The importance of hygiene in the domestic kitchen: Implications for preparation and storage of food and infant formula

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The importance of hygiene in the domestic kitchen: Implications for preparation and storage of food and infant formula

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Abstract

Aims: Public concerns relating to food safety remain high with most attention focused on manufactured foods and those served in catering operations. However, previous data have suggested that the home may be the main location for cases of food-borne disease. The aim of this paper is to review the microbiological risks associated with hygiene in the domestic kitchen related to food and infant formula safety.

Methods: Compared to other food sectors, research on consumer food hygiene, domestic food-handling and preparation of infant formula is relatively understudied. Behavioural and microbiological studies of consumer hygiene and the domestic kitchen have been reviewed to incorporate research relating to the safety of infant formula.

Results: Incidence data identify the home as an important location for acquiring food-borne disease. The domestic kitchen can be used for a variety of purposes and is often contaminated with potentially harmful micro-organisms such as *Campylobacter* and *Salmonella*. Consumer hygiene habits have frequently been found to be inadequate and relate both to microbial growth, survival and cross-contamination. Due to the reduced immune response of infants, the activities associated with the preparation of infant formula and associated bottles and equipment are of particular concern.

Conclusions: Cumulatively, the data suggest that more effort should be made to educate the consumer in food hygiene, especially when the kitchen is used to reconstitute infant formula. This information needs to be provided in a form appropriate for use by consumers.

INTRODUCTION

Food-borne disease caused by microbiological hazards is an important global public health issue.[1] Prevention of disease and improvement of human health is of paramount importance for governments, industry and consumers. Many foods brought into the domestic kitchen are frequently contaminated with naturally occurring pathogenic micro-organisms. Such pathogens cannot be detected organoleptically (seen, smelled or tasted) but can cause disease of varying severity, which may result in death. Food-borne illnesses are most often caused by faults during the handling and preparation of food and a substantial amount of food-borne disease occurs in the home. The domestic kitchen has been described as the 'front line in the battle against food-borne disease', however, domestic kitchens may be inadequately designed, lacking equipment for safe food preparation and may be used for a range of non-food purposes. There is a need for consumers to implement safe procedures during routine handling, preparation and storage of food and liquids, including powdered infant formula, to minimize the potential risk of infection. This is particularly important when the products may be prepared for individuals who could be more vulnerable to

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infection, such as young infants. Consumer food safety behaviour research studies up to 2003 have previously been reviewed[2] and this paper incorporates some areas of that review as well as some information about infant formula. Furthermore, this paper aims to discuss the incidence of food-borne disease associated with the home; and review bacterial contamination in the domestic kitchen, the risks associated with food and infant formula and the issues relevant to consumer education.

INCIDENCE OF FOOD-BORNE DISEASE

Reported incidence of food-borne disease associated with the domestic environment in the UK, Europe, the USA, Canada, Australia and New Zealand is variable and is based on reported outbreaks. Outbreaks of food-borne illness occurring in private homes are less likely to be reported than those in commercial and public premises[3] and it is believed that infections attributed to the private home are three times more frequent than those attributed to canteens.[4] Given the substantial under-reporting of food-borne disease[5] and the fact that the majority (>95%) of food-borne disease cases are thought to be sporadic[6] and less likely to be investigated by public health authorities, the actual proportion of food-borne disease cases that occur in the home is likely to be much larger than reported outbreak data suggests.[2] Nevertheless, data from England, Wales, the USA and Canada suggest that 12–20% of reported food-borne outbreaks have been attributed to the home. Data from Australia and New Zealand suggest that 20–50% of food-borne illness has been attributed to the home and data for some European countries suggest a figure of up to 95%. Overall, in Europe, Food and Agriculture Organization of the United Nations/World Health Organization[7] stated that the 'private home is the single location where most food-borne cases occur'.

Reported incidence of infection associated with the consumption of powdered infant formula milk has predominantly been associated with *Salmonella* spp. and *Cronobacter* (*Enterobacter sakazakii*). *Salmonella* was determined as a causative agent in an outbreak of formula feed, whereby 43 cases among babies were traced to Farley's Ostermilk.[8] Similarly, a widespread outbreak of *Salmonella* was reported across 14 of 17 regions in Spain due to *Salmonella virchow* contamination of powdered infant formula.[9] During the past several years, *E. sakazakii* has received increased attention as a public health concern and infections due to contaminated infant formula have been reported in a number of developed countries.[10] Most reports of infection have been from hospital nurseries and neonatal units;[11] however, there is always the potential for infection to occur in the home. Data has indicated that babies aged <5 months old, particularly neonates, babies that are preterm, low birth weight or immuno-compromised are most likely to fall victim.[12] Mortality rates from *E. sakazakii* infection have been reported to be 50–75%,[13] although this is also reported to have declined to <20% in recent years.[12]

SOURCES OF CONTAMINATION

Potential pathogens can enter the domestic kitchen via a variety of routes, for example, raw foods. Poultry is an important potential reservoir of food-borne pathogens, particularly *Campylobacter* and *Salmonella* spp. Microbiological surveys of raw, retail poultry have identified high prevalence rates[14,15] and it is clear that poultry meat continues to be a significant route for the transmission of *Campylobacter* and *Salmonella* in the domestic environment. *Campylobacter* and *Salmonella* spp. are recognized as the leading causes of bacterial gastroenteritis in humans.[16]

A number of studies have determined contamination rates of *Cronobacter* in powdered infant formula. In the UK, Iversen & Forsythe[17] isolated the bacteria from 2/82 samples of powdered infant formula milk and 3/72 samples of milk powder. In Canada, the bacteria were isolated from up to 12% of retailed dried infant formula samples.[13] Recontamination of formula can also take place during the preparation or reconstitution of the infant formula due to poorly cleaned feeding bottles or poorly maintained equipment in home and hospitals.[18] Studies have reported contamination of food and formula preparation items such as blenders, bottle-cleaning brushes and spoons,[19] which may act as intermediary vectors for cross-contamination to infant feeds.

