are ground using various methods into a thick creamy paste known as chocolate liquor or cocoa paste/mass. Cocoa butter (a colourless fat) is produced by pressing the cocoa mass (Betts, 2008).

Unpressed cocoa mass is processed into chocolate by mixing in fats (either additional cocoa butter or other vegetable fat) and sugar. To make dark chocolate, just a vanilla flavouring is added. The final product is at least 70% cocoa (solids and butter). Milk chocolate has a milk or milk powder element (usually 50% cocoa) and white chocolate consists of sugar, cocoa butter (33%), milk or milk powder and vanilla.

The fat content of milk chocolate, plain chocolate, and white chocolate are similar, at approximately 30% (Holland *et al.*, 1991). Finished chocolate product usually has a water activity of 0.4-0.5 (Betts, 2008).

Dutch process chocolate has been treated with an alkalising agent to modify the colour and produce a milder flavour.

2.3.2 The Food Supply in New Zealand: Peanuts, sesame seeds, cocoa beans

Peanuts, sesame seeds and cocoa beans are not grown in New Zealand. Consequently, the source material for all foods covered by this Risk Profile is imported. Raw materials, partially processed materials, and finished products are all imported.

Overseas trade import data collected by Statistics New Zealand was reviewed to identify import volumes of high lipid foods (see Appendix 1).

Identification of sources of imported sesame seed and tahini is complicated by a lack of detail under the tariff codes. NZFSA's imported food requirements for "tahini or crushed sesame seeds or any products containing these" currently identifies 1207.40.00.00A (*Sesamum* seeds), 2008.19.09.29H (Nuts (Other than ground-nuts) and Seeds, Roasted), and 2008.19.09.39E (Nuts (Other than ground-nuts) and Seeds Not Roasted) as the target tariff codes (NZFSA, 2009g).[3]

For the first of these codes, 739 tonnes were imported in 2009, mostly from India (629 tonnes), with smaller amounts from Mexico (64 tonnes), China (19 tonnes) and Israel (11 tonnes). Despite the considerable literature on tahini, a Middle Eastern product, the majority of sesame seed-based product imported into New Zealand is apparently imported from Asia, presumably in the form of sesame paste.

During 2009 approximately 880 tonnes of oil seed meals (which may include tahini) were imported into New Zealand. The principal sources of the oil seed meal were Australia (707 tonnes) and India (171 tonnes). Australia may only be a transit point for other sources.

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[3] Prior to August 2009 there were three additional target tariff codes. See Section 5.1.1 for further information.

For the same year approximately 3,100 tonnes of peanut butter was imported, principally from China (2,037 tonnes) and Australia (1,069 tonnes), while almost 1,700 tonnes of raw peanuts (914 tonnes from Australia, 562 tonnes from China and 180 tonnes from South Africa), 2,500 tonnes of roasted peanuts (1,793 tonnes from Australia, 487 tonnes from China and 148 tonnes from the USA) and 980 tonnes of peanut products (803 tonnes from China, 141 tonnes from Australia and 38 tones from the USA) were imported.

There are a number of small scale producers of peanut butter from raw materials in New Zealand, but the majority of the supply is imported from Australia and China. The major suppliers are ETA and Sanitarium, as well as generic supermarket brands.

A producer in Nelson imports Queensland peanuts, roasts them, adds salt and makes around 400 kg of peanut butter a week (approximately 20 tonnes per year). No other ingredients are added. The product is sold at farmers markets, through 20 South Island supermarkets and a handful of specialty stores in the North Island (Kidson, 2009).

In 2009, cocoa beans and partially processed products (e.g. cocoa paste) were imported from Ghana, Indonesia, Malaysia, Australia, Thailand, the Netherlands and Singapore (the latter is the location of a processing plant, according to the website of Cadbury New Zealand). Most imports were of cocoa beans raw/roasted, broken/whole (approximately 1,100 tonnes), cocoa paste (1,200 tonnes), cocoa butter (3,250 tonnes), and cocoa powder (unsweetened) (2,350 tonnes). Over 5,000 tonnes of bulk chocolate were imported in the same year, principally from Australia (3,477 tonnes) and Singapore (1,420 tonnes).

Imported finished chocolate products (blocks, slabs or bars, filled or unfilled, wrapped or unwrapped, weighing <2 kg) are principally imported from Australia from where approximately 9,000 tonnes were imported in 2009. Excluding filled bars, which may contain non-cocoa ingredients, approximately 5,600 tonnes of finished bars were imported in 2009. Approximately 2.5 times more bulk cocoa products (14,000 tonnes) were imported in the same period, which suggests that most of the manufacture and finishing of chocolate products is carried out in New Zealand.

Major manufacturers of chocolate in New Zealand include Cadbury in Dunedin, Richfields in Christchurch and Whittakers in Porirua. Whittakers is the only manufacturer in New Zealand that uses imported cocoa beans directly, and the beans are roasted on-site. The other manufacturers use imported cocoa "mass" and its derivatives (cocoa butter and cocoa powder).

Further details are given in Appendix 1.

2.3.3 Behaviour of *Salmonella* spp. in foods from sesame seeds, peanuts, and cocoa beans

Heat resistance of salmonellae in these foods is partly dependent on food composition. The presence of both high lipid content and low water activity has been shown to exert a protective effect on *Salmonella* cells. This enhances survival but does not permit growth.

2.3.3.1   Sesame seeds, tahini and halva

Contamination of sesame seeds with *Salmonella* spp. can occur during growth (e.g. contaminated irrigation water, contact with animal faeces), storage or processing.

If performed correctly, the roasting times and temperatures for sesame seeds should be sufficient to inactivate *Salmonella* spp. There are no data to indicate whether the high temperature preparation of halva will inactivate *Salmonella* spp.; the low water activity and high lipid environment of the tahini and glucose may be protective.

Contamination of tahini and halva can occur after heat treatment due to poor hygiene during grinding (tahini), slicing, packaging and transport. This applies particularly to product sold in bulk or non-hermetic packaging (Brockmann *et al.*, 2004; Kotzekidou, 1998).

No studies that assessed the ability of *Salmonella* spp. to survive in tahini were located. The stability of *S*. Enteritidis inoculated into halva under a range of test conditions has been reported (Kotzekidou, 1998). The water activity of halva is very low (a_w = 0.176) so salmonellae do not grow. An initial inoculum of two *S*. Enteritidis strains (7 $\log_{10}$ colony forming units (CFU)/g) was evenly distributed through halva, which was then packed in air (commercial method) or vacuum-packaging. Storage was under refrigeration (6°C) or at room temperature (18-20°C) for up to eight months. Analysis showed that the initial viable inoculum reduced immediately by about 3 $\log_{10}$ CFU/g, which was attributed to osmotic shock. However, during subsequent storage further decline was modest and counts under all storage conditions remained above 2 $\log_{10}$ CFU/g after 8 months.

2.3.3.2   Peanuts and peanut butter

The protective barrier of the shell normally prevents bacterial contamination of nuts during growth (ICMSF, 1998). If contamination does occur, *Salmonella* spp. can persist in nuts for long periods at low temperatures.

Two different thermal processes can occur during peanut butter manufacture: roasting, and possibly pasteurisation later in the process (e.g. after packaging in jars). For roasting, raw fresh peanuts are treated in hot air roasters at temperatures typically between 180°C and 240°C. A New Zealand manufacturer of peanut butter roasts imported Australian raw nuts at 230°C for 70 minutes (Pic Picot, pers. comm., May, 2010). These temperatures should be sufficient to kill *Salmonella* spp. in a short period (CDC, 2009a). Roasting of peanuts at 129°C for 45 minutes, 146°C for 15 minutes, and 163°C for 10 minutes has been reported to cause reductions of 4.3, 4.9 and 5.3 $\log_{10}$ CFU respectively (Doyle, 2009).

Pasteurisation of peanut butter (70-75°C), and temperatures used to process peanut butter or paste used as an ingredient in other products, are likely to be inadequate to eliminate *Salmonella* spp. introduced after the initial peanut roasting (CDC, 2009a).

Salmonella spp. populations are relatively stable in peanut butter, and although survival is greater at refrigeration rather than ambient temperatures the difference is not marked. After an initial decline (perhaps 2 $\log_{10}$ CFU/g) in numbers inoculated into peanut butter, further reductions in concentration are slow and the bacteria survive for weeks (Burnett *et al.*, 2000; Park *et al.*, 2008).

Salmonella spp. in peanut butter have also been shown to be tolerant of heat, surviving even after treatment at 90°C for 50 minutes. The heat resistance of *S*. Agona, *S*. Entertidis, and *S*. Typhimurium has been shown to dramatically increase when the bacteria are in peanut butter (Shachar and Yaron, 2006). During heating at up to 90°C, an initial decline of up to 2.6 $\log_{10}$ CFU/g was observed in the initial 5 minutes, from 5 to 20 minutes further reductions were modest, and after 20 minutes bacterial numbers stabilised.

The rate of inactivation of three *S*. Tennessee strains associated with a peanut butter outbreak have been compared to that of strains from sporadic cases and other serotypes (Ma *et al.*, 2009). It was found that the outbreak strains were more heat tolerant than strains from sporadic cases, and other serotypes investigated. The calculated minimum time to achieve a 7 $\log_{10}$ CFU/g reduction in numbers of the outbreak strains at 90°C was 120 minutes in peanut butter.

Further details of these experiments are given in Appendix 1.

2.3.3.3 Chocolate

The harvesting, fermentation and drying practices allow cocoa beans to be contaminated by a variety of microflora, and it would not be unexpected for *Salmonella* spp. to be introduced to the beans (da Silva do Nascimento *et al.*, 2010). Cocoa beans from three Brazilian producers were tested for *Salmonella* before and during fermentation, during drying, and during storage after drying (da Silva do Nascimento *et al.*, 2010). Only one of 119 samples was positive for *Salmonella* spp., which was a sample from the stored beans. In another study, salmonellae inoculated onto cocoa beans were still viable after 21 days at either 4°C or 21°C (Komitopoulou and Penaloza, 2009).

Roasting is performed for between 15 minutes and 2 hours at 105-150°C and is the principal step for control of *Salmonella* spp. (Barrile *et al.*, 1971).

The temperatures reached during subsequent milling, refining and conching (frictional heating only, followed by storage at approximately 45–50°C until final processing) are not considered effective for the control of salmonellae (ICMSF, 2005). Analysis of *S*. Typhimurium and *S*. Enteritidis in milk and bitter chocolate conched for 30-40 hours at 72°C showed that $D_{72°C}$ was 40 hours and 50 hours for each serotype, respectively (only high quality chocolate is conched for this length of time) (D'Aoust, 1977). In another study, the survival of a strain of *Salmonella* inoculated into cocoa butter, cocoa liquor and dark chocolate was monitored during conching at temperatures between 50 and 90°C for 23 hours (Krapf and Gantenbein, 2010). The *Salmonella* was unable to survive well in cocoa butter ($D_{60°C}$ was 5.1 hours, and the inoculum was undetectable within 30 minutes at 70°C or above), but this may have been a result of osmotic shock when the cells were inoculated. D values in cocoa liquor ranged from a $D_{50°C}$ of 16.7 hours to a $D_{90°C}$ of 0.4 hours. The salmonellae survived longest in dark chocolate; $D_{50°C}$ was 26.2 hours and $D_{90°C}$ was 0.4 hours.

Additional control is achieved in Dutch processed chocolate, which involves heating nibs, liquor or cocoa mass with sodium hydroxide or potassium carbonate at 85-115°C. This process would be expected to destroy any *Salmonella* spp. present (ICMSF, 2005).

It has been shown that chocolate increases the heat resistance of salmonellae. D values have been collated for *Salmonella* spp. in chocolate (van Asselt and Zweitering, 2006). An overall value for $D_{70°C}$ of 446.7 minutes and a z value of 20.4°C were calculated. Extrapolation of the data reported, suggests that at 100°C, the D values would be approximately ten minutes (a $D_{90°C}$ of 25 minutes was reported by Krapf and Gantenbein-Demarchi, 2010). For comparison, in broths and sugar solutions $D_{70°C}$ values for *Salmonella* spp. are less than one minute. The increased ability to resist heat in low water activity environments, such as chocolate, is a well-established characteristic of salmonellae. The fat, sugar and low water activity of chocolate probably increase the pathogen's heat resistance in chocolate (Krapf and Gantenbein-Demarchi, 2010). Additional D values are given in Appendix 1.

Ingredients added to chocolate may introduce salmonellae after processing. These include coconut, nuts, milk powder, egg products, lecithin, spices and gelatine. The confectionery ingredients of sugar, salt and vanilla are not generally considered to be sources of contamination (D'Aoust, 1977), although carmine red (a food additive) was identified as a vehicle for *S*. Cubana in candy coatings (Lennington, 1967). There are processes in place to inactivate salmonellae in coconut (Schaffner *et al.*, 1967). Soy lecithin (used as an emulsifier) contaminated with *Salmonella* spp. was the cause of a precautionary voluntary recall of chocolate products and a plant closure in Canada (there were no reported illnesses associated with the consumption of the products) (PHAC, 2006; Reynolds, 2006). Milk powders have been suspected or confirmed as a vehicle for *Salmonella* spp. transmission in several outbreaks, and the pathogen can survive in milk powder for prolonged periods of storage (D'Aoust, 1977). Added egg products represent a potential source of contamination, particularly in countries where *S*. Enteritidis PT4 is endemic.

There is considerable evidence to show that *Salmonella* spp. survive for long periods (months) in chocolate. Recovery of *Salmonella* spp. inoculated into chocolate after conching (Tamminga *et al.*, 1976), cocoa powder (Juven *et al.*, 1984), crushed cocoa, and cocoa butter oil (Komitopoulou and Penaloza, 2009) after several weeks or months has been reported. *S*. Napoli was still detectable after 12 months in chocolate bars implicated in a UK outbreak (Werber *et al.*, 2005). Further details are given in Appendix 1.

2.3.3.4 Summary

There is evidence that supports the heat resistance of *Salmonella* spp. in peanut butter and chocolate. The heat resistance of *Salmonella* spp. in tahini or halva may be similar. However, for the production of each of these high lipid foods, the raw ingredients (sesame seeds, peanuts or cocoa beans) are roasted at temperatures that would be expected to inactivate salmonellae, although no studies were located that specifically assessed this for sesame seeds or cocoa beans. In addition, these raw materials are apparently roasted at lower temperatures than peanuts. Contamination may also occur as a result of cross-contamination or the addition of other ingredients after this roasting step. Experiments with peanut butter show that further heat treatment at practicable temperatures and times will not eliminate *Salmonella* spp., and the bacteria can survive in the high fat/low water activity environment for very long periods (months).

2.4   Exposure Assessment

2.4.1   _Salmonella_ in high lipid foods made from sesame seeds, peanuts or cocoa beans

2.4.1.1   Surveys

No surveys of the prevalence of _Salmonella_ spp. in chocolate or peanut butter in New Zealand could be located.

A survey of imported tahini and tahini-containing foods (halva and hummus) for the presence of _Salmonella_ spp. was conducted from October to December 2001 (Wong _et al._, 2003). There were 256 food samples tested, representing 25 different brands. The products consisted of 169 tahini, 77 halva and 10 hummus. The hummus was in powdered form and therefore shelf stable. The samples were purchased from supermarkets and ethnic food outlets and stored as prescribed by the packaging details until tested. _Salmonella_ spp. were not detected in 25g samples from any product (prevalence 0.0%, 95th percentile confidence interval 0.0-1.4%).

2.4.1.2   Import testing

Imported food testing for tahini products was stopped shortly after the 2001 survey, and was reintroduced (as an Emergency Food Standard) in September 2003 after outbreaks and recalls of tahini products in New Zealand and Australia because of _Salmonella_ contamination.

Under standards set by the NZFSA, imports of crushed sesame products (including tahini) and peanut butter are subjected to inspection and testing. The imports requiring inspection and testing are identified by their import tariff codes (see Section 5.1.1.1 for further detail). These imported foods are selected for testing subject to a 'switching rule', whereby the number of tested consignments of a specific food belonging to an importer reduces with continued compliance with import standards (NZFSA, 2009b). This rule means that the proportion of consignments tested is usually small in relation to the total consignments arriving at the New Zealand border.

The NZFSA standard requires imports of crushed sesame products to be tested for _Salmonella_ spp. unless the importer has a multiple release permit in place, or the product has been imported from Australia since September 2009 (NZFSA, 2009g).

Data on the importation, inspection and testing of sesame products and peanut butter were provided by the NZFSA for the period January 2004 to June 2010. There were 1,581 consignments captured by the target tariff codes for crushed sesame products between January 2004 and June 2010. A portion of these will be other products that were inadvertently captured by the target tariff codes (e.g. chestnuts), as these codes are not specific to crushed sesame products. Although the weight of these consignments was not given, most were from (in descending order) India, China, Japan, Australia, and Thailand.

The data show that 156/1,581 consignments were tested, mostly from China (29 consignments), Australia (28), Taiwan (13), and Mexico (10). Of the 156 consignments tested, additional information in the records indicate that 12 consignments were not crushed sesame products and were tested for other reasons (e.g. a peanut product inadvertently

captured by the tariff codes and tested for aflatoxin). Of the remaining 144 consignments tested, 10 failed. Assuming that all 144 consignments tested were crushed sesame products, failure prevalence was 6.9% (95th percentile confidence interval 3.4-12.4%) of tested products. The failed products were as follows:

- 2004: Two consignments from Seychelles (product not specified).
- 2005: Two consignments from Syria (one specified as tahini).
- 2006: Two consignments from Egypt (one tahini, one halva).
- 2008: One consignment from Turkey (tahini).
- 2008: One consignment from Egypt (halva).
- 2009: One consignment from Egypt (tahini, halva) and one from Syria (tahini).

