Restaurant and Catering Food Safety: *Putting HACCP on the Menu*

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Chapter Three

Survival and cross-contamination of foodborne pathogens in the domestic kitchen: a review

Rijkelt R. Beumer[1*] and Harsi D. Kusumaningrum[2]

[1] Laboratory of Food Microbiology, Agrotechnology and Food Sciences, Wageningen University, Wageningen, The Netherlands
[2] Laboratory of Food Microbiology, Bogor Agricultural University, Bogor, Indonesia
*E-mail: rijkelt.beumer@wur.nl

Introduction

Infectious diseases have been recognised as serious health risks for many centuries. The mortality rate of these diseases was of great concern even as recently as the late eighteenth and the early nineteenth centuries. The increasing awareness of the importance of personal hygiene as well as the introduction of safe water supplies and sewage systems, milk pasteurisation, population wide vaccination schemes and the use of antibiotics resulted in successful control of acute infections in the course of the twentieth century (Barrett *et al.*, 1998; Lederberg, 1997). However, epidemiological data indicate that infectious diseases remain globally a serious threat for public health (WHO, 2001). Previously unknown infections (emerging infectious diseases) and the reappearance of known diseases after a significant decline in incidence (re-emerging infectious diseases) cause enormous public health problems both nationally and internationally.

With respect to foodborne disease, it was particularly during the 1980s and the early 1990s that the international incidence increased considerably as a result of infections by (re-)emerging pathogens (Redmond and Griffith, 2003). Several factors contribute to the emergence and re-emergence of infectious diseases, but most can be linked to the increasing number of people living and moving around the globe, including changes in human demographics and behaviour, changes in food production systems, rapid increases in international travel and commerce, microbial adaptation and change, and the breakdown of public health measures (Käferstein *et al.*, 1997; Knabel 1995). Understanding the route(s) of an infectious disease is critical in order to identify accessible targets for control strategies. For example, person-to-person transmission may be inhibited by proper hygiene, sanitary conditions and education. Vector-borne diseases may be prevented by control measures that either kill the vector or prevent its contact with humans. This contribution presents an overview of potential aspects in the (household) kitchen environment implicated in the transmission of infectious diseases. Although there are different organisms present in the home, including bacteria, viruses, protozoa and fungi as causal agents of diseases, this study only deals with bacterial contamination, since the kitchen plays an important role in transmission of bacterial diseases.

The role of (household) kitchens in transmission of foodborne infectious disease

Pathogenic organisms will continuously enter the home with foods (foodborne) or through water (waterborne), through food prepared in the home by an infected person (person-to-person spread), through the air, by insects or via pets (Beumer *et al.* 1999). These are considered as the primary sources of potential harmful microorganisms in the home.

In the domestic environment, the kitchen is particularly important in spreading infectious disease. The first well-known bacterial transmission in the kitchen was documented in the early part of the twentieth century, when Mary Mallon, who worked as a cook in private New York households, was identified as a healthy chronic carrier of the typhoid fever bacterium. She had been spreading typhoid fever through the foods she prepared. Due to poor personal sanitary habits, she caused more than thirty cases of typhoid fever with three deaths, while Mallon herself had never been sick with typhoid fever (Imperato, 2002). This thorough epidemiological investigation and the finding of typhoid bacteria in Mallon's stool proved the significant role of the household environment in the transmission of foodborne disease and had a great impact on the science of microbial hygiene (Lerner, 1996).

Reviewing the mechanisms of transmission of foodborne infections in the United States between the years 1960 and 1982, Bryan (1988) indicated that a colonised person handling the implicated foods (person-to-person spread) was the most frequently identified factor that contributed to staphylococcal food poisoning, shigellosis and typhoid fever. Cross-contamination was responsible for 20% of reported salmonellosis and 22% of *Vibrio parahaemolyticus* gastroenteritis.

Over the past decade, up to 87% of reported foodborne disease outbreaks in Europe, the United States, Canada and Australia have been associated with food prepared or consumed in the home (Redmond and Griffith, 2003). Historically, *Salmonella* has caused the largest proportion of reported foodborne disease outbreaks associated with private homes. Some other bacterial infections associated with this environment are caused by *Campylobacter, Staphylococcus aureus, Bacillus cereus* and *Escherichia coli* (Olsen *et al.*, 2000; WHO, 2001). The increase of incidence rates with *Salmonella* and *Campylobacter* as causal agents reflects the increased *Salmonella* and *Campylobacter* contamination rates of poultry products, which are up to 60% and 80%, respectively (Dufrenne *et al.*, 2001; Harrison *et al.*, 2001; Jørgensen *et al.*, 2002). This fact illustrates the potential risk associated with cross-contamination during preparation of raw chicken in the domestic environment.