Food and powdered infant formula are not the only routes or vehicles by which micro-organisms can enter the kitchen. The presence of soiled laundry and pets is not uncommon[20,21] and the domestic kitchen has also been found to be used for motor vehicle maintenance, gardening and even breeding chickens,[22] each bringing their own microbiological hazards. The fact that the kitchen is a multifunctional setting directly impacts upon the need for better food safety in the home.[3]

BACTERIAL CONTAMINATION OF THE DOMESTIC KITCHEN

Recognition of the importance of the home as a location for acquiring food-borne disease has prompted the assessment of levels of bacterial contamination within the domestic environment. Surveys have evaluated the microbial content of the domestic kitchen[23,24] and domestic environment.[25,26,27,28] A few surveys have evaluated microbial contamination in the domestic kitchen after food preparation.[29,30] Most studies have concluded that the domestic environment is an important source of food-borne infections and hygiene behaviour and/or cleaning practices need to be improved to reduce levels of contamination.[28,31,32] Findings have shown that the majority of domestic environmental surfaces were contaminated with pathogenic and non-pathogenic micro-organisms, and two studies found bacterial contamination levels in kitchens to be higher than in bathrooms.[26,33] Finch *et al.*[34] reported that the normal domestic environment appeared to support a fairly wide range of bacterial species. Josephson *et al.*[35] concluded that normal kitchens can be easily contaminated with a variety of bacterial contaminants including faecal

Table 1

Reported isolations of potential pathogens from specific environmental sites within food preparation areas

Environmental site	*Campylobacter spp.*	*Salmonella spp.*	*Y. enterocolitica*	*S. aureus*	*E. coli*	*Bacillus spp.*	*B. cereus*	*L. monocytogenes*	*Listeria spp.*
Dishcloth	•			•	•	•		•	•
Cleaning cloth	•	•		•	•		•		•
Washing-up	•	•		•	•				•
sponge									
Washing-up brush					•			•	•
Wash cloth		•						•	
Floor mop					•	•			•
Tea/Hand towel				•	•	•			
Sink		•	•	•	•		•	•	•
Taps				•	•		•		
Refrigerator/Door	•			•	•		•	•	•
Waste/Pedal bin	•			•	•	•			
Chopping boards	•			•	•				
Work surfaces	•				•	•			
Floors	•				•				

Adapted from Griffith[99]

coliforms, *Enterobacteriaceae* (such as *Escherichia coli*), *Campylobacter* spp. and *Salmonella* spp. Other organisms that have been detected in the domestic environment include *Staphylococcus* spp.,[23,34,35] *Bacillus* spp. and *Micrococcus* spp.,[23,28,34] and *Streptococcus* spp.[28] It has also been reported that potentially pathogenic *E. coli, Klebseiella pnneumoniae* and *Enterobacter cloacae* were the most frequently detected species in the home.[28] *E. sakazakii* has also been isolated from the home environment.[36] A review of cases and outbreaks of infections in premature babies and neonates isolated the bacteria from food/formula preparation items such as blenders, bottle-cleaning brushes and spoons.[19]

The type and density of bacterial contamination in the domestic environment is influenced by the physical nature of the site sampled.[29,37] Contaminants detected from the majority of studies more commonly isolated from wet to moist locations,[23,28,35] where survival and proliferation of organisms is favoured. Scott *et al.*[28] reiterated these findings and stated that detection of *Enterobacteriaceae* predominately occurred from wet sites. The most common locations found to be more heavily contaminated with micro-organisms in the domestic kitchen were dishcloths, cleaning cloths, sponges, sink environments and towels.[23,25,27,33,34] Kitchen sponges and dishcloths are considered to be particularly conducive environments for the growth and survival of bacteria due to being continuously moist and supplied with nutrients in the form of food scraps and organic matter.[38] Other locations that were found to be contaminated included those frequently touched, such as tap handles and fridge handles.[33,39] The frequent contamination of dishcloths and other wet samples with large numbers of organisms including *Enterobacteriaceae* suggest that these locations may not only harbour the bacteria, but also spread them round the kitchen during use.[27,38,40] Thus, it is suggested that consumers use disposable paper towels for cleaning surfaces in the kitchen, as opposed to dishcloths.

The reported isolations of potential pathogens from specific environmental sites within food preparation areas were summarized (Table 1). These data indicate the range of micro-organisms present, with other studies reporting the numbers isolated[26,41] with counts for some sites in excess of 10^8cfu/ml.[42] Problems with these types of studies, which may underestimate the presence of pathogens, include the random nature of the sampling, irrespective of the types of foods prepared and when. This may be compounded by relatively low numbers of pathogens in relation to non-pathogens, coupled with overgrowth of the latter.