There were 1,124 consignments captured by the specific target tariff code for peanut butter (2008.11.00.01D) between January 2004 and June 2010. The NZFSA standard requires imports of peanut butter to be tested for *Salmonella* spp. and aflatoxin (subject to the switching rule) unless the importer has an appropriate certification in place, or that from September 2009 the product has been imported from Australia (NZFSA, 2009a). Of the 1,124 consignments of peanut butter, 148 (13%) were sampled for testing. Five of the 148 tested consignments failed. Three of these consignments failed due to non-compliant aflatoxin levels. The remaining two failed consignments were contaminated with *Salmonella* spp. (failure prevalence 2/148, 1.4%, 95th percentile confidence interval 0.2-4.8%). The consignments contaminated with *Salmonella* spp. were from China and the Philippines and were both received at the New Zealand border in 2008.

2.4.1.3 Recalls

Between 2001 and September 2010 there were four New Zealand recalls relevant to this study:

- 2003: Two recalls of tahini and one of halva, for possible contamination with *Salmonella* (Unicomb *et al.*, 2005)
- January 2009: Peanut toffee bars, for possible contamination with *Salmonella* (The manufacturer used ingredients produced by Peanut Corporation of America, which issued a recall due to *Salmonella* contamination of peanut butter and peanut paste ingredients (see Appendix 1)

2.4.2 Food Consumption: High lipid foods

2.4.2.1 Sesame seeds and sesame seed products

Food Balance Sheet (FBS) information, maintained by the Food and Agriculture Organization of the United Nations (FAO) (FAO, 2010), indicates annual consumption of sesame seeds by New Zealanders to be 0.1 kg/person/year (0.3 g/person/day). This is based on 2007 data, the most recent year for which statistics are available. FBSs also indicate sesame seeds are not produced domestically in New Zealand i.e. all sesame seeds are imported.

An analysis of data from the 1997 National Nutrition Survey (NNS) (Russell *et al.*, 1999) generated equivalent estimates of consumption, with 35% of the population consuming sesame seed in some form on any day and an average per capita daily consumption level of 0.5 g/person/day for the total population (1.3 g/person/day for sesame seed consumers only) (ANZFA, 2001). This consumption may not be of high lipid products included in this Risk Profile; sesame seeds on bread rolls etc. are included in these figures.

An analysis of individual responses in the NNS (adults 15+ years) identified 10 respondents out of 4,636 (0.2%) who reported consuming hummus or tahini in the previous 24 hour period. The 2002 National Children's Nutrition Survey (CNS) (5-15 years) identified four respondents out of 3,275 (0.1%) who reported consumption of hummus in the previous 24 hour period (Ministry of Health, 2003). It should be noted that these surveys are both now quite old and subsequent changes in the dietary habits of New Zealanders are likely to have impacted on the frequency of consumption of these products.

Statistics New Zealand import data for sesame seed (broken or whole) suggests a steady demand in New Zealand, with an average of 800 tonnes imported per year from 2000 to 2009.

2.4.2.2 *Peanuts and peanut products*

FBS information (2007 data) indicates that New Zealanders consume 2.1 kg/person/year of peanuts (groundnuts) (5.8 g/person/day). FBSs also indicate peanuts are not produced in New Zealand i.e. all peanuts are imported.

An analysis of data from the NNS (Russell *et al.*, 1999) gave lower estimates of consumption, with 23% of the population consuming peanuts in some form on any day and an average per capita daily consumption level of 2.7 g/person/day (12.0 g/person/day for consumers only) (ANZFA, 2001).

Food frequency information collected as part of the NNS (Russell *et al.*, 1999) and the CNS (Ministry of Health, 2003) gave some additional information on peanut consumption. Of adult New Zealanders, 19% reported consuming nuts (not further specified) at least once per week, while 21.5% reported never consuming nuts. Peanut butter or other nut butters were more frequently consumed than peanuts by adult New Zealanders, with 34% of respondents reporting consumption of these products at least once per week and 31% reporting never consuming nut butters. For children, 52% reported consuming peanut butter at least once per week, while 25.7% reported eating peanut butter never or less than once per month.

Analysis of individual dietary recall records indicated that 12.6% of children and 7.2% of adults consume peanut butter on any given day. Average per capita daily consumption is 1.8 g/day for children and 1.0 g/day for adults.

Statistics New Zealand import data for peanut butter suggests an increasing demand in New Zealand, with approximately 1,450 tonnes imported in 2001, 2,840 tonnes in 2005 and 3,110 tonnes in 2009. Imports of roasted or unroasted peanuts (excluding those imported as part of mixed nuts) has markedly increased (570 tonnes in 2001, 2,040 tonnes in 2005 and 3,460 tonnes in 2009), however most peanut butter consumed in New Zealand is manufactured

overseas, so the rise in imports is more likely to be from other factors, such as an increased demand for nut-based snack foods.

2.4.2.3 Chocolate

FBS information (2007 data) does not include consumption of chocolate in New Zealand but indicates an annual consumption of cocoa beans of 0.2 kg/person/year (0.5 g/person/day). FBS information indicates no domestic production of cocoa beans in New Zealand i.e. all cocoa beans are imported.

An analysis of data from the NNS (Russell *et al.*, 1999) indicates that 41% of the population consume cocoa products in some form on any day and an average per capita daily consumption level of 0.9 g/person/day (2.2 g/person/day for consumers only) (ANZFA, 2001).

Food frequency information collected as part of the NNS (Russell *et al.*, 1999) and the CNS (Ministry of Health, 2003) gave additional information on chocolate consumption. Chocolate consumption of any frequency was reported by 83% of children and 87% of adults. Chocolate consumption frequency of at least once per week was reported by 46% of children and 32% of adults.

Analysis of individual dietary recall records indicated that approximately 25% of children would consume chocolate, chocolate bars or chocolate coated biscuits on any given day, with approximately 16% of adults consuming these foods. Based only on records that reported consumption of chocolate, average consumptions of 3.6 and 3.4 g/day were calculated for children and adults respectively.

New Zealanders are low consumers of confectionery compared to other industrialised nations (CMA, 2007). Chocolate consumption in New Zealand was reported to be relatively static between 1998 and 2003 at approximately 1.6 kg per person per year (4.4 g/person/day), and was projected to rise by only 0.3% over the period 2003 – 2008 (CMA, 2007).

Statistics New Zealand import data suggest a larger increase in the consumption of cocoa products. These data show an overall increase in imports of cocoa products (beans, paste, butter and powder), bulk chocolate and unfilled chocolate (i.e. blocks, slabs or bars) for the years 2000 to 2009. Imports of filled chocolate have remained comparably steady over the same time period (Figure 2). Approximately 12,000 tonnes of cocoa products and chocolate was imported in 2000, compared with over 21,000 tonnes in 2009.
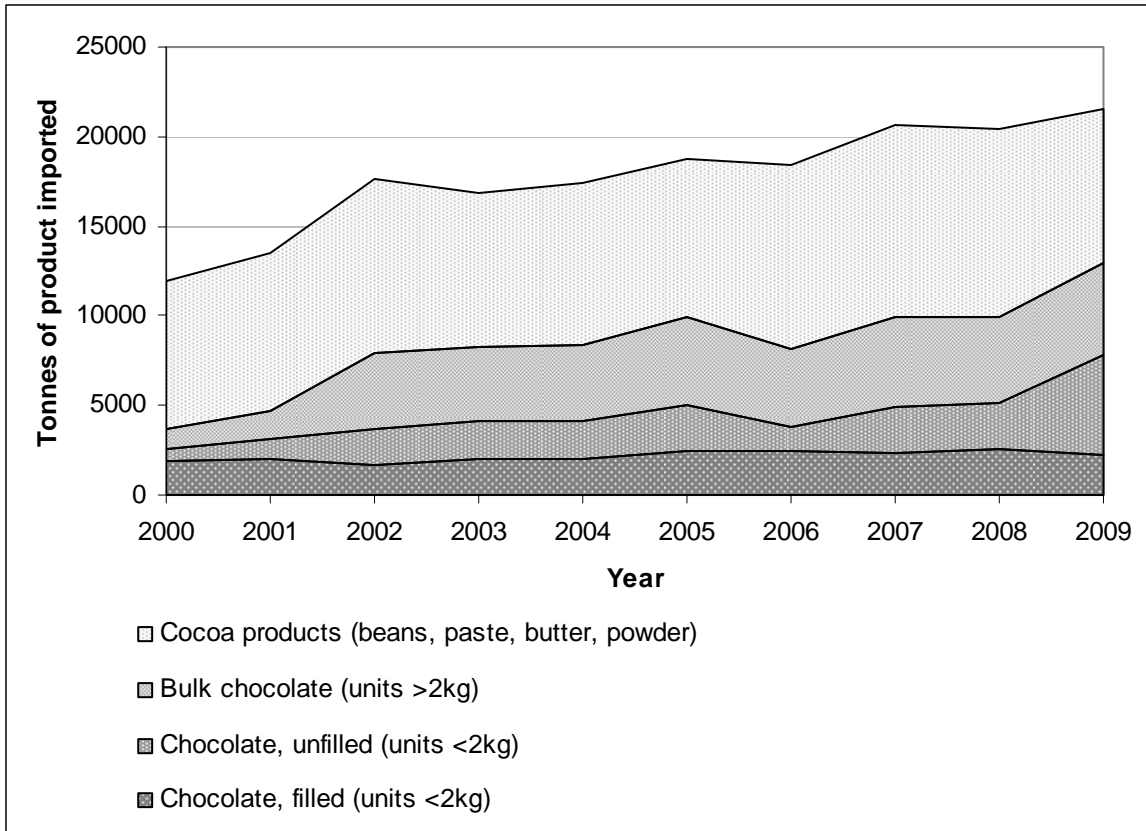
Figure 2: **Tonnes of cocoa product and chocolate imported into New Zealand, 2000-2009 (Statistics New Zealand)**

2.4.3 Evaluation of Exposure

2.4.3.1 Number of servings and serving sizes

Sesame seeds and sesame seed products

A FSANZ assessment (ANZFA, 2001) of the 24-hour diet recall records from the 1997 NNS (Russell *et al.*, 1999) estimated that 35.2% of the study population consumed sesame seed in any 24-hour period. This will presumably be due to the presence of sesame seeds in and on bread and their presence as an ingredient in recipes. Based on a New Zealand population of 4.3 million and assuming only one serving of sesame seed per consumer per day, this would equate to 5.5×10^8 servings per annum. This assumes that sesame seeds are as likely to be consumed by New Zealand children as by adult New Zealanders. However, the associated servings will be quite small. The FSANZ assessment reported mean and median daily consumption of sesame seed by consumers only of 1.3 and 0.8 g/day respectively, with a 97.5th percentile consumption of 5.9 g/day (ANZFA, 2001).

The unit records from the 1997 NNS contain reference to 10 servings of hummus and 2 servings of tahini (Russell *et al.*, 1999). Based on a survey population of 4,636 and a New Zealand population 15 years or over of approximately 3.4 million, this equates to 2.7×10^6 servings per annum of hummus and 5.4×10^5 servings per annum of tahini consumed by

adult New Zealanders. The 2002 National CNS records report another 4 servings of hummus (Ministry of Health, 2003). The CNS surveyed 3,275 children aged 5-15 years. Assuming that the findings can be generalised to all children over the age of one year, this would equate to a further 4.0×10^5 servings per annum. This gives a total of 3.1×10^6 servings of hummus consumed in New Zealand per annum. These estimates of numbers of servings are based on a small number of dietary records and will have high associated uncertainty. For consumers of hummus, the average serving size per day was 37.7 g (maximum 85.8 g) for adults and 15.5 g (maximum 32 g) for children.

Peanut butter

The unit records from the 1997 NNS contain reference to 362 servings of peanut butter (Russell *et al.*, 1999). Based on a survey population of 4,636 and a New Zealand population 15 years or over of approximately 3.4 million, this equates to 9.7×10^7 servings per annum of peanut butter consumed by adult New Zealanders. The 2002 National CNS records report another 514 servings of peanut butter (Ministry of Health, 2003). The CNS surveyed 3,275 children aged 5-15 years. Assuming that the findings can be generalised to all children over the age of one year, this would equate to a further 5.1×10^7 servings per annum. This gives a total of 1.5×10^8 servings of peanut butter consumed in New Zealand per annum.

Serving sizes were very similar for adults and children, with means and medians in the range 10-12.6 g and 95th percentiles of approximately 30 g for both adults and children (Ministry of Health, 2003; Russell *et al.*, 1999).

Chocolate

The unit records from the 1997 NNS contain reference to 431 servings of chocolate amongst the 4,636 respondents (Russell *et al.*, 1999). This does not include chocolate as an ingredient of other foods, such as biscuits, cakes and snack bars. Based on a survey population of 4,636 and a New Zealand population 15 years or over of approximately 3.4 million, this equates to 1.2×10^8 servings per annum of chocolate consumed by adult New Zealanders. The 2002 CNS records report another 366 servings of chocolate (Ministry of Health, 2003). The CNS surveyed 3,275 children aged 5-15 years. Assuming that the findings can be generalised to all children over the age of one year, this would equate to a further 3.6×10^7 servings per annum. This gives a total of 1.6×10^8 servings of chocolate consumed in New Zealand per annum (approximately 38 servings per person per year based on a population of 4.2 million).

Mean serving sizes for adults and children were 36 and 32 g respectively, with median serving sizes of 25 and 23 g respectively and 95th percentiles of 93 and 89 g respectively for adults and children (Ministry of Health, 2003; Russell *et al.*, 1999).

2.4.3.2   Frequency of contamination

Only one survey for the prevalence of *Salmonella* spp. in tahini products was located for New Zealand. *Salmonella* spp. were not isolated from 256 retail samples of tahini, halva and hummus (Wong *et al.*, 2003). No chocolate or peanut butter surveys were found.

Salmonella has been detected in import consignments of peanut butter, tahini and halva. Import testing policy means that where there is a history of compliance with import

standards, the proportion of consignments tested is usually small in relation to the total consignments arriving at the New Zealand border. The prevalence of *Salmonella* spp. contamination in imported peanut butter and crushed sesame products cannot be used as an indicator of the frequency of contamination, but does indicate that these products can still become contaminated under current manufacturing practices.

2.4.3.3   Growth rate during storage and most likely storage time

Salmonella spp. can survive but do not grow during storage.

2.4.3.4   Heat treatment

Tahini products, chocolate and peanut butter are usually consumed without heat treatment by the consumer.

2.4.3.5   Exposure summary

The information presented above indicates that most high lipid foods covered by this Risk Profile are eaten in small quantities by approximately 20-30% of New Zealanders on a daily basis. Less than one per cent of New Zealanders consume hummus or tahini on a daily basis, but the consumption of these foods may have increased since the national nutrition surveys were conducted (1997 for adults and 2002 for children). The only local survey investigating frequency of contamination in this product group was undertaken on sesame seed products, however *Salmonella* spp. were not isolated from samples cultured as part of this study.

2.5   Overseas Context

Overseas prevalence data for *Salmonella* spp. in high lipid foods from individual countries is collated in Tables 6 and 7 in Appendix 1. These tables show prevalence of *Salmonella* spp. contamination in sesame seed-based foods and nuts (pistachio kernels) of up to 15.6% and 4% respectively. No overseas surveys of peanut butter, or chocolate or its ingredients were located.

In Australia, the National Enteric Pathogen Surveillance Scheme reported isolations of 17 *Salmonella* spp. from 30 sesame seed/products on 30 occasions between 1985 and 2000 (O'Grady *et al.*, 2001).

3 EVALUATION OF ADVERSE HEALTH EFFECTS

3.1 Disease characteristics

Incubation: 6-48 hours (usually 12-36 hours).

Symptoms: Diarrhoea, abdominal pain, vomiting, nausea and fever lasting 1-7 days. Hospitalisation rate estimated at 22.1%, case fatality rate 0.8%.

Condition: Salmonellosis.

Toxins: Toxins are not produced in foods.

People Affected: The young, old, and immunocompromised are particularly at risk. In addition people of less privileged socioeconomic groups and those living in higher population densities are more at risk.

Long Term Effects: Septicaemia and subsequent non-intestinal infections can occur. Reactive arthritis may occur 3-4 weeks after gastrointestinal symptoms. Approximately 2% of a population exposed to a triggering infection will develop reactive arthritis. The disease usually resolves within six months, but may persist for more than a year in some cases (Hannu *et al.*, 2006).

Treatment: The infection is usually a self-limiting, uncomplicated gastroenteritis although fluid replacement may be required, especially in the elderly or young children. Less than 2% of clinical cases require antibiotic treatment. The site of infection and the immunity status of the case determine treatment choices. Cases of salmonellosis due to *S.* Typhimurium DT104 are of increasing concern in the UK due to the organism's resistance to ampicillin, chloramphenicol, streptomycin, sulphonamides, tetracycline, trimethoprim and cirpofloxacin. The result is that the disease due to these strains is becoming more difficult to treat (USDA, 2005).

Supplemental information on adverse health effects is given in Appendix 2.

3.2 Dose-response

The dose required to cause disease varies and is multi-factorial. Low attack rates were observed in one outbreak where 4-45 cells were consumed, and another where the dose was 6 cells in 65g of food (Anonymous, 1996). Different serotypes may have different dose responses, but *Salmonella* spp. infection is generally understood to cause disease with high attack rates at doses of 10^5 to 10^7 cells.