Accompanying the development of epidemiology and improved surveillance of foodborne disease, there is an increased interest in the collection of data that includes contributing factors to the outbreaks and the place where food was contaminated, mishandled or consumed, next to the causative agents and incriminated foods. Hence, specific factors that contribute to the occurrence of foodborne disease have become apparent and data detailing household food preparation practices from different countries are more and more documented.

Epidemiological data in different countries in Europe between 1993 and 1998 indicate that a considerable number of foodborne diseases are attributable to improper preparation practices in the domestic kitchen. A proportion of incidences is attributed to temperature misuse (44%) and to consumption of contaminated raw materials (20%). Inadequate handling including cross-contamination and insufficient hygiene, as well as environmental factors such as contamination by persons who handle foods and contaminated equipment accounted for more than 27% of the reported outbreaks. Food safety studies at household level, however, indicated that most consumers (householders) failed to associate home food handling practices with foodborne infections (Redmond and Griffith, 2003). This fact is considered a serious impediment to convince householders to change inappropriate food preparation behaviours (WHO, 2001), which are very important, since prevention of foodborne disease involves cooperation and responsibility at all stages in the food chain.

Bacterial contamination and cross-contamination in the kitchen

Until the late 1970s, little attention was paid to investigation of bacterial contamination and cross-contamination in the kitchen, as indicated by the small amount of published information in these areas in comparison to the detailed studies on bacterial contamination in the hospital environment (Kagan *et al.*, 2002; Speirs *et al.*, 1995). This may be a result of assumptions that the home is normally occupied largely by healthy adults and that there is no special need for hygiene. However, recent evidence has led to a real acceptance of the home as an important environment in the chain of infection transmission, and has resulted in a resurgence of interest and public concern about bacterial contamination as well as hygiene and cleanliness in the home (Bloomfield, 2001; Kagan *et al.*, 2002; Scott, 1996).

Early studies on bacterial contamination in the kitchen were conducted in the late 1960s, investigating the bacterial load of hand towels and the hygienic conditions of domestic dishcloths and tea towels (Speirs *et al.*, 1995). Such cloths were heavily contaminated with bacteria and suspected as one of the main vectors for spreading and dissemination of bacteria in the kitchen.

The current attention to bacterial contamination in the kitchen started in the late 1970s. Comprehensive studies of bacterial contamination in the home were carried out, which involved sampling various sites in the kitchen, bathroom and living room. The sink area and dishcloths were found to be the most frequent sites contaminated with *E. coli*, coagulase negative Micrococcaceae and *Bacillus* spp. (Finch *et al.*, 1978), as well as Enterobacteriaceae (Scott *et al.*, 1982). These results were supported by laboratory studies, which demonstrated that Gram-negative bacteria, such as *E. coli, Klebsiella* spp. and pseudomonads survived and were able to grow in cloths and in sink U-tubes (Scott and Bloomfield, 1990b). Furthermore, early studies on cross-contamination by de Wit *et al.* (1979) indicated that after preparation of artificially contaminated chicken products, target organisms were spread all over the utensils and working surfaces used. Similar results were found after preparation of a dinner with artificially contaminated minced meat (Bornleff and Hassinger, 1988) and the preparation of naturally contaminated chicken products in the kitchen (De Boer and Hahné, 1990). It was also demonstrated that when surfaces become contaminated, the bacteria were readily transmitted via hands or cloths to other surfaces (Scott and Bloomfield, 1990b).

An apparently renewed concern about home-hygiene started in about 1995 and is characterised by a recurring increase of interest in studies of home and personal hygiene, reflecting the trend of increasing incidence of illness resulting from foodborne infections. More than 80% of household food safety studies from the past twenty five years have been carried out since 1995 (Redmond and Griffith, 2003). The persistence of microorganisms, presence and density of pathogens and the potential spread of microbial contamination from contaminated food in the household kitchen have been extensively studied and re-examined. These studies indicated that domestic kitchen sites have been found repeatedly to be contaminated with a variety of bacterial contaminants, including *Listeria monocytogenes*. Several kitchen sites, particularly wet areas including sponges/dishcloths and sink drain areas continually appear to act as a reservoir that harbours and encourages the growth of potential pathogens (Beumer *et al.*, 1996; Enriquez *et al.*, 1997; Hilton and Austin, 2000; Josephson *et al.*, 1997; Rusin *et al.*, 1998; Speirs *et al.*, 1995).