MICROBIOLOGICAL RISKS ASSOCIATED WITH FOOD PREPARATION AND STORAGE

Sources of food contamination are diverse and food-borne pathogens associated with a range of raw foods are

regularly bought into the domestic kitchen. Transmission of such pathogens to humans due to the implementation of unsafe food-handling behaviours within the household is considered inevitable.[43]

The potential spread and persistence of contaminants in the domestic environment has been recognized.[23,27,44] Indeed, during food preparation, pathogens such as *Campylobacter*, *Salmonella*, *Escherichia coli* and *Staphylococcus aureus* may be spread from infected foods such as raw chicken to hand- and food-contact surfaces in the domestic kitchen. Laboratory experiments have shown that both *Campylobacter* and *Salmonella* can be easily transferred from raw chicken products to kitchen surfaces and hands[44,45] and dissemination of such pathogens to hands, cloths and hand- and food-contact surfaces during preparation of a chicken meal has previously been demonstrated.[31,32] Research has shown that *Campylobacter* and *Salmonella* can persist on food-contact surfaces for significant lengths of time, which may lead to increased risks of cross-contamination between household members, ready-to-eat (RTE) foods and other food-contact surfaces.[16,44]

Ideally, to prevent cross-contamination in the kitchen, raw and cooked foods have to be handled separately. However, the strict separation of raw poultry, raw meat and RTE foods is not always possible in the domestic kitchen. Many kitchens may not have the space to adequately separate raw and cooked preparation areas.[46] Furthermore, the risk of cross-contamination is reported to increase when large amounts of food are prepared in the domestic kitchen.[47]

Effective cleaning of contaminated surfaces is required to minimize the risk of cross-contamination in the domestic kitchen. Scott and Bloomfield[48] found that when contaminated cloths or surfaces came into contact with fingers, equipment and surfaces, organisms were transferred in sufficient numbers to represent a potential hazard if subsequent contact was made with food.

The role of hands in the transmission of disease is well established[49] and effective hand washing and hand drying is considered to be an important control measure for preventing the transmission of food-borne diseases. Contamination of food via the hands may be through direct contact or indirectly through poor practice such as handling and contaminating equipment that is subsequently used for food preparation.[50] Transient contaminants on the skin should be removed by washing and drying to eliminate the risk of cross-contamination.[51] Research has suggested that pathogens such as *Campylobacter* and *Salmonella* can survive on hands for enough time after initial contamination to further cross-contaminate around the kitchen environment.[52,53] In addition, after handling raw chicken 73–100% of hands have been found to be contaminated with bacteria such as *Campylobacter*[45,54,55] and 18% contaminated with *Salmonella*.[45]

Numerous studies have researched the effectiveness of hand washing and hand drying efficacy.[56,57] Results have indicated that a quick rinse or wash of hands may not completely remove pathogens such as *Campylobacter jejuni* after handling contaminated foods.[58] In addition to this, research has shown that when hands are wet, touch-contact associated with bacterial transfer is facilitated.[59] The hand drying process is considered to be of critical importance to maximize the reduction of transient and resident bacteria.[60] If hands are shaken dry, bacteria such as *Campylobacter* spp. are likely to remain, especially if only water had been used for washing.[52] Hand drying can provide an additional 90% reduction in transient bacterial flora.[61] Thus, it is imperative for consumers to not only wash their hands adequately, but also to dry them adequately. Failure to wash hands at all or adequately, followed by wiping them on a hand or tea towel may result in the transfer of pathogens (such as *Campylobacter*) to the towel.[32] A contaminated towel may then act as a vector for transferring bacteria, including pathogens, to other people who also use the towel.

Practices such as post-heating cooling, frequently misunderstood by consumers,[62,63] need to be controlled sufficiently to prevent the risk of multiplication of surviving bacteria. Fast cooling reduces the time that a food spends at critical temperatures and hence reduces bacterial growth. To achieve adequate cooling procedures it has been suggested that foods should be divided into smaller quantities[64] and placed into a shallow container,[65] not exceeding 50mm in depth,[66] that allows maximum heat transfer through container walls.[64] Additional food safety practices that are needed to facilitate rapid cooling include stirring during cooling,[67] and loosely covering or leaving foods uncovered during the cooling period to facilitate heat transfer from the surface of the food.[64] In addition, the use of cold water/ice is considered to increase cooling procedures.[64,68]

Storage of food products above refrigeration temperature and below the recommended hot holding temperature of 63°C[69] encourages the proliferation of bacterial cells, germination of spores and possible toxin production to potentially dangerous levels. Inadequate temperature control during storage is frequently implicated as a cause of food-borne illness. Experimental findings have illustrated the ease with which transferred organisms can grow on RTE foodstuffs held at ambient temperature.[70] The microbial lag phase and generation time of a bacterial population in food increases as refrigeration temperature decreases.[71] The recommended requirement for refrigerated foods is <8°C[69] and it is recommended that refrigerators should be set to keep food at 5°C or cooler.[72]

MICROBIOLOGICAL RISKS ASSOCIATED WITH DISINFECTION OF FEEDING BOTTLES AND PREPARATION AND STORAGE OF POWDERED INFANT FORMULA

Reconstituted powdered infant formulas are considered to be a food class of high risk because of the susceptibility of the infant population to enteric bacterial pathogens, severe response to enterotoxins and increased mortality.[73] Powdered infant formula is not a sterile product and provides an ideal growth

medium for spoilage and pathogenic bacteria. Proper precautions should be taken during the handling and reconstitution of formula prior to feeding in order to prevent contamination and proliferation of bacteria.