The most commonly used dose-response model was produced by the joint risk assessments of *Salmonella* spp. in eggs and broiler chickens by FAO/WHO (FAO/WHO, 2002). Results from a number of human feeding trials of *Salmonella* serotypes have been analysed to develop dose-response models (most recently by Oscar (Oscar, 2004) using a three phase linear model). These feeding trials have a number of deficiencies, particularly at low doses, as described in the FAO/WHO report. Consequently the FAO/WHO model augmented the data with information from outbreak reports. These reports were screened and a final 20

outbreaks were used in the database (12 Enteritidis, 3 Typhimurium, Heidelberg, Cubana, Infantis, Newport and Oranienburg). Several vehicles of transmission were implicated including meat, eggs, dairy products and water. A beta-Poisson model was used to develop the mathematical relationship, and a maximum likelihood technique used to generate the curve best fitting the data. The graph shows that for the ingestion of 10^{10} cells there was a probability of around 0.9 of illness, while the ingestion of 10^1 cells resulted in a probability of around 0.02. Thus the probability of illness from exposure to small doses is low. For outbreaks where food has only a low concentration of contamination, but has been widely consumed, a small proportion of consumers will become ill.

It has been repeatedly reported that the probability of disease following ingestion of small numbers of cells is higher when the implicated food has a high fat or protein content. For example, chocolate or peanut butter may protect cells from gastric juices so permitting a lower dose than usual to cause infection. Experimentation has also shown this to be the case for high fat foods (minced beef) and high protein foods (egg white). It was concluded that the pH of the microenvironment of the organism in the food matrix is crucial in determining its resistance to stomach acids (Waterman and Small, 1998).

Investigation of a number of outbreaks involving chocolate and peanut butter has shown that low numbers of cells in the food can cause outbreaks:

- An investigation into an outbreak of *S*. Mbandaka from peanut butter in Australia found that opened jars of peanut butter from case households and unopened jars from retail outlets were contaminated at levels as low as 3 CFU/g (Burnett *et al.*, 2000; Scheil *et al.*, 1998).
- Chocolate bars implicated in a UK salmonellosis outbreak in 1982 were contaminated with *S*. Napoli at an average of 1.6 MPN/g (Greenwood and Hooper, 1983). The mean weight of the bar was 16.6 g suggesting an average of 26 cells per bar. Additional testing of chocolate bars from the same outbreak estimated a range of 2-23 cells/g (Gill *et al.*, 1983). The chocolate bars were consumed at least 7 months after production and *S*. Napoli could still be isolated from the bars after 12 months.
- Investigation of a 1985-86 outbreak involving Belgian chocolate coins consumed in North America found that *S*. Nima was present at 0.043-0.24 MPN/g (Hockin *et al.*, 1989). Approximately 25g of chocolate was consumed by cases, predominantly very young children.
- Investigation of a 1987 outbreak of *S*. Typhimurium in Norway and Finland caused by chocolate found that ingestion of fewer than 10 cells was sufficient to cause symptomatic disease (Kapperud *et al.*, 1990). This was based on analysis of retail chocolate samples, which found that 90% of samples contained less than 10 cells per 100g of chocolate.

3.3 New Zealand Outbreak Information and Human Health Surveillance

The number of cases and incidence of notified salmonellosis since 2003 is shown in Table 1.

The notification rate per 100,000 population for cases of salmonellosis in New Zealand from 2000-2009 is shown in Figure 3. The rate has been stable since 2005 at approximately 30 per 100,000.

Table 1:   **Incidence data for salmonellosis in New Zealand**

Year	Number of cases	Incidence (cases/100,000)
2003	1,401	37.5
2004	1,080	28.9
2005	1,383	37.0
2006	1,335	32.3
2007	1,274	30.1
2008	1,346	31.5
2009	1,129	26.2

Source: ESR (2010b)
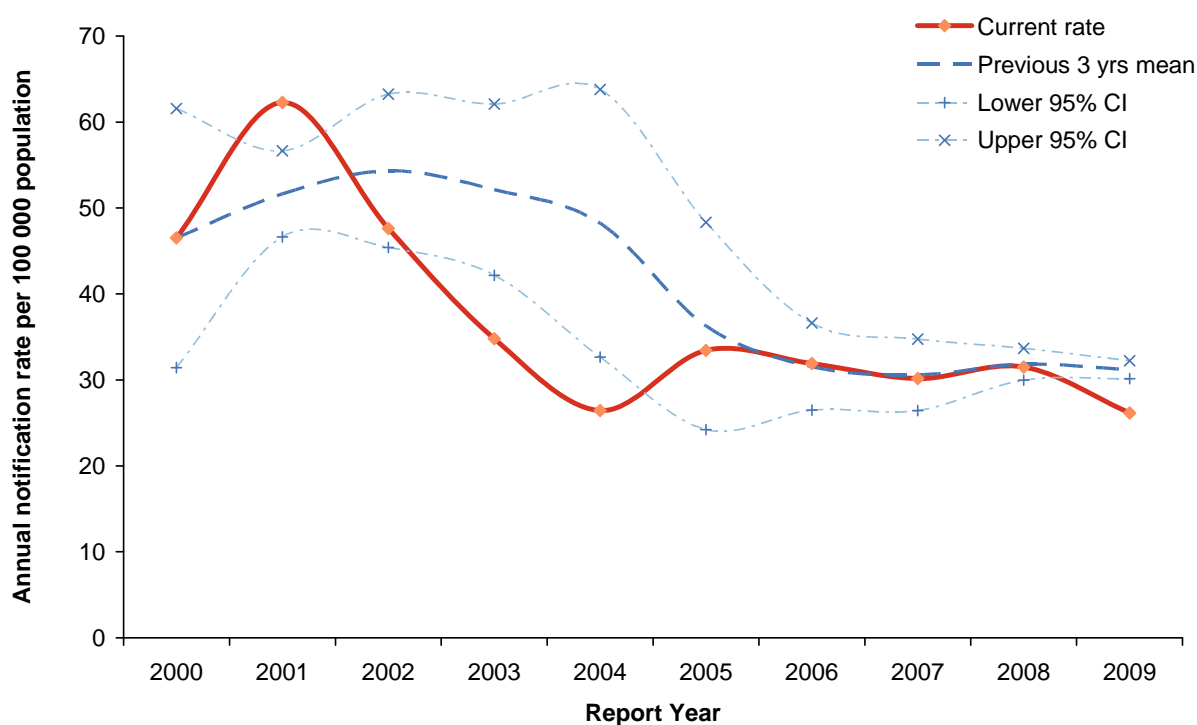
Source: Lim *et al*., 2010

Figure 3:   **Incidence of notified salmonellosis in New Zealand 2000-2009**

The incidence of salmonellosis is characterised by a late summer peak and a winter trough. Two changes to this cyclic pattern have occurred since 1998:

- A spring peak occurred in 1998 and each subsequent year, corresponding to the emergence of *S*. Brandenburg as an important cause of human salmonellosis in New Zealand.
- The winter trough has become less pronounced due to the increasing numbers of cases infected by *S*. Typhimurium (Anonymous, 2001).

High salmonellosis rates are often reported from the lower South Island; in 2009 the highest rates in the South Island were from South Canterbury (34 cases, 61.2/100,000) and Southland (56 cases, 50.1/100,000). Only Tairawhiti had a higher rate in the same year (32 cases, 69.3/100,000) (ESR, 2010b).

In terms of gender, the rates are similar for males (26.2/100,000 in 2009) and females (25.7/100,000 in 2009) (ESR, 2010b). Age specific rates are highest for the <1 year age group (123.7/100,000 in 2009), and 1 to 4 year olds (89.9/100,000 in 2009) (ESR, 2010b).

3.3.1   Clinical outcomes

Hospitalisation and fatality rates for notified cases of salmonellosis in New Zealand are given in Table 2.   These outcomes are not always reported for each case, so percentages are expressed in terms of the number of cases for which outcomes are reported.   The hospitalisation rate and number of deaths has been stable over many years.

Table 2:   Outcome data for salmonellosis in New Zealand, 2003-2009

Year	Hospitalised cases	Fatalities	Reference
2003	167/1118 (14.9%)	0/1401	ESR, 2004b
2004	109/871 (12.5%)	0/1080	ESR, 2005b
2005	142/1134 (12.5%)	1/1383 (0.07%)	ESR, 2006b
2006	148/1111 (13.3%)	1/1335 (0.07%)	ESR, 2007b
2007	110/833 (13.2%)	1/1274 (0.08%)	ESR, 2008a
2008	123/896 (13.7%)	1/1346 (0.07%)	ESR, 2009b
2009	134/716 (18.7%)	1/1129 (0.09%)	ESR, 2010b

3.3.2   Serotypes causing disease in New Zealand

Between 2000 and 2009 there were 15,040 notified cases of non-typhoid salmonellosis in New Zealand and a *Salmonella* serotype was available for 11,554 of these (Adlam *et al.*, 2010).   The five serotypes that caused the most notified salmonellosis cases during this period were:

- *S*. Typhimurium   6,724 cases (58%)
- *S*. Enteritidis   1,012 cases (9%)
- *S*. Brandenburg   700 cases (6%)
- *S*. Infantis   523 cases (5%)
- *S*. Saintpaul   249 cases (2%)

A table of specific phage types for these serotypes, and the year in which the prevalence of that type was highest, is given in Appendix 2.   Serotypes linked to contamination of high lipid foods as part of outbreaks, for example *S*. Montevideo, represent a small proportion of the serotypes identified from reported salmonellosis cases in New Zealand (Adlam *et al.*, 2010).

Some *Salmonella* serotypes that are of international concern are rarely reported in New Zealand. Some *S.* Enteritidis phage types are able to infect egg contents by transovarian transmission and *S.* Enteritidis PT4 is a well-studied example. New Zealand does not appear to have a reservoir of these *S.* Enteritidis phage types. Another serotype of concern is *S.* Typhimurium DT104 because it can be resistant to multiple antibiotics, but reported incidents of human illness from this serotype are rare in New Zealand. New Zealand cases of human illness caused by these serotypes appear to be infections principally acquired overseas (Lake *et al.*, 2004a).

3.3.3 Outbreaks

The number of reported outbreaks of salmonellosis in recent years in New Zealand is given in Table 3 (figures exclude *S.* Typhi and *S.* Paratyphi). The number of cases reported as part of outbreaks is approximately 9% of those reported as sporadic cases (Adlam *et al.*, 2010).

Table 3: Reported outbreak data for salmonellosis in New Zealand 2003-2009

Year	Salmonellosis outbreaks/ total enteric outbreaks	Cases/Total enteric outbreak cases[1]	Reference
2003	23/315 (7.3%)	59/2649 (2.2%)	ESR, 2004a
2004	5/313 (1.6%)	74/3971 (1.9%)	ESR, 2005a
2005	26/338 (7.7%)	120/2343 (5.1%)	ESR, 2006a
2006	22/481 (4.6%)	74/6162 (1.2%)	ESR, 2007a
2007	8/477 (1.7%)	141/7821 (1.8%)	ESR, 2008b
2008	15/428 (3.5%)	163/6295 (2.6%)	ESR, 2009a
2009	12/586 (2.0%)	76/10176 (0.7%)	ESR, 2010a

[1] Includes both suspected and confirmed cases.

A search of the Episurv outbreak database was carried out in April 2009 to identify cases and outbreaks of salmonellosis where high lipid foods such as sesame seeds, peanut butter and chocolate consumption had been reported. The time-frame analysed was 1999-2009.

3.3.3.1 Salmonellosis outbreaks caused by tahini

There were two outbreaks caused by tahini and tahini products contaminated with *S.* Montevideo. These outbreaks occurred in Auckland during August and September 2003 and involved a total of ten cases. The outbreaks were the focus of epidemiological and environmental investigations and were found to be related (Unicomb *et al.*, 2005).

Eight of the cases reported consumption of sesame-based products and three retail outlets were identified as the sources of these foods. Tahini and hummus samples from all three premises tested positive for *S.* Montevideo, and the isolated strain was found to be closely related (based on DNA analysis) to the isolates from the salmonellosis cases. The food handlers at these premises tested negative for *Salmonella* spp. and no food safety failures were identified.

The tahini from the three premises was produced by the same company in Lebanon. Further testing of this company's products obtained from New Zealand wholesalers identified tahini

and halva that were contaminated with the same strain of *S*. Montevideo. The concentration of *S*. Montevideo in eight samples of tahini, one sample of hummus and one sample of halva ranged from <0.03 MPN/g to 0.46 MPN/g. Two tahini samples (one from a premises and one from a wholesaler) also tested positive for *S*. Orion 15+ but no cases of *S*. Orion 15+ were linked to this outbreak.

New Zealand issued two recalls of sesame products during August and September 2003 which resulted in the destruction of 1,749 kg of tahini and 17 kg of halva. During November 2002 and June-July 2003, outbreaks of *S*. Montevideo in Australia caused by contaminated sesame seed products imported from Lebanon and Egypt had led to product recalls in Australia. The Egyptian brand of tahini involved in the 2002 Australian outbreak was also recalled in New Zealand during July 2003 as a result of testing by a food business; no outbreaks were linked to this product in New Zealand.

Importation of tahini became the subject of an Emergency Food Standard, and sampling for tahini and halva at the New Zealand border was introduced on 25 September 2003 (see Section 5.1.1).

3.3.3.2   *Salmonellosis outbreaks where tahini was a possible cause*

There have been five outbreaks of salmonellosis in the last decade in which Middle Eastern food premises or foods likely to contain tahini were suspected, but where investigations failed to find a definite source.

In autumn 1999, 45 cases of *S*. Enteritidis PT9a in Auckland were linked in a multiple point source exposure outbreak. Consumption of Turkish food was strongly associated with illness (40% of cases had eaten Turkish food in the three days prior to onset of illness). Six Turkish food restaurants, cafés and stalls were implicated and most cases had consumed a doner kebab. Extensive sampling of implicated foods and food handlers' faecal specimens failed to detect the pathogen. The authors concluded that the contaminated ingredient was a component of Turkish food but it could not be identified (Simmons and Manning, 1999).

An outbreak of *S*. Montevideo involving 11 laboratory-confirmed cases occurred in Auckland during late September 2000 (Ehlers and Simmons, 2000). The cases had consumed food from the same Middle Eastern takeaway premises. A range of kebab foods were implicated including vegetarian, chicken and lamb kebabs. However *Salmonella* spp. were not detected in the multiple food and ingredient samples submitted for analysis. It was acknowledged that the samples were submitted two weeks after the consumption of implicated food by the last case (and so any contaminated food may have been consumed before sampling). Faecal cultures identified one of the three food handlers (reportedly asymptomatic) to be a carrier of *S*. Montevideo. An assessment of the process of preparation of meat products at the premises identified a number of food safety issues including inadequate cooking of meats and poultry, and cross contamination from raw to cooked meats. The authors concluded that given the continuing point source and variable nature of food components consumed, the most likely source of illness was an infected but asymptomatic food handler. The source of the food handler's infection was not identified.

An outbreak of *S*. Enteritidis PT9a in 2005 involved 25 cases in the Auckland region (Anonymous, 2005). A case control study implicated foods consumed at a Middle Eastern

takeaway, which included hummus. Tahini from the premises was tested and was negative for *S*. Enteritidis PT9a, but was positive for *S*. Orion. Faecal specimens from the food handlers were negative for salmonellae.

An outbreak of *S*. Montevideo associated with a kebab takeaway stall was notified on in October 2007 (Ruscoe, 2008). Three *S*. Montevideo isolates were identified from notified cases in the Hutt Valley district prompting enhanced case investigations. In total, seven laboratory-confirmed cases and three probable cases with onset of illness between 3 and 7 October 2007 were recorded. All 10 cases had eaten at the same takeaway kebab stall between 1 and 4 October and this was the only common factor. All sauces were brought to the stall ready to use but hummus and yoghurt were made on site. Cross contamination was identified as a risk factor. Imported tahini paste and yoghurt made at the premises were tested but *Salmonella* spp. were not detected. The source of the *S*. Montevideo remains unknown.

In another outbreak, 85 confirmed cases of *S*. Chester in the Bay of Plenty were notified from October 2007 to February 2008. A number of clusters emerged, but a busy food premises in Tauranga became a focus for investigation as it was the only business linked to 43 of the cases. Hummus was the only common ingredient in dishes eaten by cases. Hummus was made on the premises with imported tahini. All food and environmental samples returned negative results, however four food handlers were asymptomatic carriers of *S*. Chester and one food handler was symptomatic. A contaminated imported food was suspected because this was a new strain of *S*. Chester in New Zealand, the cases were geographically dispersed, and there were earlier cases who had not visited the food premise. No specific food vehicle was identified. The food handlers may have become ill from contact with contaminated ingredients (Adlam *et al.*, 2010).

3.3.3.3   Salmonellosis outbreaks where other high lipid foods were suspected

There were additional outbreaks reported between 1999 and 2009 where high lipid foods including chocolate (e.g. chocolate cake) and peanut products (e.g. chicken satay) were suspected, but these were not supported by laboratory evidence or epidemiological studies.

Chocolate mousse was the suspected cause of an outbreak in 2002 of *S*. Typhimurium DT160. Two of the four confirmed cases in this outbreak were food handlers but there was no evidence to implicate the chocolate mousse as the vehicle of infection (Adlam *et al.*, 2010). These outbreaks could have been caused by other contaminated ingredients in the foods, by other foods consumed, by food safety failures such as cross-contamination or by other risk factors (e.g. person-to-person spread).

3.3.4   Case control studies and risk factors

Two case-control studies of salmonellosis have been conducted in New Zealand to identify the causes of increased notifications of people infected with *S*. Typhimurium DT160 (Thornley *et al.*, 2002; Thornley *et al.*, 2003) and *S*. Brandenburg (NZFSA, 2002) (Appendix 2). Neither case-control study addressed the consumption of high lipid foods as a risk factor.