The attention not only pointed to the investigation of bacterial contamination in domestic environments, but also to the survival of bacteria in this setting. Detailed studies on bacterial survival on specific objects have been reported, including survival of *Salmonella* Typhimurium on wooden and plastic chopping boards (Gough and Dodd, 1998), attachment of *S. aureus* on domestic preparation surfaces (Frank and Chmielewski, 1997) and survival of *Salmonella* and *Campylobacter* in a dry film on formica surfaces (Humphrey, 2001). Furthermore, cross-contamination also received additional attention. Zhao *et al.* (1998) demonstrated that bacteria could be readily transferred to chopping boards after cutting and handling contaminated raw chicken. A large number of bacteria survived on the chopping boards for at least 4 hours and could cross-contaminate fresh vegetables if the boards were not cleaned sufficiently. Following preparation of chicken contaminated with *Salmonella* and *Campylobacter*, these bacteria could be isolated from the hands and food contact surfaces sampled (Cogan *et al.*, 1999). Moreover, a quantification study on bacterial cross-contamination in common food service tasks indicated that the transfer rates were highly variable depending on the nature of surfaces involved (Chen *et al.*, 2001).

Regarding the renewed attention that exists for the household kitchen environment, it can be noted that most of the studies are qualitative assessments. Only a few areas have been examined quantitatively in any detail (Chen *et al.*, 2001; Zhao *et al.*, 1998). More and more quantitative data from systematic studies are needed for the purposes of risk assessment and risk management in the domestic environment. Continued quantitative research in microbial contamination and persistence in this environment is essential for improving the understanding of factors contributing to foodborne disease.

Measures for preventing cross-contamination in kitchen environments

Infectious diseases have raised the need for effective hygiene in the home for many years. In practice, cleaning is not the only important issue; knowing how to prevent contamination is just as crucial. Effective hygiene in the home is the total sum of measures used to prevent contamination with pathogens, thereby aiming to avoid the occurrence of infectious disease. These measures include hygiene during food preparation as well as personal hygiene.

Simple personal hygiene including the use of soap was the silent success of public health in the pre-disinfectant era (Bloomfield and Scott, 1997). Increased life expectancy since the first half of the twentieth century can be attributed to improved personal hygiene status, resulting in decreased infectious disease incidence. Then came the era of disinfectants. Together, these have made a lasting effect on public health. However, while men can make choices of action that will protect their health in response to the increasing media attention to life-threatening microbial agents, the public have recently adopted a new definition of "clean". Rather than being washed free of dirt and other substances, sites must be free of microorganisms (Levy, 2001). This was prompted particularly by the promotion of hundreds of antibacterial products touted to eliminate microorganisms from homes and persons.

Several discussions have been initiated in order to determine what level of clean up will be required to be satisfactory from the point of view of public health in the home. Drying of cloths and surfaces, for example, as well as cleaning with detergent will result in reducing bacterial populations. It was, however, shown that drying alone cannot be relied upon to prevent the transfer of infectious microorganisms from household surfaces to the householder, and reduction by detergent cleaning is only a temporary event when the cloths are kept moist (Scott and Bloomfield, 1990a). If a high rate of reduction of microorganisms from sponges or cloths is a final target of measure, soaking in a solution of bleach should be incorporated, or, alternatively, the cloths should be heated for one minute in a microwave or immersed in boiling water for 5 minutes (Ikawa and Rossen, 1999). Heat is an effective form of disinfection, although it may not be applicable to large surface areas and may be unreliable in unskilled hands (Beumer *et al.*, 1999). Chemical disinfectants or hygienic cleaners can be used for decontamination of sites and surfaces in situations where the former methods are either impractical or deemed to be inadequate for the particular situation. However, the effects may be relatively short lived and recontamination of these sites may occur quite rapidly either as a result of transfer of microorganisms or by re-growth of residual survivors on surfaces that remain damp. This clearly indicates that to be effective, hygiene procedures should be applied for a specific purpose, rather than as a part of a routine cleaning process (Beumer *et al.*, 1999). The question of how safe is safe enough is a real concern where there are vulnerable household members in the home, including young children, pregnant women, elderly persons and people who are extremely ill or undergoing therapies which compromise their immune systems and their host defences. People may now find themselves questioning how at-risk they are and what they can do to protect themselves. While effective hygiene is undoubtedly essential, the use of disinfectants may not necessarily be aggressive enough, especially if they are meant for household use with a lower human and environmental safety profile compared to a hospital (Greene, 2001; Levy, 2001). Their use, however, should have a role as a part of an overall hygiene strategy within the home.