There are three main routes by which micro-organisms can enter infant formula: (1) through the raw material used for producing the formula; (2) through contamination of the formula or other dry ingredients post-pasteurization; and (3) through contamination of the formula as it is reconstituted by the caregiver prior to feeding.[7] Microbial contamination of the formula has implications both for the quality assurance procedures during manufacture and how the product will be subsequently prepared and stored by the end users. Even low levels of contamination are considered to be a risk factor, given the potential for multiplication during the preparation and holding time prior to consumption of reconstituted formula.[10] Studies have shown that in reconstituted dried infant formula some harmful micro-organisms are highly thermo-tolerant, which has considerable implications for manufacture and subsequent preparation, use and storage.[74]

Some organisms are known to have good long-term survival properties[75] and have been isolated from a range of home, food production and healthcare environments.[36,76] Research has also shown that organisms found in powdered infant formula are able to grow on infant feeding equipment.[77] Low populations (1cfu/ml) of micro-organisms in reconstituted formula may grow to potentially hazardous levels (>10^7cells/ml) when stored at room temperature for 10 hours – such levels would be reached sooner in formula held at 35–37°C.[13,78] Furthermore, some bacteria found in powdered formula milk can grow slowly at some refrigerator temperatures,[77] especially if they are not operating below 5°C. Studies have found that large numbers (21–25%) of consumers' refrigerators exceed recommended temperatures[79,80] thereby providing conditions that encourage the proliferation of organisms to potentially dangerous levels. The growth and survival properties of bacteria on preparation and feeding equipment and in reconstituted formula has implications for the importance of adequate decontamination of feeding utensils after use and proper temperature control of reconstituted formula. To minimize microbiological risks during the preparation and storage of powdered infant formula, key recommendations have been outlined by the Department of Health[81] and the UK Food Standards Agency.[82]

Infant feeding bottles and components can act as transfer sites for pathogenic micro-organisms. Therefore, effective cleaning and sterilization/disinfection of feeding bottles and components is important to prevent contamination of the formula as it is reconstituted by the caregiver prior to feeding. As some infants (premature and low birth weight babies) may have reduced immunity, the management of the reconstitution process and subsequent storage prior to use are particularly important. The latter may be especially significant when feeding does not immediately follow formula preparation.

ROLE OF THE CONSUMER

Consumers are the important final link in the food chain to assure safe food consumption and prevent illness.[83,84] Multiple food safety responsibilities are required by consumers because they not only purchase products but also process and provide food for themselves and for others. Therefore consumers have responsibilities as purchasers, storers, providers and processors of food and need to be conscious of the nature and safety of food products.[85] Food-handling practices employed by consumers in the domestic kitchen influence the risk of pathogen survival and multiplication, as well as cross-contamination to other products.[86] Given that 92% of women and 61% of men prepare meals (if not every day) at least once or twice a week,[87] it is extremely important that food is handled in a manner that does not increase the risk of food-borne disease.

Consumers can prevent pathogenic contamination of the domestic environment during food preparation, by implementing appropriate food safety behaviours to prevent direct and indirect cross-contamination from foods such as raw poultry, raw meat and/or raw eggs. Such behaviours include immediate and adequate hand washing and hand drying after handling raw poultry, meat and/or eggs and implementation of effective cleaning procedures, particularly including the use of disposable paper towels.

Observation studies have shown that some consumers implement all necessary food safety behaviours as a matter of routine, while others do not.[55,88] A similar pattern of behaviours relating to feeding bottle cleaning and disinfection and reconstitution of powdered formula has been found[89] where some parents implement all 'recommended' methods and practices, but other parents do not. This indicates that recommended practices are achievable and are implemented in daily life by some consumers.

Caregivers, such as mothers of young infants, have an important responsibility to prevent infant diarrhoea and other infections by implementing safe handling behaviours when preparing and storing complementary food and powdered formula milk. Even low levels of microbial contamination are considered to be a risk factor[10] given the potential for multiplication during the preparation and holding time prior to consumption of reconstituted formula. The growth and survival properties of bacteria on preparation and feeding equipment and in reconstituted formula has implications for consumers and caregivers to ensure the adequate decontamination of feeding utensils after use and proper temperature control of reconstituted formula.