3.4   Adverse Health Effects Overseas

The incidence of notified cases of salmonellosis in New Zealand is similar to rates in other developed countries, particularly Canada, Denmark and Iceland (see Appendix 2).   Reported incidence rates vary between countries, e.g. 155/100,000 population in Slovakia, 8/100,000 population in Spain.   In contrast to New Zealand, in the EU the dominant serotype is *S*. Enteritidis (see Appendix 2).

Information on overseas outbreaks of salmonellosis in which high lipid foods have been implicated are summarised in Appendix 2. These outbreaks are geographically widely distributed, reflecting the widespread international trading of these foods, and use of the foods as an ingredient in a variety of products. The source of contamination was identified in only a few outbreaks, and these are further discussed in Section 5.2.

3.5   Health Burden of Infection with *Salmonella* spp.

An estimate of the burden of foodborne disease for New Zealand (Cressey and Lake, 2007) includes an estimate for foodborne salmonellosis of 111 disability adjusted life years (DALYs).   This represents 60.7% of the total 186 DALYs for salmonellosis, with the percentage foodborne being derived from an expert consultation process.   This placed foodborne salmonellosis fourth on the list for foodborne disease burden (after campylobacteriosis, norovirus infection, and perinatal listeriosis).

The burden of disease to the health system and society in general has also been considered through a cost of illness estimate based on the same incidence data as was used for the DALY calculations (Cressey and Lake, 2008). This estimated the total cost for salmonellosis as $4.8 million, with foodborne infections costing $2.8 million.

In the USA, foodborne salmonellosis cases are estimated to cost the economy $US2.3 billion annually (1998 $US) (Dickson *et al.*, 2002). European estimates of the cost of salmonellosis are more in line with New Zealand estimates (given population differences), with Kemmeren *et al*. estimating the cost of salmonellosis in the Netherlands to be €8.8 million in 2004 (Kemmeren *et al.*, 2006).

3.6   Adverse Health Effects Summary

The incidence of salmonellosis in New Zealand has remained relatively steady since 2005 and is comparable with reported incidence in some developed countries (reported incidence varies considerably between countries). *S*. Typhimurium is the most commonly isolated serotype from human cases. Human health surveillance data has only linked sesame products with outbreaks of salmonellosis in New Zealand; there have been no reports of peanut or cocoa products causing salmonellosis. After the introduction of the tahini importation standards in 2003, there have been three salmonellosis outbreaks for which sesame products were a possible source, but this was not confirmed.

4 EVALUATION OF RISK

4.1 Existing Risk Assessments

No risk assessments could be located regarding *Salmonella* spp. in high lipid foods for New Zealand or overseas. A number of case control studies have been conducted overseas, usually associated with outbreak investigations (summarised in Appendix 2). These have been conducted in association with outbreaks in order to confirm the vehicle(s) of exposure.

4.2 Estimate of Risk for New Zealand

4.2.1 Risk associated with high lipid foods

The risk of *Salmonella* spp. contamination of chocolate first became apparent between 1966 and 1968 when a number of confectionery products in the USA were recalled (D'Aoust, 1977). Outbreaks linked to other high lipid foods have been more recent with the first documented outbreaks of salmonellosis from peanut butter consumption and a peanut-flavoured snack bar reported in 1996 in Australia and the United Kingdom respectively. Outbreaks linked to sesame seeds and their products date from 2000. Presumably prior to this date, the link was unrecognised.

Tahini, halva, peanut butter and chocolate all have a low water activity that prevents microbial growth, but the composition of such foods allows *Salmonella* spp. to survive for long periods. These high lipid foods have a long shelf life and are usually consumed without further heat treatment by the consumer after purchase.

A roasting process is included in the manufacture of tahini, peanut butter, and chocolate and this should inactivate any *Salmonella* spp. on the raw sesame seeds, peanuts or cocoa beans. While the dry heat involved in roasting is less efficient at killing bacteria than moist heat (Farkas, 2001), the times and temperatures found for roasting of cocoa beans, sesame seeds and peanuts suggest that *Salmonella* spp. reductions should be substantial. This has been supported by a study using peanuts (Doyle, 2009), but no studies of the effect of roasting on *Salmonella* spp. on sesame seeds or cocoa beans were identified. There are only a few overseas salmonellosis outbreak investigations where the cause of contamination was identified, but those that do suggest that post-heat treatment contamination is the most likely source of *Salmonella* spp. in these high lipid foods (CDC, 2007a, 2007b; Elson, 2008; Gill *et al.*, 1983; Ng *et al.*, 1996; Powell, 2009; Scheil *et al.*, 1998). Nevertheless, the survival of *Salmonella* spp. through sesame seed processing (including roasting) has been postulated, based on the results of a survey in Germany (Brockmann *et al.*, 2004) and outbreak investigations (Unicomb *et al.*, 2005). In the absence of studies on the effect of roasting on *Salmonella* spp. in sesame seeds, it is unclear whether this might result from inadequate processing, or normal processing being insufficient.

If tahini is produced without the roasting step there is greater opportunity for any *Salmonella* present on the raw sesame seeds to be carried through into the final product. USA manufacturers have recalled tahini produced from raw sesame seeds because of the possibility of *Salmonella* contamination (Table 8, Appendix 1). It is not known whether any tahini imported into New Zealand is manufactured from unroasted sesame seeds.

The New Zealand import testing programme and outbreak data from New Zealand and overseas have only reported contaminated tahini that was imported from the Seychelles and Middle Eastern countries. The available literature indicates that Middle Eastern countries manufacture tahini from roasted sesame seeds. Larger volumes of sesame paste are apparently imported into New Zealand from Asian countries, and information on the production process for this material was not located. However, no *Salmonella* contamination of these products has been found from import testing. Neither have these products been linked to outbreaks.

Chocolate and peanut butter are consumed by approximately 20-30% of the population on a daily basis, based on national surveys in 1997 and 2002. Data collected by these surveys also indicate that <1% of New Zealanders consume hummus or tahini on a daily basis, although consumption of these foods may have risen subsequently.

The serving sizes for all these foods are modest. Normally, this would translate into low exposures on an individual basis and ameliorate any risk of infection. However, there have been salmonellosis outbreaks involving these high lipid foods in which comparatively low concentrations of cells have caused illness. This may be due to a high prevalence of exposure to low numbers of cells causing illness in a small proportion of those exposed, as well as lipids in the foods protecting cells from the acid in the stomach thus increasing the probability of infection.

Consequently a more important factor in estimating risk is prevalence of contamination, rather than concentration. The one relevant survey in New Zealand, of sesame seed products, did not detect contamination. Based on import volumes and import testing data, sesame products from Asia represent the bulk of this type of product imported into New Zealand, but testing of consignments from Asia has not found any contamination. Nevertheless, import testing has detected *Salmonella* spp. contamination of tahini/halva from other countries and *Salmonella* spp. contamination of peanut butter; twelve consignments were detected with *Salmonella* spp. contamination between 2004 and 2009 (10 tahini/halva, 2 peanut butter). This suggests that contamination is sporadic, and further surveys are unlikely to have much value.

An analysis of 204 outbreaks of non-typhoidal salmonellosis that were reported in New Zealand from 2000 to 2009 (Adlam *et al.*, 2010) found that foodborne transmission was suspected in approximately half of the outbreaks. However, there was laboratory based evidence to suggest a source of infection in only 22 of these outbreaks. Of these 22 outbreaks, an infected food handler was identified in 11, while of the remaining outbreaks, a food vehicle was identified in seven outbreaks, two of which involved tahini. The number of cases linked to outbreaks represented 5-9% of all notified cases. Given the low number of outbreaks where a food vehicle is identified, and that there is very limited information on the transmission of infection for non-outbreak cases, it is plausible that high lipid foods have a greater role in transmission than currently identified.

Compared with many other foods, the amounts of these products consumed by New Zealanders are low. Contamination is likely to be sporadic, but when it does occur the potential for illness is high, for the reasons described above. On the basis of the small number of outbreaks of salmonellosis attributed to these high lipid foods together with import controls at the borders and food safety programmes in place for New Zealand manufacturers,

it seems likely that these foods represent a minor component of the overall foodborne risk of this illness to New Zealanders. However, an increase in popularity of foods such as tahini and hummus could increase the risk in future.

4.2.2   Risks associated with other foods

An egg survey for *Salmonella* spp. has been completed (Wilson, 2007) and this found a low prevalence of *Salmonella* spp. contamination on the surface of eggs in New Zealand, with no contamination within eggs being detected.

Data from surveys of retail poultry products has confirmed the low prevalence of contamination by *Salmonella* spp. indicated by testing of samples from the end of the processing line and reported to the National Microbiological Database. These data, and results of the case-control studies considered in the Risk Profile on *Salmonella* spp. in poultry (Lake *et al.*, 2004b), indicate that transmission in poultry currently represents a minor component of salmonellosis aetiology in New Zealand.

The potential for transmission of *S*. Brandenburg in sheep meat has been investigated, as part of a broad investigation into this pathogen (NZFSA, 2002). Takeaway foods were identified as an important risk factor in the *S*. Typhimurium DT160 case-control study (Thornley *et al.*, 2002; Thornley *et al.*, 2003). Two outbreaks related to umu functions have been reported. In a common source outbreak in Auckland, the implicated food was potato salad with egg mayonnaise which had been improperly stored (Callaghan and Simmons, 2001) and in the other the implicated food was Palusami (umu cooked packs of taro in coconut milk wrapped in taro leaves) that had been privately imported from Samoa (Ng and Simmons, 2002).

A notable outbreak of salmonellosis linked to contaminated flour occurred in 2008-2009 (Lisa McCallum, ESR, pers. comm.). A total of 75 cases of salmonellosis were reported from October 2008 to January 2009, caused by *S*. Typhimurium PT42. Twelve cases were hospitalised and there were no fatalities. The majority of the cases resided in Canterbury (22/75) and Otago (17/75).

A case-control study found elevated an odds ratio (OR) of 3.6 compared to controls for eating, licking or tasting uncooked baking mixture (p=0.001; 95% C.I. 1.2-10.7). Flour samples were collected and tested for *Salmonella* spp. from open packets in cases' homes (4/26 positive), unopened packets that had been on sale in retail outlets prior to withdrawal (2/41 positive) and retrieved/withdrawn flour (3/23 batches of flour positive). Contamination levels were estimated for 3 of the positive samples. *Salmonella* spp. counts ranged from 1 per 300g to 1 per 50g.

A recent New Zealand study, using molecular sub-typing data and Bayesian techniques ('modified Hald model') estimated the attributable food source for human salmonellosis cases in New Zealand in 2003 (Mullner *et al.*, 2009). The authors urged caution in interpreting these results since molecular sub-typing data for pork were sparse and more biased than data for other food animal species. An estimated 60.2% (Bayesian credible interval 47-74%) of food sourced human salmonellosis was attributed to transmission by pork. High lipid foods were not considered in this analysis.

4.2.3   Risk assessment options

At this stage a quantitative risk assessment on this food/hazard combination would not be possible due to incomplete data.

4.3   Data gaps

The data gaps identified in this Risk Profile are:

- Prevalence of *Salmonella* spp. in chocolate and peanut butter in New Zealand (although surveys are unlikely to detect the presence of sporadic contamination unless very high numbers of samples are taken).
- Sources and prevalence of contamination in tahini imported into New Zealand (more comprehensive data than that currently available from import testing).
- Information on the importation of unroasted sesame products, and emerging high lipid foodstuffs potentially contaminated with *Salmonella* spp. e.g. nut butters, blended snack foods including tahini or sesame paste (apart from hummus).
- The heat resistance of *Salmonella* spp. in tahini during the manufacture of halva and on sesame seeds and cocoa beans during roasting.
- The roasting temperatures and times used for the products that are manufactured in New Zealand or imported to New Zealand (including sesame products from Asia).
- Dose-response information specific for high lipid foods.
- Transmission routes for the majority of reported salmonellosis cases in New Zealand.

5 AVAILABILITY OF CONTROL MEASURES

5.1 Risk Management Strategy

In March 2009 NZFSA released their Salmonella Risk Management Strategy 2009-2012 (NZFSA, 2009d). The Strategy aims to achieve a 30% reduction in the reported annual incidence of foodborne salmonellosis after five years. The strategy focuses on non-typhoid *Salmonella* and begins with a primary focus on intelligence gathering from a wide range of food sectors.

The objectives of the *Salmonella* risk management strategy are to:

- Quantify the proportion of foodborne cases attributable to:
  - specific foods
  - animal feeds
  - domestically produced versus imported foods
  - multi-resistant and virulent *Salmonella* genotypes associated with foods
- Identify sources of *Salmonella* contamination of specific foods and animal feeds
- Determine the relative value of different interventions throughout the food chain in reducing the risk of salmonellosis
- Make prioritised risk management decisions on appropriate *Salmonella* control measures across the food chain, and according to data availability
- Design and implement an effective monitoring and review programme to support strategic goals.

5.1.1 Relevant Food Controls

5.1.1.1 Regulatory Controls – Import Standards

Some imported high lipid foods have been identified as high risk by the NZFSA and are subject to *Salmonella* spp. monitoring at the New Zealand border (testing is at the importer's expense) (NZFSA, 2007, 2009f). Importers of peanut butter or tahini (or crushed sesame seeds or any food containing tahini or crushed sesame seeds) that do not hold recognised assurances, certification or permits, must participate in a testing regimen before their products are cleared for distribution on the New Zealand market. The NZFSA has published a sampling and testing protocol (NZFSA, 2009b). Briefly:

- Imported foods have assigned tariff codes. Customs New Zealand uses these codes to identify whether a food in a consignment is to be stopped for testing.
- The sampling frequency is determined based on the sampling and testing history for an individual importer of a specific food. The frequency of sampling reduces provided the importer's specific food remains compliant with testing standards.
- The number of lots which are sampled depends on the number of lots in the consignment, e.g. if there are 2-8 lots in the consignment, 2 lots will be sampled.

Further information on the identification and testing of these high risk foods, called 'prescribed foods' under the Food Act 1981, is specified in regulatory documents called Imported Food Requirements (IFRs). These IFRs replaced similar guidelines called Standard

Management Rules (SMRs) in July 2009, when the Ministry of Agriculture and Fisheries Verification Agency became part of the NZFSA and assumed responsibility for import quality control.

Tahini

The NZFSA has put in place an IFR for Tahini or crushed sesame seeds or any products containing these (NZFSA, 2009g). This IFR covers:

- Tahini and crushed sesame seeds including sesame seed paste, sesame paste, sesame butter.
- Foods containing tahini or crushed sesame seeds including hamas tahini, tehina, tahina, tahineh, halva, halawa, helva, hummus, babaganoush and eggplant dip.

The current IFR is the outcome of two regulatory steps the New Zealand Government took in response to the salmonellosis outbreaks and tahini recalls in 2003. In 2003 the Director-General of Health put in place an Emergency Food Standard for tahini-based products that required sampling of imported consignments of these foods for the presence of *Salmonella* spp. A permanent Import Food Standard for tahini came into force in June 2004. The tariff codes targeted for import testing were:

- 1207.40.00.00A *Sesamum* seeds (sesame seeds)
- 2005.59.00.00B Prepared or preserved homogenised vegetables other than potatoes peas beans (for tahini – certain importers only)
- 2005.90.09.09G Other vegetables and mixtures etc preserved etc other not frozen (for tahini – certain importers only)
- 2008.19.09.29H Roasted nuts (other than ground-nuts) & seeds whether or not mixed together
- 2008.19.09.39E Un-roasted nuts (other than ground-nuts & seeds) whether or not mixed together
- 2103.90.00.29D Other sauces & preparations (not mixed condiments or seasonings) (for tahini & soy sauce certain suppliers only).

The current IFR was updated in August 2009 to remove import clearance requirements for tahini or crushed sesame seed products exported from Australia, and to restrict the target tariff codes to:

- 1207.40.00.00A Sesamum Seeds
- 2008.19.09.29H Nuts (Other than ground-nuts) and Seeds, Roasted
- 2008.19.09.39E Nuts (Other than ground-nuts) and Seeds Not Roasted.

Data from import inspection and testing has been presented in Section 2.5.1.

There are procedures in place to facilitate clearance of imported foods that fall under these tariff codes but are not any of the foods targeted by the IFR.

Unless recognised permits are available (as specified in the IFR, e.g. multiple release permits obtained by an importer), imported tahini, crushed sesame seeds and their products must be

tested for *Salmonella* spp. The IFR criteria for compliance is a nil tolerance of *Salmonella* per 25g.

Samples of these sesame-based foods are taken in accordance with NZFSA's sampling and testing protocol. Ten samples (200 g or more) are taken per lot and individual units or packets are samples if these are available. A maximum of five samples from a lot may be tested as a composite. A Food Act Officer (FAO) can reject a lot if the samples from that lot are *Salmonella* positive. Untested lots in a non-compliant consignment (i.e. where other lots tested *Salmonella* positive) can be sampled and tested, but if further testing is not carried out these untested lots must be rejected by the FAO.

Peanuts and peanut butter

The NZFSA has put in place an IFR for peanuts (and pistachio nuts), which also covers peanut products (e.g. a food containing greater than 30% peanuts) (NZFSA, 2009e). This IFR requires these foods to be tested for aflatoxin. Testing for pathogens is not required.

There is a separate IFR in place for peanut butter (NZFSA, 2009a). The tariff code targeted under this IFR is: 2008.11.00.01D (Peanut Butter). This tariff code is not included in the IFR for peanuts and pistachio nuts.