CONSUMER FOOD HYGIENE EDUCATION

An improvement in consumer food safety behaviour is likely to reduce the risk and incidence of food-borne disease. A reduction of food-borne disease in the general population depends on positively altering the behaviour of food-handlers.[90] Food control authorities cannot intervene in every household[91] and therefore educational initiatives are required to reduce the incidence of food-borne

illness within the food safety continuum from 'farm to table'.[92] Educational strategies are required to reduce prevalence of behaviours associated with infection, increase consumer awareness of risks, and motivate consumers to change unsafe behaviours.[93] It has been suggested that the use of information related to the food habits and beliefs of consumers is essential if the disease control messages are to effect behavioural change.[94] To maximize the effectiveness of educational initiatives, strategies should be based on the knowledge of consumer attitudes towards hygiene behaviours, actual hygiene behaviours and an understanding of receptivity for advice and preference for sources and message types. In recognition of this, use of techniques such as social marketing have been advocated.[95,96,97]

The importance of preventing food-borne infections from in-home preparation has now been acknowledged and a number of countries have, or are planning, food safety initiatives. In the UK, a considerable amount of food hygiene information is available to consumers, however, such information is largely uncoordinated and mostly delivered to consumers through local authorities.[62] Provision of generic, managed and co-ordinated general and targeted food safety education resources in the UK may not only decrease important time and financial costs within local authorities, but also increase consumer confidence in the accuracy of information provided and alleviate the risk for potential confusion of information from different sources.[98] It is suggested that development of a dual strategy for consumer food hygiene education should be implemented in the UK. Raising the general profile of food hygiene education coupled with a more specific risk-based targeted approach may encourage voluntary change of specific domestic food-handling behaviours.

It is considered that effective consumer education for the safe preparation, handling and storage of infant formula would optimally include health professionals such as midwives, hospital nurses and health visitors giving demonstrations of adequate cleaning procedures, different disinfection processes and the reconstitution of powdered formula, supported by documentation to consumers and caregivers.

Strategy formation for parents and consumers should be based on scientific research and social marketing principles, which will facilitate the development of highly focused messages with tailored intervention materials.

References

1 World Health Organization. Address by the Director General to the 53rd World Health Assembly. 15 May 2000. Geneva. Reference A53/3
2 Redmond EC, Griffith CJ. Consumer food-handling in the home: A review of food safety studies. *Journal of Food Protection* 2003; 66(1): 130–161
3 Scott E. Food safety and food-borne disease in 21st century homes. *The Canadian Journal of Infectious Diseases and Medical Microbiology* 2003; 14(5): 277–280
4 Borneff J. Effective hygienic measurements in households today. *Zentralblatt fur Bakteriologie Mikrobiologie und Hygiene* 1998; 187: 404–413
5 Handysides S. Underascertainment of infectious intestinal disease. *Communicable Disease and Public Health* 1999; 2: 78–79
6 Food Standards Agency. Food-borne Disease: Developing a Strategy to Deliver the Agency's Targets. Agenda item 4. 2000(b) October. Paper FSA 00–05–02
7 Food and Agriculture Organization of the United Nations/World Health Organization. Statistical information on food-borne disease in Europe. Microbiological and chemical hazards. Conference paper presented at FAO/WHO pan-European conference on food safety and quality. 25–28 February. Report no: 01/04. Agenda item 4b. Budapest; FAO/WHO, 2002
8 Cole-Hamilton I, Livermore A, Watson J. Food and Nutrition in Practice. UK: Heinemann Educational Publishers, 1987
9 Usera MA, Echeita A, Aladueña A, Blanco MC, Reymundo R, Prieto MI, *et al*. Interregional food-borne salmonellosis outbreak due to powdered infant formula contaminated with lactose-fermenting *Salmonella virchow. European Journal of Epidemiology* 1996; 12(4): 377–381
10 International Food Safety Authorities Network. *Enterobacter sakazakii* in powdered infant formula. No 1/2005 *Enterobacter sakazakii*. Geneva: INFOSAN Information Notes, 2005
11 Forsythe S. *Enterobacter sakazakii* and other bacteria in powdered infant formula milk. *Maternal and Child Nutrition* 2005; 1: 44–50
12 Food and Agriculture Organization of the United Nations/World Health Organization. *Enterobacter sakazakii* and other micro-organisms in powdered infant formula: meeting report. MRA Series 6. Geneva: FAO/WHO, 2004. http://www.who.int/foodsafety/publications/micro/mra6/en
13 Nazarowec-White M, Farber JM. Incidence, survival and growth of *Enterobacter sakazakii* in infant formula. *Journal of Food Protection* 1997; 60(3): 226–230
14 Harrison WA, Griffith CJ, Tennant D, Peters AC. Incidence of *Campylobacter* and *Salmonella* isolated from retail chicken and associated packaging in South Wales. *Letters in Applied Microbiology* 2001; 33: 450–454
15 Meldrum RJ, Tucker D, Edwards C. Baseline rates of *Campylobacter* and *Salmonella* in raw chicken in Wales, United Kingdom, in 2002. *Journal of Food Protection* 2004; 67(6): 1226–1228
16 De Cesare A, Sheldon B, Smith K, Jaykus L. Survival and persistence of *Campylobacter* and *Salmonella* species under various organic loads on food contact surfaces. *Journal of Food Protection* 2003; 66(9): 1587–1594
17 Iversen C, Forsythe S. Isolation of *Enterobacter sakazakii* and other Enterobacteriaceae from powdered infant milk formula and related products. *Food Microbiology* 2004; 21: 771–777
18 European Food Safety Authority. Opinion of the scientific panel on biological hazards (BIOHAZ) related to the microbiological risks in infant formulae and follow-on formulae. *European Food Safety Authority Journal* 2004; 113: 1–34
19 Muytjens H, Kollee L. *Enterobacter sakazakii* meningitis in neonates: Causative role of formula? *Pediatric Infectious Disease Journal* 1990; 9(5): 372–373
20 Beumer RR, Kusumaningrum H. Kitchen hygiene in daily life. *International Biodeterioration & Biodegradation* 2003; 51: 299–302
21 Gerba CP. Application of quantitative risk assessment for formulating hygiene policy in the domestic setting. *Journal of Infection* 2001; 43: 92–98
22 Worsfold D, Griffith CJ. Food safety behaviour in the home. *British Food Journal* 1997; 99: 97–104

23 Speirs JP, Anderton A, Anderson JG. A study of the microbial content of the domestic environment. *International Journal of Environmental Health Research* 1995; 5: 109–122
24 Kennedy J, Blair IS, Mcdowell DA, Bolton DJ. The microbiological status of non/food contact surfaces in domestic kitchens and the growth of *Staphylococcus aureus* in domestic refrigerators. *Food Protection Trends* 2005; 25(12): 974–980
25 Beumer RR, Te Giffel MC, Spoorenberg E, Rombouts FM. *Listeria* species in domestic environments. *Epidemiology and Infection* 1996; 117: 437–442
26 Ojima M, Toshima Y, Kaja E, Ara K, Kauran S, Ueda N. Bacterial contamination of Japanese households and related concern about sanitation. *International Journal of Environmental Health Research* 2002; 12: 41–52
27 Scott E, Bloomfield S. A bacterial survey of hygiene in the home. In: Collins CH, editor. Disinfectants: Their use and Evaluation of Effectiveness. SAB Tech Series 16. London: Academic Press, 1981
28 Scott E, Bloomfield SF, Barlow CG. An investigation of microbial contamination in the home. *Journal of Hygiene (Cambridge)* 1982; 89: 279–293
29 Gorman R, Bloomfield S, Adley CC. A study of cross-contamination of food-borne pathogens in the domestic kitchen in Republic of Ireland. *International Journal of Food Microbiology* 2002; 76: 143–150
30 Worsfold D, Griffith CJ. Cross-contamination in domestic food preparation. *Hygiene and Nutrition in Foodservice and Catering* 1996; 1: 151–162
31 Cogan TA, Bloomfield SF, Humphrey TJ. The effectiveness of hygiene procedures for prevention of cross-contamination from chicken carcass in the domestic kitchen. *Letters in Applied Microbiology* 1999; 29: 354–358
32 Redmond EC, Griffith CJ, Slader J, Humphrey TJ. Microbiological and observational analysis of cross-contamination risks during domestic food preparation. *British Food Journal* 2004; 106(8): 581–597
33 Rusin P, Orosz-Coughlin P, Gerba C. Reduction of faecal coliform and heterotrophic plate count bacteria in the household kitchen and bathroom by disinfection with hypochlorite cleaners. *Journal of Applied Microbioligy* 1998; 85: 819–828
34 Finch JE, Prince J, Hawksworth M. A bacteriological survey of the domestic environment. *Journal of Applied Bacteriology* 1978; 45: 357–364
35 Josephson KL, Rubino JR, Pepper IL. Characterization and quantification of bacterial pathogens and indicator organisms in household kitchens with and without the use of a disinfectant cleaner. *Journal of Applied Microbiology* 1997; 83: 737–750
36 Kandhai MC, Reij MW, Gorris LGM, Guillaume-Gentil O, Van Schothorst M. Occurrence of *Enterobacter sakazakii* in food production environments and households. *Lancet* 2004; 363: 39–40
37 Scott E, Bloomfield S. A bacterial survey of hygiene in the home. In: Collins CH, editor. Disinfectants: Their Use and Evaluation of Effectiveness. SAB Tech Series 16. London: Academic Press, 1981
38 Doyle MP, Ruoff KL, Pierson M, Weinberg W, Soule B, Michaels BS. Reducing transmission of infectious agents in the home. Part II: Control Points. *Dairy Food & Environmental Sanitation* 2000; 20(6): 418–425
39 Mendes MF, Lynch DJ, Stanley CA. A bacteriological survey of kitchens. *Environmental Health* 1978; October: 227–231
40 Redmond EC, Griffith CJ. Consumer use of cloth wipers: Risk potential for cross-contamination and recontamination in the domestic kitchen. Prague: International Association of Food Protection, 2005
41 Sharp K, Walker H. A microbiological survey of communal kitchens by undergraduate students. *International Journal of Consumer Studies* 2003; 27(1): 11–16
42 Hilton AC, Austin E. The kitchen dishcloth as a source of and vehicle for food-borne pathogens in a domestic setting. *International Journal of Environmental Health Research* 2000; 10: 257–261