The IFR for peanut butter was updated in August 2009 to remove import clearance requirements for peanut butter exported from Australia. Unless recognised assurances/certification or permits are available (as specified in the IFR, e.g. the peanut butter is of Australian origin and is certified free from *Salmonella* spp.), imported peanut butter must be tested for aflatoxin and *Salmonella*. The IFR microbiological criteria for compliance is a nil tolerance of *Salmonella* per 25g.

Under the peanut butter IFR, samples of peanut butter for *Salmonella* testing are taken in accordance with NZFSA's sampling and testing protocol, with sampling from each product type (e.g. salted, crunchy). Five samples (100g or more) are taken per lot. The five samples from a lot may be tested as a composite. A Food Act Officer (FAO) can reject a lot if the samples from that lot are *Salmonella* positive. Untested lots in a non-compliant consignment (i.e. where other lots tested *Salmonella* positive) can be sampled and tested, but if further testing is not carried out these untested lots must be rejected by the FAO.

A reminder to all New Zealand importers and retailers regarding the risks from peanut butter was issued by the NZFSA on 2nd February 2009 (reissued 17 May 2010) during the large outbreak of *S*. Typhimurium in the USA caused by peanut butter and peanut paste produced by the Peanut Corporation of America (PCA) (NZFSA, 2010a). A review of peanut products imported into New Zealand containing ingredients produced by PCA found one product; Zoneperfect Peanut Toffee Bars. A national recall on this product was instigated on 21 January 2009 with the reason for the recall as "potentially contaminated with *Salmonella*" (NZFSA, 2009c).

Measures to control *Salmonella* contamination in food containing a peanut-derived product were announced by the US Food and Drug Administration (FDA) in March 2009 (USFDA,

2009).[4]   One of the recommendations by the FDA was that "Manufacturers of foods containing a peanut-derived product as an ingredient obtain peanut-derived product only from suppliers with validated processes in place to adequately reduce the presence of *Salmonella* spp. (e.g., by 5 logs).".   Manufacturers of roasted peanuts and peanut butter in the US are having thermal processes validated for efficacy in achieving this reduction.

5.1.1.2   Regulatory Controls: Food Act 1981.

If the product is for domestic consumption only (i.e. New Zealand and Australia), then a Food Safety Programme (FSP) approved under the Food Act 1981 is required.

5.1.1.3   Industry Controls

Cocoa beans and chocolate ingredients are not subject to imported food controls. Information on *Salmonella* spp. monitoring was obtained from three local chocolate manufacturers. All three manufacturers have HACCP programmes in place, with specific controls for *Salmonella* spp.   For ingredients, approved suppliers provide certificates of analysis for each consignment delivered. Those ingredients include sugar, cocoa mass, cocoa butter, orange peel, kiwifruit, nuts, coconut, soya lecithin and vanilla flavouring.   Some testing of ingredients before use is conducted.   At the manufacturing plant, environmental swabs are analysed either specifically for *Salmonella* spp. or for hygiene indicators such as faecal coliforms. Final product testing is also carried out, either on a batch basis or at timed intervals.

5.2   Options for Risk Management

Sources of contamination are rarely identified during investigations of outbreaks of salmonellosis linked to high lipid foods. The factors that have been identified or suggested as potential sources in the scientific literature (see Appendix 2) include:

- Leaking roof and sprinkler system contaminating peanuts during processing (CDC, 2007a, 2007b);
- Auger blade used to move peanuts after roasting was contaminated with mouse faeces (Ng *et al.*, 1996; Powell, 2009; Scheil *et al.*, 1998);
- Possible survival of the pathogen in foreign matter during roasting of cocoa beans or cross contamination from unroasted beans (Craven *et al.*, 1975);
- Possible contamination in the chocolate factory by birds (Kapperud *et al.*, 1990);
- Possible contaminated water at factory producing chocolate bars (Gill *et al.*, 1983);
- Leaking water pipe contaminating chocolate crumb (Knowles *et al.*, 2007).

These findings suggest that contamination during processing after roasting is most important. Preventive measures to avoid recontamination during processing after the roasting step have been described for the chocolate industry (Cordier, 1994).

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[4] See also guidance documents published by the US Grocery Manufacturers Association concerning *Salmonella* control GMA (2009a). Annex to Control Of *Salmonella* In Low-Moisture Foods. Grocery Manufacturers Association, Washington, DC. http://www.gmaonline.org/science/Salmonellaguidanceannex.pdf. Accessed 10 June 2010, GMA (2009b). Control Of *Salmonella* In Low-Moisture Foods. Grocery Manufacturers Association, Washington, DC. http://www.gmaonline.org/science/SalmonellaControlGuidance.pdf. Accessed 10 June 2010.

The roasting stage is a major critical control point for *Salmonella* spp. in the production of these high lipid foods. After roasting, once the raw materials are ground or mixed into a high lipid material, *Salmonella* spp. display considerable heat resistance in the resulting mass or paste. Further heat treatment is unlikely to be effective, and exclusion of contaminated (imported) materials and prevention of post-heat treatment contamination during processing are more suitable options. Import monitoring of tahini and peanut butter is currently conducted in New Zealand. Major New Zealand chocolate manufacturers have risk management procedures and monitoring schemes in place.

In future, other emerging high lipid foodstuffs may warrant import monitoring programmes similar to those currently in place for tahini and peanut butter. Such foodstuffs include pistachio and almond nuts/butters, as these may not receive the same roasting treatment as other products.

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7 APPENDIX 1: HAZARD AND FOOD

The following information is taken from a number of different sources but, unless otherwise referenced, is primarily derived from a data sheet prepared by ESR under a contract for the Ministry of Health in 2000-2001 (ESR, 2001). The data sheets are located on the NZFSA website.[5] They are intended for use by regional public health units and will be updated from time to time. Please be aware that new information on the subject may have arisen since this document was finalised.

7.1 *Salmonella*

7.1.1 Growth

Temperature: Minimum 7°C, growth greatly reduced at <15°C. Maximum 49.5^{o}C. Optimum 35-37°C. Some evidence for growth at temperatures <7°C exists, but this is serotype specific, the data are still not universally accepted and doubts surrounding the experimentation exist.

pH: Minimum 3.8, optimum, 7-7.5, maximum 9.5. The minimum pH is influenced by other factors such as temperature, acid present, and the presence of nitrite or other additives.

Atmosphere: Can grow in the presence or absence of air as a facultative anaerobe. The growth rate on beef muscle stored at 20°C under nitrogen is only slightly less than that obtained when stored under air (Grau, 1983). At high concentrations of CO_2 (50-60%), growth is strongly inhibited on beef steak and minced beef at 10-11°C, but at 20°C there is little inhibition (Luiten *et al.*, 1982; Silliker and Wolfe, 1980).

Water activity: Minimum 0.94, optimum 0.99, maximum >0.99.

7.1.2 Survival

Salmonella spp. are known to survive well in foods and on surfaces.

Temperature: *Salmonella* spp. can survive well in foods for long periods at low refrigeration temperatures. In frozen foods, although salmonellae numbers are considerably reduced, some survive for long periods. Some foods, including meat, ice-cream and butter, appear to be protective of *Salmonella* spp. during freezing and frozen storage. Rapid freezing promotes survival with lower frozen storage temperatures and less fluctuation giving greater survival (Jay *et al.*, 2003).

Frozen storage near 0°C result in greater death or injury to bacterial cells. In minced chicken breast (pH 5.8), 60-83% of *Salmonella* cells survived storage at -20°C for 126 days, whereas at -2°C and -5°C only 1.3% to 5.8% of cells respectively were still viable after 5 days.

pH: *Salmonella* spp. appear to be significantly less tolerant of low pH (pH 2.5; hydrochloric acid) than *Shigella* spp. or *Escherichia coli*. These last two organisms possess additional acid survival systems that are not present in salmonellae (Gorden and Small, 1993; Lin *et al.*,

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[5] See http://www.nzfsa.govt.nz/science/data-sheets/index.htm . ESR originally prepared the data sheets for the Ministry of Health in 2001.

1995).

Water Activity: Growth is inhibited when the water activity is 0.93-0.95. Survival in dry environments is a characteristic of these organisms. For example, they can survive in bitter and milk chocolate (aw 0.3-0.5) for months. Exposure to low aw environments can greatly increase the subsequent heat resistance of these organisms.

7.1.3   Inactivation

Note that in microbiological terms "D" refers to a 90% (a decimal or 1 $\log_{10}$ cycle) reduction in the number of organisms.

Temperature: Inactivation is greater during the freezing process rather than subsequent frozen storage, but those cells that survive remain viable. Freezing does not ensure the inactivation of salmonellae in foods.

D times: at 60°C usually 2-6 min; at 70°C usually 1 min or less. Some rare serotypes (e.g. *S*. Senftenberg) are significantly more heat resistant than the others, but this organism is not considered to be important as a food pathogen (Doyle and Mazzotta, 2000). It is reported that the heat resistance of *S*. Senftenberg is only significant when reported in moist foods. When the water activity is lowered, other strains become more resistant (Goepfert *et al.*, 1970; van Asselt and Zweitering, 2006).

D times for *Salmonella* spp. can depend on the type of food involved. Long D times have been reported for experiments with *S*. Typhimurium in milk chocolate. Values reported were up to 1,050 min at 70°C, 222 min at 80°C and 78 min at 90°C (Goepfert and Biggie, 1968).

pH: Low pH values and the nature of the acidulant determines the rate of death. Temperature is also a factor.

Decreasing temperature increases the inhibitory effects of pH and NaCl (Alford and Palumbo, 1969). In broth, at 10°C, growth of 22/23 strains were inhibited by pH 5 and 2% NaCl. At pH 5.8, 5% NaCl at 10°C was required to inhibit growth. Increasing the salt concentration slightly decreased survival time at 10°C.

Water activity: Salmonellae behave in a different way in high lipid foods compared to the majority of foods. Usually at water activity levels below those allowing growth, salmonellae die slowly. However due to the protective nature of high lipid foods cells are not inactivated.

Radiation: The greater penetrative capability of gamma irradiation has advantages over beta and UV radiation. In chocolate, the latter are only effective in thin films or layers. An irradiation dose of 0.45 megarad is required to disinfect cocoa powder but organoleptic changes take place (D'Aoust, 1977).

Antimicrobial effects: An antagonistic effect toward *S*. Gallinarum and *S*. Typhimurium was observed in media containing 5% processed cocoa powder. Anthocyanin compounds present in chocolate were suggested as the lethal agents (Busta and Speck, 1968). The presence of a substance in cocoa powder inhibitory towards salmonellae was confirmed by Zapatka *et al.*, (1977) (Zapatka *et al.*, 1977). Although the substance was not defined, the authors found that

its bactericidal activity was diminished by casein. The activity was arrested at a ratio of 1:1 casein to cocoa powder. However there does not appear to be the same effect in chocolate itself because salmonellae have been shown to survive.

Pressure: Foods with low water activity, such as raw almonds, impart a baro-protective quality to *S*. Enteritidis when subjected to high hydrostatic pressure (HHP; 14,500-101,500 psi). Future research is investigating the possibility of applying HHP to low water activity foods suspended in water (Goodridge *et al.*, 2006).

7.2 The Food Supply: High lipid foods made from sesame seeds, peanuts and cocoa beans

7.2.1 New Zealand imports of high lipid foods

New Zealand does not grow peanuts, sesame seeds, or cocoa beans. Raw materials, partially processed materials, and finished products are all imported.

Overseas trade import data collected by Statistics New Zealand was reviewed to identify import volumes of high lipid foods (Table 4).

Table 4: **Imported high lipid products, 2009 (Statistics New Zealand)**

Product	HS10 Code[1]	Gross weight (kg)	Principal countries of origin
Sesame seeds and their products			
Sesame oil	1515.50.00.00	211,818[2]	China, Singapore, Mexico, Japan, Taiwan
Sesame seeds	1207.40.00.00	738,844	India, Mexico, China, Israel
Oil seed meals (excl. soya and mustard) (May include tahini)	1208.90.00.00	881,537	Australia, India
Nuts (other than ground nuts) and seeds, roasted[3]	2008.19.09.29	486,451	USA, Australia
Nuts (other than ground nuts) and seeds, unroasted[3]	2008.19.09.39	325,614	USA
Peanuts and their products			
Peanut butter	2008.11.00.01	3,107,153	China, Australia
Groundnuts, roasted, mixtures	2008.11.00.21	44,155	China, Australia
Groundnuts, roasted, other than mixtures	2008.11.00.31	2,479,223	Australia, China, USA
Groundnuts, not roasted, prepared or preserved	2008.11.00.39	982,435	China, Australia, USA
Groundnuts, in shell, not roasted	1202.10.00.00	69,352	China, South Africa
Groundnuts, shelled, not roasted	1202.20.00.00	1,610,329	Australia, China, South Africa
Cocoa beans and their products			
Cocoa beans raw/roasted, broken/whole	1801.00.00.00	1,115,252	Ghana, Singapore

Product	HS10 Code[1]	Gross weight (kg)	Principal countries of origin
Cocoa paste (not-defatted)	1803.10.00.00	1,209,246	Singapore, Indonesia
Cocoa butter	1804.00.00.00	3,251,198	Malaysia, Singapore, Indonesia, Thailand
Cocoa powder (unsweetened)	1805.00.00.00	2,353,745	Singapore, Malaysia, Indonesia, The Netherlands
Cocoa powder (sweetened)	1806.10.00.00	601,837	Australia
Chocolate (bulk form)[4]	1806.20.00.00	5,135,728	Australia, Singapore
Chocolate (<2kg, filled)	1806.31.00[5]	4,338,001	Australia
Chocolate (<2kg, unfilled)	1806.32.00[6]	5,586,923	Australia

[1] HS10, Harmonised System 10-digit code used to identify imported commodities, also known as tariff codes.
[2] Gross weight is in litres.
[3] Products under this tariff code are targeted for inspection as they may contain crushed sesame products.
[4] The sum of tariff codes 1806.20.00.10 (>2 kg, 30% or more dairy product) and 1806.20.00.90 (>2 kg, <30% dairy product).
[5] The sum of tariff codes 1806.31.00.01, 1806.31.00.11, 1806.31.00.19 and 1806.31.00.29 (blocks, slabs or bars, <2 kg, filled).
[6] The sum of tariff codes 1806.32.00.01, 1806.32.00.11, 1806.32.00.19 and 1806.32.00.29 (blocks, slabs or bars, <2 kg, unfilled).

7.2.2   Production, processing and standards

Any relevant standards produced by the Codex Alimentarius Commission, Food Standards Australia New Zealand and the NZFSA are listed against the relevant foods below. The NZFSA regulates *Salmonella* in imported tahini and peanut butter.

7.2.2.1   *Sesame seeds*

Sesame seeds from the *Sesamum indicum* plant are unusually high in oil, comprising approximately half of the seed's weight. Sesame is primarily grown by small farmers in developing countries, who extract the seeds by shaking the cut and dried sesame plants. After initial screening and cleaning, the seeds are hulled either mechanically or using water (aqua-hulling). When water hulled, the seeds remain white after baking and are commonly used on hamburger buns.   The mechanically hulled seeds are produced under low temperature conditions. Mechanically hulled seeds are used for bakery and confectionery products, and to produce tahini (Brockmann *et al.*, 2004).

In 2001, the three major sesame producer countries were India, China and Myanmar. The primary market for sesame in the United States is for the whole seed used in a variety of baked goods (Brockmann *et al.*, 2004). This was still the case in 2007, when Asia produced 64% of the world's supply of seed, and Africa 31% (with Sudan, Uganda, Ethiopia, Nigeria producing the largest amounts in that continent)[6].

Sesame paste used in Asian cuisine is made from entire unhulled sesame seeds, whereas the Middle Eastern tahini is made from hulled seeds[7].

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[6] Source: http://www.sesamegrowers.org/worldstatusofsesame.htm
[7] Source: http://en.wikipedia.org/wiki/Tahini

7.2.2.2   Tahini

Other names for tahini include sesame paste, tehinah, tehena and tehineh. Tahini consists of 18-25% protein, 44-59% fat (oil), ~13.5% carbohydrate, 2.3% fibre, 3-5% ash and <1% moisture (Sawaya *et al.*, 1985 and as summarised by Elleuch *et al.*, 2007).   Tahini is produced from sesame seeds that have been sieved to remove foreign matter, dehulled (mechanically or by the use of salt water), re-sieved to remove hulls, washed in water (may be hot water, e.g. 50°C), dried under hot air (e.g. spin-dried 80°C for 15 minutes), then roasted, cooled and ground to a paste (Elleuch *et al.*, 2007; Brockmann *et al.*, 2004; Kotzekidou, 1998). The reported roasting regimes vary; one hour under "6 grills" so that the temperature of the seed at the end of roasting is 120°C (Elleuch *et al.*, 2007), 100°C for 2.5-3 hours (Birer, 1985, reproduced by Sengun *et al.*, 2005), up to 2 hours at 120, 150 or 180°C (Kahyaoglu and Kaya 2006). A lower temperature roasting (80-90°C) was reported by (Kotzekidou, 1998). Kahyaoglu and Kaya (2006) report the widespread use of rotary drum roasters in Turkey.   The roasted seeds are ground into a viscous oily paste.   Grinding generates heat and the temperature of the product at this stage can reach 130°C (Brockmann *et al.*, 2004).   One paper suggests that there may be recycling of the sesame paste during grinding (Akyurt *et al.*, 2010), which would produce a smoother product. When bottled, the tahini made by this process separates slightly with a layer of oil settling on the top of the product.