43 Jones MV. Application of HACCP to identify risks in the home. *International Biodeterioration & Biodegradation* 1998; 41(3–4): 191–199
44 Humphrey TJ, Martin K, Whitehead A. Contamination of hands and work surfaces with *Salmonella enteritidis* PT4 during the preparation of egg dishes. *Epidemiology and Infection* 1994; 113: 403–409
45 De Boer E, Hahne M. Cross-contamination with *Campylobacter jejuni* and *Salmonella* spp. from raw chicken products during food preparation. *Journal of Food Protection* 1990; 53(12): 1067–1068
46 Varnam AH, Evans MG. Food-borne Pathogens: An Illustrated Text. Aylesbury: Wolfe Publishing Limited, 1991
47 Ryan MJ, Wall PG, Gilbert RJ, Griffin M, Rowe B. Risk factors for outbreaks of infectious intestinal disease linked to domestic catering. *Communicable Disease Report (Review)* 1996; 6(13): R179–R182
48 Scott E, Bloomfield SF. The survival and transfer of microbial contamination via cloths, hands and utensils. *Journal of Applied Bacteriology* 1990; 68: 271–278
49 Emery HC. Changing poor hand washing habits – A continuing challenge for sanitarians. *Dairy Food and Environmental Sanitation* 1990; 10: 8–9
50 Taylor J, Holah JT. Hand Hygiene in the Food Industry: A review. Review no 18. Campden and Chorleywood: Food Research Association Group, 2000
51 Brown P, Kidd D, Riordan T, Barrell RA. An outbreak of *Campylobacter jejuni* infection and the possible role of cross-contamination. *Journal of Infection* 1998; 17: 171–176
52 Coates D, Hutchinson DN, Bolton FJ. Survival of thermophillic campylobacters on fingertips and their elimination by washing and disinfection. *Epidemiology and Infection* 1987; 99: 265–274
53 Pether JVS, Gilbert RJ. The survival of salmonellas on fingertips and the transfer of the organisms to food. *Journal of Hygiene (Cambridge)* 1971: 69: 673–681
54 Chen Y, Jackson KM, Chea FP, Schaffer DW. Quantification and variability analysis of bacterial cross-contamination rates in common food service tasks. *Journal of Food Protection* 2001; 64(1): 72–80
55 Redmond EC, Griffith CJ, Slader J, Humphrey TJ. The evaluation and application of information on consumer hazard and risk to food safety education. London: Food Standards Agency, 2001
56 Michaels B, Gangar V, Schultz A, Arenas M, Curiale MS, Ayers T *et al*. Water temperature as a factor in hand-washing efficacy. In: Edwards JSA, Hewedi MM, editors. Culinary Arts and Sciences III. Global and National Perspectives. Al-Karma, Egypt: The Worshipful Company of Cooks Centre for Culinary Research at Bournemouth University, 2001
57 Miller ML, James-Davies LA, Milanesi LE. A field study evaluating effectiveness of different hand soaps and sanitizers. *Dairy Food and Environmental Sanitation* 1994; 14: 155–160
58 Acuff GR, Vanderzant C, Hanna MO, Ehlers JG, Gardner FA. Effects of handling and preparation of turkey products on the survival of *Campylobacter jejuni*. *Journal of Food Protection* 1986; 49: 627–631
59 Patrick DR, Findon G, Miller TE. Residual moisture determines the level of touch-contact associated bacterial transfer following hand washing. *Epidemiology and Infection* 1997; 119: 319–325
60 Michaels B, Gangar V, Ayers T, Meyers E, Curiale MS. The significance of hand drying after hand washing. In: Edwards JSA, Hewedi MM, editors. Culinary Arts and Sciences III. Global and National Perspectives. Al-Karma, Egypt: The Worshipful Company of Cooks Centre for Culinary Research at Bournemouth University, 2001
61 Michaels B, Ayers T. Hazard analysis of the personal hygiene process. Presented at the Second NSF International Conference on Food Safety, 11–13 October 2000, Savannah, Georgia, USA.
62 Redmond EC, Griffith CJ, King S, Dyball M. Evaluation of consumer food safety