The information available in the literature suggests that most tahini is made from hulled and roasted seeds, though unhulled, roasted seeds may also be used.   However, there is no information to confirm that all tahini is produced from roasted seeds. It is possible that some tahini is manufactured without a roasting step.

The water activity (a_w) of tahini analysed from manufacturing plants in Jordan ranged from 0.12 to 0.18 (average 0.16). The average pH was 5.9 (range 5.8-6.0) (Yamani and Isa, 2006).

Hummus (also called homous, hummous and hoummos) is made with tahini, mashed cooked chickpeas, lemon juice, olive oil, salt and garlic. A simple tahini-based sauce (tarator) consists of tahini, lemon juice, salt and garlic, thinned with water. Due to the lemon juice, the pH is usually around 5.5 although has been recorded as high as pH 7. The presence of lactic acid bacteria in hummus has also been reported as a possible inhibitory hurdle (Yamani and Al-Dababseh, 1994).

Assuming roasting occurs during production, it is likely that the presence of pathogens in tahini is the result of post-roasting contamination.

Standards:

- The NZFSA has put in place an Imported Food Requirement for tahini or crushed sesame seeds or any products containing these (NZFSA, 2009g). Products must have nil *Salmonella* per 25g.
- The Codex Standard for "Tehena" is 259-R-2007. This standard specifies composition, quality and hygiene standards and does not specify standards for microbiological contamination.

7.2.2.3 Halva

There are many other names for halva, including halawa, halaweh and havah. Halva is the name given to a large range of confections made in the Middle East, Central Asia and India. The main ingredient used as the base of halva varies widely, e.g. semolina, flour, vegetables such as carrots, potatoes, beetroots, winter melons, yams and squashes, fruit purées, puréed lentils or mung beans, or egg (Davidson, 2006). The halva best known in Europe and North America is made from ground sesame seeds, and only this type is considered in this Risk Profile.

Sesame-based halva is made by manually mixing ground sesame seeds (tahini) with acidified heated glucose syrup at 120°C to 140°C. The sugar concentration of the syrup is at least 80° Brix (i.e. 80 g w/w sugars to 20 g water in a 100 g solution). Flavours (e.g. vanilla) and other ingredients such as pistachios, walnuts and cocoa powder can be added to the hot mass before packaging (Brockmann *et al.*, 2004; Kotzekidou, 1998). Traditional recipes consist of tahini, sugar (or honey), citric acid and *Saponaria officinalis* (soapwort) root extract. The ratios are 50% tahini, 25-35% sugar, 12-25% glucose and 1% additives (flour, whipping agents).

A chemical analysis of 120 turkish halva samples (Kahraman *et al.*, 2010) found the following mean composition:

- 31.0% sesame oil (range 24.5-40.2%)
- 63.9% tahini, calculated as sesame oil x 1.9 (range 46.6-76.4%)
- 42.8% sugar (range 32.7-46.2%)
- 14.3% protein (range 11.1-17.4%)
- 1.8% moisture (range 1.0-2.5%)
- 1.6% ash (range 0.8-2.4%)
- 0.7% acidity, an indicator of oil freshness (range 0.1-1.2)
- 7.2 meq/kg peroxide value, an indicator of oil oxidation that is used to measure the effectiveness of storage conditions (range 4.2-16.4).

Moisture-proof wrappers are usually used to protect against relative humidity in the atmosphere. The pH of the final product is 6 and the moisture content is <3% (Kahraman *et al.*, 2010; Kotzekidou, 1998).

7.2.2.4 Peanuts

Peanuts (groundnuts, monkey nuts, earth nuts) are harvested by machines, shaken to remove excess soil and positioned upside down in the field in windrows to dry in the sun for two to three days. The peanuts can then be shelled and packed for further processing.

Standards:

- The NZFSA has put in place an Imported Food Requirement for peanuts (and pistachio nuts) but this is only for regulating aflatoxin levels (NZFSA, 2009e).
- Codex Standard 200-1995 specifies the composition, quality and hygiene standards for peanuts intended for human consumption.

7.2.2.5 Peanut butter

Peanut butter manufacturers place fresh peanuts into a hot air roaster at 180°C - 240°C. The ovens are designed to ensure an even roast. Rapid cooling to 30°C arrests the cooking process and retains natural oils in the peanut. Where peanut butter is made without the peanut skins, the peanut travels through rubber belts that gently rub off the outer skin – this process is known as blanching. The kernels are split, hearts removed and the kernels are finally ground in two stages: firstly as peanuts alone, and then with added ingredients (salt, sweeteners and stabilizers). The grinding time is controlled to prevent heat generation and resulting off-flavours (the heat generated during grinding and milling is typically 71-77 °C for approximately 20 minutes). Some brands also contain additional vegetable oils to make the product more spreadable. Natural peanut butters do not contain any added oil or stabilizers so oil can separate out and needs to be stirred back in before use. The final product is a highly concentrated colloidal suspension of lipid and water in a peanut meal phase. The product is usually pasteurised at 70-75°C for 20 minutes or less before being hot filled into jars (Burnett *et al.*, 2000; Ma *et al.*, 2009; Shachar and Yaron, 2006).

In the USA, peanut butter must contain a minimum of 90% peanuts with no artificial sweeteners, colours or preservatives (except salt). Peanut butter spreads contain 60% peanuts and additional sugar and/or salt. The water activity of commercial peanut butters in a study from the United States ranged from 0.20 to 0.33, the fat content was approximately 55%, the water content was 0.5-2%, and the pH was 6.1-6.4 (Burnett *et al.*, 2000).

Standards:

- Under the Australia New Zealand Food Standards Code (Standard 1.1.2), peanut butter is defined as a peanut-based spread containing no less than 850 g/kg of peanuts.
- The NZFSA has put in place an Imported Food Requirement for peanut butter to protect consumers from aflatoxins and *Salmonella* (NZFSA, 2009a). Products must have nil *Salmonella* per 25g.

7.2.2.6 Cocoa beans

There are three main types of cocoa bean; criollo, forastero and trinitario. In New Zealand the forastero cocoa bean and its derivatives are generally used for chocolate.

Cocoa pods contain the beans and a pulp. The mixture is removed from the pods and fermented to break down and remove the pulp and to start development of the chocolate flavour. During fermentation, natural microflora are allowed to grow and these modify oxygen levels, pH and temperature (up to 50°C). Fully fermented beans carry yeasts, acetic and lactic acid bacteria and thermophilic *Bacillus* species. After fermentation, the beans are dried and the final water content is <8% (Betts, 2008).

7.2.2.7 Chocolate

Chocolate is any product made primarily of cocoa solids and cocoa fat (cocoa butter). Production costs are lowered by reducing the cocoa solid content or by substituting cocoa butter with a non-cocoa fat.

Unpressed cocoa mass is processed into chocolate by mixing in fats (either additional cocoa butter or other vegetable fat) and sugar. Sometimes vanilla or lecithin (an emulsifier) will be added (dark chocolate). To make milk chocolate, the cocoa mass will be cooked with condensed milk and sugar to make milk chocolate crumb, which is remixed with cocoa liquor and cocoa butter. The chocolate or milk chocolate mixture is then refined, conched (mixed in a container with metal beads, which homogenises the cocoa and eliminates a gritty texture), and tempered (controlled crystallisation to maintain texture). White chocolate is made from cocoa butter, sugar, vanilla and milk or milk powder.

Dried beans can be stored for 3 to 12 months before processing, although prolonged storage can result in staling. Dried beans are cleaned, with foreign bodies removed, and roasted at 105-150°C for up to 2 hours to further develop the chocolate taste (Betts, 2008). The microflora of the cocoa bean before and after roasting at 150 °C has been determined (Barrile *et al.*, 1971). The detectable number of micro-organisms per gram of bean before roasting ranged from 3×10^5 to 4.7×10^7. After roasting for 40 minutes the loading was 10^3 to 1.6×10^5 organisms per gram. The genus *Bacillus* accounted for 91% of the 277 bacteria isolated before and after roasting. All isolates from roasted beans were *Bacillus* spp. No salmonellae were identified in this study.

After roasting, the beans are graded then broken and shelled. Air current technology separates the broken bean cotyledons or "nibs" from the shells. The nibs are ground between steel rollers and liquefied to make a chocolate liquor known as "mass". During the grinding, the starchy component of the bean becomes a fine powder, the temperature also rises and the fat component (cocoa butter) (~50-58%) melts. The molten fat covers the ground cocoa solid. The mass is cooled so that it solidifies then pressed to extract the cocoa butter. The remaining presscake of solid compressed cocoa (known as cocoa cake) is finely ground into a high-grade cocoa powder. Unpressed cocoa mass, cocoa butter and cocoa powder are imported into New Zealand. These derivatives can be used in various compositions to make different types of chocolate.

Standards:

- Under the Australia New Zealand Food Standards Code (Standard 1.1.2), chocolate is defined as a confectionery product characterised by the presence of cocoa bean derivatives. It should be prepared from a minimum of 200 g/kg of cocoa bean derivatives and should contain no more than 50 g/kg of edible oils, other than cocoa butter or dairy fats. Cocoa is defined as the powdered product prepared from cocoa beans from which a portion of the fat may have been removed, with or without the addition of salt and/or spices.
- Codex Standards 87-1981 (revised 2003) determine the essential composition quality and hygiene factors for chocolate and chocolate products. The Standard contains a useful summary table of the chocolate types and their constituents in percentage terms. Chocolate (bittersweet chocolate, semi-sweet, dark) contains not less than 35% total cocoa solids (of which > 18% shall be cocoa butter and > 14% shall be fat-free cocoa solids). The other main types of chocolate that have composition specifications are sweet, couverture, milk, family milk, milk chocolate couverture and other (including white).

- There are Codex Standards for the composition and hygiene of cocoa mass and cocoa cake (Standard 141-1983, revised 2001) cocoa butter (Standard 86-1981, revised 2001) and cocoa powders (Standard 105-1981, revised 2001).

7.2.3   Behaviour of *Salmonella* spp. in foods from peanuts, sesame seeds, and cocoa beans

Sesame seeds, cocoa beans and peanuts are all grown in pods so any *Salmonella* spp. contamination would be expected to occur after the seeds, beans or nuts are released from their pods naturally (e.g. as sesame pods dry) or during harvesting. These food ingredients may also be contaminated during transportation, processing (e.g. fermenting cocoa beans) and storage.

The potential for long-term environmental persistence of *Salmonella* spp. in harvesting areas has been demonstrated in almond orchards. In 2001, *S*. Enteritidis PT30 was isolated from three Californian farms linked to an outbreak associated with the consumption of raw almonds. The long term persistence of the pathogen over a five-year period was evaluated using swabs dragged across the orchard floor (Uesugi *et al.*, 2007). In general, isolation frequency increased during and immediately after harvest when large amounts of dust were generated. All 53 *Salmonella* spp. isolates over the study period were identified as *S*. Enteritidis PT30. Although this illustrates long term persistence of *Salmonella* spp. in dust, the potential for contamination of products depends on whether contaminated dust is present during processing and the adequacy of controls.

No studies on the survivability of *Salmonella* spp. on the dried surfaces of sesame seeds, cocoa beans or raw peanuts were located. The tolerance of *Salmonella* spp. to desiccation has been demonstrated in a model system (Hiramatsu *et al.*, 2005). Eighteen *Salmonella* strains were dried onto paper discs at 35°C and stored at various temperatures. At an inoculum level of 10^7 CFU/disk, 14/18 disks contained salmonellae that survived the drying process with populations of 10^3-10^4 CFU/disk. After drying, four selected strains of salmonellae (*S*. Oranienburg, *S*. Chester, *S*. Enteritidis, *S*. Litchfield) survived for 22-24 months stored at 4°C; all were recoverable after the storage period at similar concentrations to the starting populations. In contrast, the concentrations of five *Salmonella* strains dried on to disks were reduced to below the detection level (< 2 $\log_{10}$ CFU/disk) after 35-70 days at 25°C-35°C.

7.2.3.1   Tahini and halva

No studies that assessed the ability of *Salmonella* spp. to survive in tahini were located. The stability of *S*. Enteritidis inoculated into halva under a range of test conditions has been reported (Kotzekidou, 1998), and this is described in Section 2.3.3.1.

7.2.3.2   Peanuts and peanut butter

The survivability of *Salmonella* spp. on nuts has been reported. *S*. Senftenberg, *S*. Anatum and *S*. Typhimurium survived storage on pecans stored at -18, -7, 5 and 21°C for several weeks. *S*. Senftenberg and *S*. Anatum were not detectable on in-shell nuts after 16 weeks at 21°C but there was little decrease in viable populations when storage was at -18, -7 and 5°C for 32 weeks (Beuchat and Heaton, 1975).

The desiccation tolerances of five *Salmonella* spp. on roasted peanuts has been reported (Hiramatsu *et al.*, 2005). *Salmonella* serotypes Oranienburg, Chester, Enteritidis, Litchfield and Typhimurium were inoculated onto roasted peanuts which were then dried at 25°C for 24 hours. All five strains survived on the roasted peanuts at numbers approximately 100-fold higher than on paper discs used as controls. This experiment was repeated with chocolate and the same results were observed (Hiramatsu *et al.*, 2005).

The survival characteristics of high (5.68 $\log_{10}$ CFU/g) and low (1.51 $\log_{10}$ CFU/g) inocula of a five-serotype mix of *Salmonella* spp. in five commercial peanut butters and two spreads have been determined (Burnett *et al.*, 2000). The serotypes were *S*. Agona, *S*. Enteritidis, *S*. Michigan, *S*. Montevideo and *S*. Typhimurium. The inoculated samples were stored for 24 weeks at 5 or 21ºC. In the high inoculum samples, after an initial decline of approximately 2 $\log_{10}$ CFU/g, further reductions in concentration were slow, and all but one sample had viable salmonellae after 24 weeks. Survival was better at the refrigeration temperature. Similar results were observed for the low inoculum products.

This observation was supported by a study of the survival of *S*. Tennessee in five commercial brands of peanut butter (Park *et al.*, 2008). A three strain mixture was inoculated into the peanut butter at 6-7 $\log_{10}$ CFU/g and the food stored at either 4 or 22°C. Over 14 days the population decreased by 0.15-0.65 $\log_{10}$ CFU/g at 4°C and 0.34 – 1.29 $\log_{10}$ CFU/g at 22°C. There was a statistically significant difference between the decreases at each temperature for only one of the five products.

The heat tolerance of *Salmonella* spp. in peanut butter has also been demonstrated, with survival even after treatment at 90°C for 50 minutes. The heat resistance of *S*. Agona, *S*. Entertidis, and *S*. Typhimurium has been shown to dramatically increase when the bacteria are in peanut butter (Shachar and Yaron, 2006). All three serovars were found to be rapidly killed at 70°C in saline (7 $\log_{10}$ CFU/g reduction in 5 minutes). Preheated peanut butter inoculated with either 5.4 or 8.4 $\log_{10}$ CFU/g of each serotype was heated at 70, 80 or 90°C for up to 50 minutes. An initial decline of up to 2.6 $\log_{10}$ CFU/g was observed in the first 5 minutes, from 5 to 20 minutes further reductions were modest, and after 20 minutes bacterial numbers stabilised, at approximately 1.5 and 5 $\log_{10}$ CFU/g for each inoculum level respectively.

Another experiment exposed *Salmonella* spp. in peanut butter to a heat treatment of 80°C for 30 minutes, during which the expected 3 $\log_{10}$ CFU/g decline was observed (Shachar and Yaron, 2006). A second heat treatment of 70, 80 or 90°C was then applied for up to 50 minutes. Over this time the decline in numbers was smaller, less than 2 $\log_{10}$ CFU/g. The authors hypothesised that the *Salmonella* spp. cells aggregated into clumps in different microenvironments within the peanut butter, and the least protected bacteria would die rapidly followed more slowly by bacteria in other environments. It was proposed that the low water activity/high fat areas were the most heat protective. They also concluded that thermal treatments are inadequate to consistently destroy *Salmonella* spp. in highly contaminated peanut butter, and the pasteurisation step would not be enhanced by longer times or higher temperatures. *Salmonella* spp. are likely to survive in peanut butter for the duration of its expected shelf life.

Studies of *Salmonella* spp. serovars using low water activity model systems (sugar broths) have investigated heat tolerance (Mattick *et al.*, 2001). *S*. Typhimurium DT104 inocula were

tested with 54 combinations of temperature (55 to 80°C) and a_w (0.65 to 0.90). The results were used to construct thermal inactivation model curves which were then compared to results from inoculation into blended foods. In pecorino cheese, pepperoni sausage, strawberry jam and dried apricots, *S*. Typhimurium died more quickly than predicted by the broth models. However, in peanut butter (a_w = 0.50 and pH = 6.1) and coconut cake, *S*. Typhimurium survived longer than predicted. The times/temperatures for a 1.5 log reduction in peanut butter were: 98 minutes at 55°C (predicted 13.6 minutes), 24 minutes at 65°C (predicted 5.6 minutes) and 6 minutes at 74°C (predicted 1.7 minutes).

The rate of inactivation of three *S*. Tennessee strains associated with an outbreak caused by contaminated peanut butter have been compared to that of strains from sporadic cases and other serotypes (Ma *et al.*, 2009). Commercial peanut butter was inoculated and heated at 71, 77, 83 and 90°C. The calculated minimum times to achieve a 7 $\log_{10}$ CFU/g reduction in numbers at 90°C were longer for the outbreak strains (120 minutes) than strains from sporadic cases and other serotypes (55 and 86 minutes respectively).

7.2.3.3 Chocolate

Serotype-specific D values for *Salmonella* spp. in chocolate are shown in Table 5.