education initiatives in the UK and determination of effective strategies for food safety risk communication (RRD-8). London: Food Standards Agency, 2005
63 Redmond EC, Griffith CJ. Consumer attitudes and perceptions towards microbial food safety in the domestic kitchen. *Journal of Food Safety* 2004; 24 (3): 169–194
64 US Department of Health and Human Services, Public Health Service, Food and Drink Association. Food Code 1999. Washington, DC: US Department of Health and Social Services, 1999. http://www.cfsan.fda.gov/~dms/fc99-toc.html
65 Farber JM, Hughes A. General guidelines for the safe handling of foods. *Dairy Food and Environmental Sanitation* 1995; 15: 70–78
66 Department of Health. Chilled and Frozen – Guidelines on Cook Chill and Cook Freeze Catering Systems. London: HMSO, 1993
67 Health Services Agency, Environmental Health Department. Guidelines for cooking, cooling and reheating foods at home. Information Bulletin No 97–14. Riverside County: Environmental Health Department, 1997. http://www.rivcoeh.org
68 Ryno RR, Leftwich MW. Exposure time of warm leftovers to temperatures suitable for microbial growth in a home-type refrigerator. *Journal of Food Protection* 1981; 44(7): 513–515
69 Department of Health. Guidance on the Food Safety (Temperature Control) Regulations 1995. London: Department of Health, 1995
70 Bradford MA, Humphrey TJ, Lappin-Soctt HM. The cross-contamination and survival of *Salmonella enteritidis* PT4 on sterile and non-sterile foodstuffs. *Letters in Applied Microbiology* 1997; 24: 261–264
71 International Scientific Forum on Home Hygiene. Recommendations for a Selection of Suitable Hygiene Procedures for Use in the Domestic Environment. Milan: Intramed Communications Ltd, 1998
72 Food Safety and Hygiene Working Group. Industry Guide to Good Hygiene Practice: Catering Guide. Food Safety (General Food Hygiene) Regulations 1995. London: Chadwick House Group Ltd, 1997
73 Rowan NJ, Atkinson JG. Effectiveness of cleaning and disinfection procedures on the removal of enterotoxigenic bacillus cereus from infant feeding bottles. *Journal of Food Protection* 1998; 61(2): 196–200
74 Weir E. Powdered infant formula and fatal infection with *Enterobacter sakazakii*. *Canadian Medical Association Journal* 2002; 166(12): 1570
75 Edelson-Mammel SG, Buchanan RL. Long-term survival of *Enterobacter sakazakii* in powdered infant formula. Phoenix: International Association for Food Protection Conference, 2004
76 Vasavada PC. Enterobacter sakazakii: The quest for tests. *Food Safety Magazine* 2005; August/September
77 Iversen C, Lane M, Forsythe SJ. The growth profile, thermo-tolerance and biofilm formation of *Enterobacter sakazakii* grown in infant formula milk. *Letters in Applied Microbiology* 2004; 38: 378–382
78 Pagotto FJ, Nazarowec-White M, Farber JM. *Enterobacter sakazakii*: Infectivity and enterotoxin production in vitro and in vivo. *Journal of Food Protection* 2003; 66(3): 370–375
79 Van Garde SJ, Woodburn MJ. Food discard practices of householders. *Journal of the American Dietetic Association* 1987; 87: 322–329
80 Daniels RW. Increasing food safety awareness. *Food Technology* 2001; 55: 132
81 Department of Health. Bottle feeding. London: COI Publications, 2006
82 Food Standards Agency. Revised guidance on powdered infant formula. London: Food Standards Agency, 2006. http://www.food.gov.uk/news/newsarchive/2006/dec/infantform
83 The Pennington Group. Report on the circumstances leading to the 1996 outbreak of infection with *E. coli* 0157 in Central Scotland. The implications for food safety and the lessons to be learned. Edinburgh: The Stationery Office, 1997
84 Zhang P, Penner K. Prevalence of selected unsafe food consumption practices and their associated factors in Kansas. *Journal of Food Safety* 1999; 19: 289–297
85 Communicable Diseases Network, Australia and New Zealand Working Party. Food-borne Disease: Towards Reducing Food-borne Illness in Australia. Australia: Technical Report Series No 2, 1997
86 Roberts T, Ahl A, Mcdowell R. Risk assessment for microbial hazards. In: Roberts T, Jensen H, Unnevehr L, editors. Tracking Food-borne Pathogens from Farm to Table. Conference proceedings, 9–10 January. Miscellaneous Publication No 1532. Washington, DC: US Department of Agriculture, Economic Research Service, 1995
87 Nicolaas G. Cooking: Attitudes and Behaviour. OPCS Social Survey Division. Omnibus Survey Publications: Report 5. London: HMSO, 1995
88 Griffith CJ, Peters A, Redmond EC, Price P. Food safety risk scores applied to consumer food preparation and the evaluation of hygiene interventions. London: Department of Health, 1999
89 Redmond EC, Griffith CJ. An analysis of 'in-use' infant feeding bottles and a comparison of four bottle disinfection methods. Consultancy report for Laboratoires Rivadis, France, 2007
90 Howes M, McEwen S, Griffiths M, Harris L. Food handler certification by home study: Measuring changes in knowledge and behaviour. *Dairy Food and Environmental Sanitation* 1996; 16(11): 737–744
91 World Health Organization. Food Safety: Resolution of the executive board of the WHO. 105th session. EB105.R16. Geneva: WHO, 2000
92 Meer RR, Misner SL. Food safety knowledge and behaviour of expanded food and nutrition programme participants in Arizona. *Journal of Food Protection* 2000; 63(12): 1725–1731
93 Yang S, Leff MG, McTague D, Horvath KA, Thompson J, Murayi T *et al*. Multi-state surveillance for food handling and preparation and consumption behaviours associated with food-borne diseases 1995 and 1996. *Morbidity and Mortality Weekly Report* 1998; 47: 33–54
94 Ehiri JE, Morris GP. Hygiene training and education of food handlers: Does it work. *Ecology of Food Nutrition* 1996; 35: 243–251
95 Redmond EC, Griffith CJ, Peters AC. Use of social marketing in the prevention of specific cross-contamination actions in the domestic environment. In: Proceedings of the 2nd NSF International Conference on Food Safety: Preventing Food-borne Illness through Science and Education. Savannah, Georgia, 11–13 October 2000
96 Redmond EC. Food safety behaviour in the home: Development, application and evaluation of a social marketing food safety education initiative. PhD thesis. Cardiff: University of Wales, 2002
97 Redmond EC, Griffith CJ. Evaluation of the effectiveness of a small-scale social marketing-based food safety education initiative using observation. *British Food Journal* 2006; 108(9): 753–770
98 Redmond EC, Griffith CJ. Assessment of consumer food safety education provided by local authorities in the UK. *British Food Journal* 2006: 108(9): 732–752
99 Griffith CJ. Food safety in catering establishments. In: Farber JM, Todd ECD, editors. Safe Handling of Foods. New York: Marcel Dekker, 2000