Table 5: **Serotype-specific D-values for *Salmonella* spp. (from Doyle and Mazzotta, 2000)**

Salmonella serotype	Medium	D-value (minutes)				Reference
		70°C	71°C	80°C	90°C	
Typhimurium	Molten milk chocolate	678-1050	396[1]	222	72-78	2
Senftenberg 775W	Molten milk chocolate	360-480	276[1]	96-144	36-42	2
Eastbourne	Molten chocolate (in thin film)		270			3
Anatum	Molten chocolate 0% moisture		1200			4
Anatum	Molten chocolate 1% moisture		510			4
Anatum	Molten chocolate 2% moisture		240			4
Anatum	Molten chocolate 4% moisture		210			4

[1] D-values at 71 °C were from Lee *et al.*, 1989.
[2] Goepfert and Biggie, 1968.
[3] Lee *et al.*, 1989.
[4] Barrile and Cone, 1970.

A critical factor in the heat resistance of salmonellae is the available moisture (water activity). *S*. Senftenberg is usually considered to have higher heat resistance than other strains in moist foods, while other strains of salmonellae are reported to have higher heat resistance than *S*. Senftenberg in foods of low water activity (Goepfert *et al.*, 1970). The

authors studied eight strains of *Salmonella* in solutions and observed that all strains tested showed greater heat resistance than *S*. Senftenberg as the environment became drier. Sucrose afforded greater protection compared with fructose, glycerol and sorbitol. Sucrose was also significantly more effective than salt and glycerol in protecting *Salmonella* spp. at 60°C in solutions of aw = 0.85-0.98.

The heat resistance of *S*. Anatum in milk chocolate at 71°C was greatly reduced by the addition of 1-4% moisture (Barrile and Cone, 1970). Water added in amounts greater than 6% resulted in irreversible separation of fat from chocolate mass.

Analysis of chocolate inoculated with 10^6 CFU/g and 10^3 CFU/g of *S*. Eastbourne and *S*. Typhimurium after the conching stage of production found that *S*. Eastbourne could be recovered after 9 months storage, but *S*. Typhimurium could not (Tamminga *et al.*, 1976). Both serotypes were inactivated more rapidly in bitter chocolate than in milk chocolate. A possible reason for the observation in milk chocolate is the lower level of cocoa, which contains compounds that have an antimicrobial effect, and the presence of casein, which diminishes this antimicrobial effect (Busta and Speck, 1968; Park *et al.*, 1979; Zapatka *et al.*, 1977).

S. Typhimurium and *S*. Enteritidis were both detected in milk and bitter chocolate stored for 15-18 months at room temperature (Rieschel and Schenkel, 1971 (in German) cited in (D'Aoust, 1977)). *S*. Napoli was still detectable after 12 months in chocolate bars implicated in a UK outbreak (Werber *et al.*, 2005). There is also evidence that salmonellae survive for up to 13 years in chocolate stored at ambient temperature, although this appears to be strain specific (Hockin *et al.*, 1989).

Survival of *Salmonella* spp. in cocoa powder is enhanced by low water activity. *S*. Montevideo and *S*. Heidelberg were inoculated (approximately 10^6 CFU/g) into cocoa powder and stored at 25°C (Juven *et al.*, 1984). Three different water activities were used; 0.43 (5.3-5.4% water content), 0.52 (6.2-6.5%) and 0.75 (10.2-10.8%) (Note: nib cocoa powder is marketed with water activity below 0.45). At a_w 0.43 both serotypes declined by approximately 4 $\log_{10}$ CFU/g after one week, but were detectable in cocoa powder for up to 7 weeks, while at a_w 0.75 neither serotype was detected after one week.

In a recent study, the fate of *Salmonella* spp. in dry confectionery raw materials (cocoa butter oil, crushed cocoa and hazelnut shells, whole almond kernels and cocoa beans) was investigated (Komitopoulou and Penaloza, 2009). The strains used originated from chocolate associated outbreaks (*S*. Napoli, *S*. Oranienburg (1), *S*. Montevideo, *S*. Enteritis PT30), from chocolate (*S*. Poona, *S*. Oranienburg (2)) and from culture collections (*S*. Typhimurium LT2 and *S*. Senftenberg 775W). Both lawn-collected (from a plate surface) and broth grown inocula were used (lawn-collected cells display similar attributes to cells in biofilms and can display more resistance to stressors).

Once inoculated into each ingredient, each sample was stored at either 21°C or 5°C for up to 21 days. Survival was high (general decline over a 21 day period was 1-2 $\log_{10}$ CFU/ml) although the ability of *Salmonella* spp. to survive in dry conditions was strain and food matrix dependent. Overall, of the eight strains tested, the two outbreak strains *S*. Oranienburg (1) and *S*. Enteritidis PT30 consistently showed the highest survival potential.

Storage at 5°C maintained cell viability significantly better compared to room temperature storage. In general, lawn collected cells were better able to survive than broth cells.

Coconut may be added as an ingredient to chocolate and is also defined as a tree nut. Raw coconut meat also has high lipid content (up to 33%). Raw, unprocessed coconut supports the growth of salmonellae. Desiccation to 2-4% moisture content reduces microbial loading but is insufficient to destroy all salmonellae (Doyle and Mazzotta, 2000). Roasting is ineffective and leads to discolouration and general deterioration. However, pasteurisation of raw coconut meat by incubation in a water bath at 80°C for 8 to 10 minutes effectively kills *Salmonella* and results in an organoleptically acceptable product. This process is now widely used by the coconut industry (Schaffner *et al.*, 1967).

7.3   Prevalence of *Salmonella* in sesame seeds, peanuts, cocoa beans and their products overseas

Overseas data for the prevalence of *Salmonella* spp. in sesame seeds and sesame products is collated in Table 6. The prevalence of *Salmonella* spp. in other seeds is also presented where data were presented in the same source documents.

Overseas data for the prevalence of *Salmonella* spp. in surveys that included peanuts are shown in Table 7. In the Australian survey, *S.* Fremantle is an Australian environmental serovar rarely reported clinically in humans (82 Australian cases since 1990). It is found in waters, kangaroos, feral goats, camels, reptiles and soils (Eglezos *et al.*, 2008). This positive sample is likely to have occurred at the orchard level.

No food source was identified in an outbreak of *S.* Schwarzengrund infections in England and Wales involving 98 cases from November 2006 to February 2007 (HPA, 2007). From the 98 cases, 81 shared the same pulsed field gel electrophoresis (PFGE) profile. A link with Brazil nuts was made suggested by Little *et al.*, but was not proven (Little *et al.*, 2008). In late 2007, a confectionery company closed four production lines of coated Brazil nuts due to isolations of *S.* Schwarzengrund from the final product. The PFGE from these tests was indistinguishable to the earlier outbreak isolates.

No surveys on the prevalence of *Salmonella* spp. in peanut butter, cocoa beans or chocolate were located.

Table 6: **Overseas data on the prevalence of *Salmonella* spp. in sesame seeds (and other seeds) and sesame products**

Country	Year	Food tested (No. samples)	No. positive (%)	*Salmonella* serotype	Reference
Germany	2001	- Sesame paste (12) - Halvah (71) - Sesame seed (16) - Pastry (5) - Sesame oil (7) - Cereal (6) Total (117)	1 (8%) 8 (11%) 2 (13%) 0 0 0 11 (9.4%)	Typhimurium DT 104, Typhimurium DT 134, Offa, Tennessee and Poona	Brockmann *et al.*, 2004
Saudi Arabia	1982/83	Tahini (50) from 10 processing plants[1]	2/10 (20%) plants positive	Hadar, Agona, Einsbuettel, Ubrecht	Ayaz *et al.*, 1986
Jordan	2006?	Tahini (42) from 14 manufacturing plants[2]	0/42	n/a	Yamani and Isa, 2006
Turkey	2007-2008	Halva (120) from producers and retailers in the Marmara region	0/120	n/a	Kahraman *et al.*, 2010
Turkey	2005?	Halva (63) from retail markets in Izmir	0/63	n/a	Sengun *et al.*, 2005
Turkey	1988?	Halva (93) from supermarkets	1/93	n/a	Özkaya, 1988, interpreted in Kahraman *et al.*, 2010
England & Wales	2001	Halva (151)	6 (4%)	Typhimurium DT 104	Little, unpublished cited in Willis *et al.*, 2009
England & Wales	2003	Sesame seed products (160)	25 tahini samples from Lebanon and Cyprus (15.6%)	Cubana, Lille, Mbandaka, Senftenberg, Tennessee	Personal communication cited in Willis *et al.*, 2009
England (London)	2006	Edible seeds (367)	7 (2%)	Ahmadi, Give, Senftenberg, Shangani, Muenster	Personal communication cited in Willis *et al.*, 2009

Country	Year	Food tested (No. samples)	No. positive (%)	*Salmonella* serotype	Reference
United Kingdom	2007-2008	RTE dried seeds (3735) from 3390 retail premises - Sesame (771) - Linseed (284) - Sunflower (976) - Alfalfa (58) - Melon/egusi (47) - Mixed seeds[3] (350)	23 (0.6%) 13 (1.7%) 1 (0.4%) 1 (0.1%) 1 (1.7%) 4 (8.5%) 3 (0.9%)	Drypool, Agona, Bergen, Binza, Chittagong, Virchow, Sculcoates, Montevideo, Newport, Schwarzengrund, Senftenberg, Tennessee.	Willis *et al.*, 2009

[1] Five samples amalgamated from each plant.

[2] Three samples taken from a single batch in each plant and analysed after 0, 2 and 4 months.

[3] Mixed seeds containing sesame, contamination 3/228 (1.3%). Mixed seeds with no sesame 0/122.

Table 7:   Overseas data on the prevalence of *Salmonella* spp. in peanuts and other nuts

Country	Year	Food tested (No. samples)	No. positive (%)	*Salmonella* serotype	Reference
Australia	2003-2006	-Peanuts (pre-roasted) (653) -Almonds (pre-roasted) (60) -Cashews (pre-roasted) (100) -Hazelnuts (pre-roasted) (48) -Brazil (pre-roasted) (60)	0 1 (0.016) 0 0 0	 Fremantle	Eglezos *et al.*, 2008
Australia	2003-2006	-Peanuts (RTE) (343) -Almonds (RTE) (42) -Cashews (RTE) (45) -Hazelnuts (RTE) (51) -Brazil (RTE) (40)	0 0 0 0 0		Eglezos, 2010
England	2008	Retail RTE nuts[2] (727) -Pistachios (25) -Peanuts (26)	1 (0.1) 1 (4) 0	 Havana	Little *et al.*, 2009
United Kingdom	2008-2009	Retail RTE nuts[3] (2,886) -Brazil nuts (469) -Mixed nuts (5 types of nut, including peanuts) (105) -peanuts (148)	3 (0.1) 2 (0.4) 1 (0.9) 0	 Senftenberg (0.23 MPN/g) Senftenberg and Tennessee (0.09 MPN/g)	Little *et al.*, 2010

[1] The rest of the serovars (28 in total) numbered 2 and 1 each.

[2] Roasted nut kernels only, raw kernels were excluded. *Salmonella* spp. were not detected in all varieties of nuts tested except pistachios (i.e. almonds, Brazils, cashews, hazelnuts, macadamia, peanuts, pecans, pine nuts and walnuts).

[3] *Salmonella* spp. were not detected in all varieties of nuts tested except brazil nuts (i.e. almonds, Brazils, cashews, hazelnuts, macadamia, peanuts, pecans, pine nuts, pistachios, walnuts, chestnuts, soya nuts and mixed nuts).

NS: Not stated

7.4   Overseas recalls

This section provides a summary of relevant food recalls from Australia, Canada, the EU, the UK and the USA. Recalls are not necessarily linked to human illness. It is not intended to be an extensive list of all recalls but provides an indication for how often recalls have been issued for the high lipid foods considered in this Risk Profile.

It was necessary to take different approaches with each recall database since these operate in different ways. Searches were restricted to the period January 2006 to the most up-to-date information available (the searches were conducted in September 2010), except for Australia, where records back to 2000 were readily available, and for the USA where the search was restricted to January 2008-September 2010. The sources and methods used to retrieve the recall data were as follows:

Australia: Food recalls recorded by FSANZ from 2000 to September 2010 were scanned for relevant records.[8]

Canada: All recalls reported by the Canadian Food Inspection Agency from January 2006 were scanned for relevant records.
(Source: http://www.inspection.gc.ca/english/corpaffr/recarapp/recal2e.shtml).

EU: A search function (portal) was used to retrieve records from the Rapid Alert System for Food and Feed, from January 2006. There are 31 countries that participate in this system (including the UK).[9]
(Source: https://webgate.ec.europa.eu/rasff-window/portal/)

UK: All recalls reported by the UK Food Standards Agency from January 2006 were scanned for relevant records.
(Source: http://www.food.gov.uk/enforcement/alerts/)

USA: The USFDA website has an extensive database of recalls. The advanced search function was used to identify relevant recalls.
(Source: http://www.fda.gov/Safety/Recalls/default.htm)

Where recall reports clearly involved the same product, these have been combined in the following tables.

7.4.1   Tahini and halva recalls

In Australia, FSANZ issued seven recalls for potential *Salmonella* contamination of tahini or halva from 2000 to 2010:

- 2001: Three recalls for halva sold manufactured by the same company and associated with an outbreak (see Table 13, Appendix 2).

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[8] The FSANZ website (http://www.foodstandards.gov.au) only contains recent recalls. The full dataset was kindly provided by FSANZ
[9] Search function parameters entered: Notified between 01/01/2006 and 31/08/2010; Type = Food; Classification = alert; Hazard category = pathogenic microorganisms. 621 records retrieved, which were sorted by product category and scanned.

- 2002-03: One recall for hummus and baba ghanoush in 2002. In addition, there were two recalls of tahini and one of halva as a result of outbreak investigations and routine testing (Unicomb *et al.*, 2005).

Recalls of possible *Salmonella* contamination of tahini or halva extracted from the other databases are listed in Table 8. In addition, there were multiple recalls across the years 2007 and 2008 due to *Salmonella* contamination of sesame seeds (e.g. hulled sesame seeds, mixed seeds that included sesame seeds). There were various countries of origin reported for these seeds: Egypt, India, Bolivia, Iran, Burkina Faso, and Italy.

Table 8: **Recalls of tahini, hummus or halva due to the possibility of *Salmonella* contamination: Canada, EU, UK and the USA (2006-2010)**

Country/countries where recalled	Date of recall notice (month, year)	Product[1]	Product country of origin
Ireland	February 2007	Houmous	UK
UK	March 2007	Tahini	Greece
Germany, France, Netherlands	March 2007	Halva	Turkey
USA	May 2007	Tahini	Not specified
Canada, USA	May, August, September 2007	Organic raw sesame tahini, organic roasted sesame tahini, natural sesame tahini, dressing containing tahini	USA
Belgium, Germany, France, Poland, Spain, UK	July 2007	Halva	Greece
UK	April, 2008	Houmous	Not specified
UK	March 2009	Halawa	Not specified
Germany, France, Netherlands, Switzerland	April 2009	Halva	Turkey
Canada	May 2009	Tehina	Not specified
USA	March 2010	Organic raw tahini	USA
Canada	August, 2010	Tahini	Lebanon
Canada	July 2010	Tahini	Packed in Quebec

[1] Product names are presented here as spelt in the original source

7.4.2 Peanut butter recalls

FSANZ did not issue any recalls of peanut butter due to possible *Salmonella* contamination from 2000 to September 2010.

Recalls of possible *Salmonella* contamination of peanut butter/paste extracted from the other databases are listed in Table 9. Many of these recalls are linked to the contamination of peanut butter and peanut paste by a large manufacturer in the USA in 2009, and further information on the subsequent salmonellosis outbreak is given in Appendix 2. Searches of the USFDA recall database revealed many recalls for possible *Salmonella* contamination of products containing peanut butter. A large proportion of these were associated with the 2009 recall since the contaminated peanut butter or peanut paste was used as an ingredient in many foods.

Table 9: **Recalls of peanut butter due to the possibility of** *Salmonella* **contamination: Canada, EU and UK (2006-2010)**

Country/countries where recalled	Date of recall notice (month, year)	Product	Product country of origin
Bahamas, Barbados, Bermuda, Cayman Islands, Cyprus, Iceland, Jamaica, Netherlands, Portugal, Saint Kitts and Nevis, Saint Lucia, Spain, Trinidad and Tabago, British Virgin Islands	February 2007	Peanut butter	USA
Canada	Multiple recalls throughout 2009	Various peanut butter products	USA
Belgium, Bulgaria, Croatia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovenia, Spain, Sweden, UK	January, February 2009	Snack bars containing peanut ingredients	Canada, USA

7.4.3 Chocolate recalls

FSANZ did not issue any recalls of chocolate due to possible *Salmonella* contamination from 2000 to September 2010.

Recalls of possible *Salmonella* contamination of chocolate extracted from the other databases are listed in Table 10, including a major recall in 2006 due to possible contamination with *S. Montevideo*. Searches of the USFDA recall database revealed many recalls for possible *Salmonella* contamination of products containing chocolate. However, it should be noted that many of these products contained other ingredients such as pistachios and peanuts, or were products where chocolate chips were an ingredient.

Table 10: **Recalls of chocolate due to the possibility of *Salmonella* contamination: Canada, EU and UK (2006-2010)**

Country/countries where recalled	Date of recall notice (month, year)	Product	Product country of origin
Antigua and Barbuda, Barbados, Bermuda, Canada, Cayman Islands, Cyprus, Faroe Islands, France, Gibraltar, Guyana, Iceland, Ireland, Kenya, Lebanon, Malta, Pakistan, Peru, Portugal, Singapore, Spain, UK, USA, Uruguay, Venezuela	June 2006	Chocolate bars and blocks	UK
Canada	October 2007	White chocolate baking squares	
Distributed to Belgium	May 2008	White imitation chocolate	Netherlands
Distributed to Czech Republic, France, Slovakia, Netherlands	January 2010	Chocolate products	Slovakia

8 APPENDIX 2: EVALUATION OF ADVERSE HEALTH EFFECTS

Salmonellae possess virulence determinants that enable them to adhere to small intestinal epithelial cells, provided they survive the low pH of the stomach and other innate immune host defence mechanisms (Jay *et al.*, 2003). After entering epithelial cells, pathogenic salmonellae may multiply within a protective vacuole. Disruption of cellular tight junctions, leading to paracellular passage of ions, water and immune cells together with induction of host inflammatory cells is likely to contribute to the production of diarrhoea (Haraga *et al.*, 2008).

The *Salmonella* serotypes that have been most commonly isolated from sporadic salmonellosis cases in New Zealand between 2000 and 2009 are shown in Table 11.

Table 11: *Salmonella* **serotypes that caused 50 or more cases over the years 2000 to 2009 – peak occurrence and total cases (Adlam *et al.*, 2010)**

Salmonella serotype	Peak occurrence[1]										Total cases
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Typhimurium DT160		+									**2,147**
Typhimurium DT1	+	+	+								**729**
Brandenburg	+	+									**700**
Typhimurium DT135	+	+									**698**
Typhimurium DT156	+	+									**562**
Infantis									+	+	**523**
Typhimurium DT101	+										**505**
Enteritidis PT9a	+	+									**432**
Typhimurium DT42	+										**257**
Saintpaul						+					**249**
Typhimurium DT12a							+				**237**
Typhimurium DT9	+										**182**
Typhimurium RDNC-May 06									+		**154**
Heidelberg		+									**150**
Virchow					+		+				**141**
Typhimurium DT74							+				**139**
Typhimurium DT23		+									**138**
Typhimurium RDNC[2]				+						+	**137**
Mississippi						+					**95**
Enteritidis PT4	+		+								**95**
Thompson							+				**92**
Agona							+				**92**
Weltevreden		+					+				**88**
Montevideo			+	+							**79**
Mbandaka							+		+		**76**
Newport		+					+				**68**

Salmonella serotype	Peak occurrence[1]										Total cases
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Stanley									+		65
Enteritidis PT6a									+		62
Corvallis							+				61
Salmonella sp. 4,5,12:d :-					+			+			59
Typhimurium DT8								+			58
Enteritidis PT1		+									58
Enteritidis PT1b									+		57
Hadar	+	+	+								55
Typhimurium RDNC Aug-01				+							50

[1] + denotes where number of cases exceeds ten year mean plus one standard deviation for a given serotype.

[2] Typhimurium RDNC is not a single serotype, but a grouping of serotypes. RDNC stands for 'reaction does not conform' and indicates that the isolate does not match any recognised serotypes. RDNC can sometimes be followed by the month and year of isolation.

Two serotypes that have caused major problems overseas are *S*. Enteritidis which is capable of transovarian transmission into eggs (especially PT4) and the antibiotic resistant *S*. Typhimurium DT104.

S. Enteritidis PT4 became the most prevalent *Salmonella* serotype causing human infection in the United Kingdom during the 1980s and 1990s. This was, in part, due to the fact that chicken eggs can be infected with *S*. Enteritidis PT4 internally or externally by the time they are laid, or can subsequently become contaminated after lay (ACMSF, 1993). Similar problems occurred in the USA, but involved a wider range of phage types.

New Zealand does not appear to have a reservoir of the phage types associated with transovarian transmission into eggs. The notified human cases of salmonellosis infected with *S*. Enteritidis PT4 have usually recently travelled overseas.

Antibiotic resistant *S*. Typhimurium DT104 is infrequently isolated from humans in New Zealand (one isolate in 2009). This type was not identified amongst the non-human isolates submitted to the Enteric Reference Laboratory in 2009 (ESR, 2009c).

8.1   New Zealand Salmonellosis Case Control Studies

There have been two case control studies of salmonellosis in New Zealand.

A study of *S*. Typhimurium DT160 was prompted by a marked increase in the number of DT160 human isolates which began in May 2001. The epidemic of *S*. Typhimurium DT160 infection among humans occurred in parallel with illness due to the same pathogen in wild birds, particularly sparrows. The organism was also isolated from poultry during 2001. The strongest finding from the case-control study was an association between infection with *S*. Typhimurium and direct contact with wild birds (mOR = 12.3, CI: 2.8-54.6). However, this high risk activity was associated with only a few cases.

The second case-control study was conducted by ESR in late January 2002 as a component of the NZFSA quantitative risk assessment of *Salmonella* spp. in New Zealand sheep meat

(NZFSA, 2002). The aim of the study was to quantify the incidence of human infection with *Salmonella* spp., in particular *S.* Brandenburg, and to estimate the contribution of New Zealand sheep meat consumption to this incidence. The results of the study have been reported (Baker *et al.*, 2007). Several factors were significantly associated with an elevated risk of salmonellosis, e.g. contact with other sick people (OR 8.73, 95% CI 2.08-62.91), overseas travel (OR 9.97, 95% CI 1.72-167.46). *S.* Brandenburg infection was significantly associated with occupational contact with live or dead sheep or lambs (OR 9.97, 95% CI 1.62-196.29) or having a household member who had occupational contact with sheep or lambs (OR 4.28, 95% CI 1.23-21.31). Overall the study indicated that infection with *S.* Brandenburg had not become a foodborne disease, and instead was an important zoonotic disease representing a risk to farmers and others with direct occupational contact with infected sheep.

8.2   Adverse Health Effects Overseas

Table 12 shows the reported incidence of salmonellosis (not including infections from *S.* Typhi or *S.* Paratyphi). New Zealand's five-year annualised rate of 31 per 100,000 (2005-2009) is comparable with Canada, Belgium, Denmark, the UK, Iceland and Norway.

Table 13 gives some examples of overseas salmonellosis outbreaks associated with high lipid sesame seed foods that have been reported in the literature. Table 14 shows outbreaks associated with peanuts, peanut butter, almonds, pistachios and coconuts and Table 15 gives some examples of outbreaks associated with chocolate and cocoa products.

A recent outbreak of *S.* Typhimurium PT3 in the USA (CDC, 2009a, 2009b) illustrates how peanut butter and peanut paste produced in one plant can be incorporated into many different food streams, and how difficult it is to investigate an "ingredient driven" outbreak. The investigation focused upon the consumption of peanut butter used in institutions and by peanut butter and paste used in food products, a particular risk being identified in peanut butter crackers. In January 2009, production of all peanut products was stopped by Peanut Corporation of America (PCA), and the company has subsequently filed for bankruptcy. Shipments of product were traced to approximately 2,100 accounts and sub-accounts. The ingredients had been used in cookies, crackers, cereal, candy, ice-cream, pet treats and other foods. A total of 2,833 peanut-containing products were recalled. The scale of distribution makes this one of the largest recalls in the United States. The number of cases has declined significantly since December 2008 but new cases are still occurring because consumers may be unaware that have a recalled product at home and many of the products have a long shelf life. The most recently reported illness began on 31 March 2009. Half of the cases were under 16 years old, 21% of cases were aged less than 5 years and 17% were aged over 59 years.

Table 12:   Reported incidence data for notified cases of salmonellosis overseas

Country	Incidence (cases/100,000)	No. of cases	Year	Reference
Australia	40.1	8,267	2006	1
Australia	44.6	9532	2007	2
Australia	38.9	8304	2008	2
North America				
USA	15.43	45,322	2005	3
USA	15.45	45,808	2006	4
Canada	29.61	9,594	2005	5
Canada	29.39	9,619	2006	5
Europe				
EU notifications	31.1	151,995	2007	6
Belgium	37.5	3,973	2007	6
Czech Republic	171.6	17,910	2007	6
Denmark	30.5	1,662	2007	6
Finland	51.9	2,737	2007	6
France	8.7	5,510	2007	6
Germany	67.3	55,400	2007	6
Ireland	10.2	440	2007	6
Netherlands	11.9	1,245	2007	6
Slovakia	155.1	8,367	2007	6
Spain	8.2	3,658	2007	6
Sweden	43.1	3,930	2007	6
United Kingdom	22.7	13,802	2007	6
Non EU countries				
Iceland	30.2	93	2007	6
Norway	35.2	1,649	2007	6
Switzerland	23.7	1,802	2007	6

References: All sources accessed during June and July 2007 or April 2009

1. www.health.gov.au/pubhlth/cdi/nndss Australian National Notifiable Diseases Surveillance System, www.ozfoodnet.org.au,
2. http://www9.health.gov.au/cda/source/Rpt_4.cfm Australian National Notifiable Diseases Surveillance System
3. www.cdc.gov/mmwr Historical summaries of Notifiable Diseases in United States 1974 – 2005
4. http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5553a1.htm Summary of Notifiable Diseases 2006
5. www.dsol-smed.phac-aspc.gc.ca Public Health Agency of Canada: Centre for Infectious Disease Prevention and Control.
6. www.eurosurveillance.org EFSA, 2009

Table 13:   Examples of overseas outbreaks of salmonellosis from consumption of sesame seed products

Country	Year	No. cases	Implicated food and serotype	Suggested reason for contamination	Reference
Australia, Sweden[1]	2001	17 27 (15 <10 yrs old)	Halva imported from Turkey (2 brands; pistachio, plain, vanilla and chocolate flavours) *S*. Typhimurium DT104[2]	Unknown	O'Grady *et al.*, 2001; De Jong *et al.*, 2001
New South Wales, Australia	2002	55	Tahini imported from Egypt *S*. Montevideo	Unknown. No food safety failures identified in the Australian retail outlets.	Unicomb *et al.*, 2005
Victoria, Australia	2003	3	Tahini imported from Lebanon *S*. Montevideo	Unknown. No food safety failures identified in the Australian retail outlets.	Unicomb *et al.*, 2005

[1] *S*. Typhimurium DT104 was isolated from the halva in Sweden and Australia. During 2001 there were also increased notifications of cases with *S*. Typhimurium DT104 in Germany, Norway and the United Kingdom. The Turkish halva was the suspected cause of the increased notifications in these countries (Aavitsland et al., 2001; Brockmann, 2001; Little, 2001b). There were 18 confirmed and 11 suspected cases in the Norwegian report (Aavitsland et al., 2001).

2. During the course of the investigation, *S*. Typhimurium U302 was isolated from one sample of the implicated brand of halva, and *S*. Oranienburg and *S*. Amsterdam were isolated from two samples of halva of a brand produced in Lebanon.

Table 14:   Examples of overseas outbreaks of salmonellosis from consumption of peanuts and peanut butter

Country	Year	No. cases	Implicated food and serotype	Suggested reason for contamination	Reference
USA (46 States), Canada	2008-2009	714 (1 case in Canada) (116 hospitalised, possible contribution to 8 deaths).	Peanut products distributed to institutions/manufacturers/food service. *S.* Typhimurium PT3[1]	Unknown	CDC, 2009a, 2009b
USA (47 States)	2006-2007	628	Serotype implicated detected in open jars of peanut butter from cases. *S.* Tennessee	A leaking roof and a sprinkler system were believed to be the vehicle of infection, washing *S.* Tennessee from the raw peanuts and peanut dust into the finished product.	Anonymous, 2007; CDC, 2007b
Australia[2] Canada England, Wales Scotland	2001	53 cases S. Stanley, 2 cases of S. Newport 34 cases S. Stanley, 10 cases of S. Newport 8 cases S. Stanley 2 cases S. Stanley Total 109 cases from 3 continents (97 cases S. Stanley, 12 cases S. Newport)	Imported peanuts, flavoured or roasted. *S.* Stanley and *S.* Newport	Unknown	Kirk *et al.*, 2004; Little, 2001a

Country	Year	No. cases	Implicated food and serotype	Suggested reason for contamination	Reference
Australia	1996		Peanut butter *S*. Mbandaka (*S*. Mbandaka and *S*. Senftenberg subsequently recovered from open and unopened jars)	Roasted peanuts identified as source. Auger blade used to move peanuts after roasting was contaminated with mouse faeces.	Ng *et al.*, 1996; Powell, 2009; Scheil *et al.*, 1998
England, Wales	1994-1995	27 cases (of which 26 were in children)	Peanut butter coated Kosher RTE savoury snack (imported from Israel) *S*. Agona PT15[3]	Unknown	Killalea *et al.*, 1996

[1] During the investigation, *S*. Tennessee was isolated from an unopened jar of peanut butter. The strain was indistinguishable from the *S*. Tennessee strain that caused the 2006/07 outbreak in peanut butter.

[2] Laboratories isolated *S*. Stanley, *S*. Newport, *S*. Kottbus, *S*. Lexington and *S*. Unnamed from the implicated brand of peanuts. The investigation in Australia led to wider investigations in Canada, England, Wales and Scotland. The peanuts originated from China but were distributed via Singapore and several major Asian cities.

[3] The peanut butter used for the coating was heated to 75 °C. Reporting of this outbreak lead to a case-control study in Israel, which also implicated the snack as the cause of incidence of *S*. Agona cases (Shohat et al., 1996).

Table 15:   Examples of overseas outbreaks of salmonellosis from consumption of chocolate and cocoa products

Country	Year	No. cases	Implicated food and serotype	Suggested reason for contamination	Reference
Sweden	Unknown	110	Cocoa powder *S*. Durham	Unknown	Gästrin *et al.*, 1972 (in Swedish) , cited in ICMSF, 1998
Canada (7 Provinces), USA (23 States)	1973-1974	119 (mostly children , average age 3 yrs; 38% cases hospitalised)	Chocolate balls *S*. Eastbourne.	Contaminated cocoa beans suggested as source. Contamination may have survived roasting (perhaps in the centre of foreign matter accompanying the raw beans) or cross contamination from raw bean dust to post-roasting beans cooled by blown air may have occurred. Recirculation of old and new chocolate between storage tanks and moulding plants probably contributed to prolonging the contamination.	Craven *et al.*, 1975
England, Wales	1982	245 (mostly children)*	Two types of chocolate bars produced in Italy *S*. Napoli.	Contaminated water used during processing (e.g. warm water jackets for storage vessels) was one possible source; *S*. Napoli had been isolated from water sources in northern Italy	Gill *et al.*, 1983
Canada, USA	1985-1986	29 in Canada 4 in USA (mostly children)	Gold-foil wrapped chocolate coins from Belgium *S*. Nima	Bacterial quality routinely monitored but tests did not include *Salmonella* spp.	Hockin *et al.*, 1989
Norway, Finland	1987	349 in Norway 12 in Finland (Median age 6 yrs)	Chocolate *S*. Typhimurium	Identical strain to that isolated from birds in the factory region – possible contamination of chocolate processing line by the birds.	Kapperud *et al.*, 1990

Country	Year	No. cases	Implicated food and serotype	Suggested reason for contamination	Reference
Germany, across Europe	2001-2002	439 Germany 16 Denmark 18 Sweden 6 Netherlands	Chocolate bar *S*. Oranienburg	Unknown	Anonymous, 2002; Werber *et al.*, 2005
United Kingdom	2006	42 (Median age 4 yrs)	Chocolate *S*. Montevideo	Leaking water pipe contaminated crumb.	Knowles *et al.*, 2007

* 600,000 of the implicated chocolates bars were sold. Four-fifths were withdrawn from the market which possibly averted a much large outbreak.

8.2.1 Case control studies

Case control studies investigating the causes of infection with *Salmonella* spp. where high lipid foods represented an elevated risk are summarised in Table 16.

Table 16: Case control studies of salmonellosis and high lipid foods overseas

Country	Risk/protective factors	Matched Odds Ratios (OR) (95% confidence interval, CI)	Reference
Germany, across Europe	Daily consumption of chocolate Shopping at large discount stores Consumption of chocolate from discount stores	OR: 4.8 (1.3-26.5) OR: 4.2 (1.2-23.0) OR: 5.0 (1.1-47.0)	Werber *et al.*, 2005
England, Wales	Consumption of kosher peanut snack	OR: 87.8 (7.5-2400)	Killalea *et al.*, 1996
Australia	Comprehensive questionnaire listing 105 foods (45 controls; 3 per case) Peanut butter -crunchy peanut butter -smooth peanut butter -generic brand Hot chips[1] Buns[1]	 OR: 6.5 (0.9-119.3) OR: 1.4 (0.3-5.1) OR: 2.7 (0.6-11.6) OR: 42.4 (lower CI=6.9 OR: 15.0 (1.3-525.5) OR: 6.0 (1.4-64.4)	Scheil *et al.*, 1998
USA	Eaten peanut butter Eaten peanut butter more than once a week Eaten implicated brand of peanut butter	OR: 1.9 (0.8-5.2) OR: 3.5 (1.4-9.9) OR: 10.9 (3.8-43.0)	CDC, 2007b
Canada, USA	Consumed almonds purchased in bulk from implicated retailer	OR: 21.1 (3.6-∞)	Isaacs *et al.*, 2005
USA	Eaten any peanut butter product in the 7 days before illness began[2] Eaten prepackaged peanut butter crackers in the 7 days before illness began -Austin peanut butter crackers -Keebler peanut butter crackers	OR: 2.53 (1.26-5.31) OR: 12.25 (5.51-30.9) OR: 29.68 (8.95-154.66) OR: 5.38 (1.74-18.32)	CDC, 2009a

[1] Statistically associated with illness but analysis by brand found no statistical association.
[2] There was no association with eating roasted peanuts or national jarred peanut butter sold in grocery stores.