Recently, guidelines for home hygiene (IFH, 2000) have been introduced in order to respond to the need for improvements in hygiene awareness and hygiene practices in the home. The key features of these guidelines are based on the concept of risk assessment and risk prevention. Also, in The Netherlands a 'Hygienic code of the private household' based on Hazard Analysis Critical Control Points (HACCP) has been drawn up (Voedingscentrum, 1999). It was considered that such guidelines draw on all aspects of home hygiene relating to infectious disease control and give comprehensive and consistent information on procedures to prevent infection and the transfer of pathogens in the home (Beumer *et al.*, 1999).

Reflecting on the increase of infections by pathogens that (re-)emerged in recent times, the effectiveness of measures for preventing cross-contamination should be continuously evaluated. Hygienic codes that have been developed need also to be continuously updated and justified, if necessary, to minimize the bacterial transmission in the domestic environment by any newly identified or previously unknown pathogens. Any effective measures to control or reduce the microorganisms in the home would reduce public health concerns related to their exposure.

Behaviour of selected pathogens related to foodborne disease in the domestic environment

Salmonella

Historically, *Salmonella* has caused the largest proportion of reported foodborne disease outbreaks associated with private homes, as described previously. The salmonellae are among the most ubiquitous microorganisms that cause bacterial diarrhoea. There is a widespread occurrence in animals, especially in poultry, cattle and swine. *Salmonella* lives in the intestinal tracts of animals and birds. Foods of animal origin become contaminated following faecal contamination of the environment and equipment and have been identified as vehicles for transmitting these pathogens to human beings and spreading them to kitchen environments. Cross-contamination is produced by contaminated raw foods during further processing and preparation. Although salmonellae do not form spores, they can survive for relatively long periods in foods and other substrates. *Salmonella* can grow at room temperature and albeit slowly, at chill temperature. Salmonellae can also become established and multiply in the environment and in equipment of a variety of food-processing facilities (USDA, 2003).

Over the past few decades *Salmonella* Enteritidis was the most important cause of *Salmonella* infection in Europe and the United States associated with the consumption of shelled eggs and poultry (Olsen *et al.*, 2000; WHO, 2001). Stringent procedures for cleaning and inspecting eggs, implemented since the

1970s, have made salmonellosis caused by external faecal contamination of eggshells extremely rare. However, *S.* Enteritidis silently infects the ovaries of apparently healthy hens and contaminates the eggs before the shells are formed (CDC, 2003). Furthermore, like any other strain of *Salmonella*, which resides in chickens' and turkeys' intestines, *S.* Enteritidis can find its way into the processed chicken carcass where it can cause serious health risks to humans.

Campylobacter

Campylobacter jejuni is now reported to be the leading cause of bacterial diarrhoea in humans in the countries where records are kept. Campylobacters ('*Vibrio fetus*') have been known to cause disease in animals since in the early 1900s, but they have been generally recognised only recently as a cause of human disease. Campylobacters occur widely as part of the normal intestinal flora of many animals, especially chickens and turkeys, and enter the human food chain during slaughter of the animals. In addition, raw milk and poorly treated water supplies are also important sources of *Campylobacter* infections. *C. jejuni* will not multiply on chilled food or on shelf stable foods stored below 30°C. This species survives better at chill temperature than at ambient temperature. It also survives for several months in frozen minced meat and poultry. Furthermore, it was thought that these bacteria were unable to persist on kitchen surfaces, but this may have been due to a limitation of the recovery technique used. If more sensitive methods are applied, campylobacters can be recovered from surfaces 24 hours after contamination (Humphrey, 2001). Reflecting the fact that *C. jejuni* will not readily grow in food, it is believed that dissemination of the organism may occur through contamination of the environment and the hands of kitchen personnel with subsequent cross-contamination of prepared food (USDA, 2003).

Bacillus cereus

Bacillus cereus is a bacterium that is common in the natural environment and in a variety of foods. The organism is so widespread that it is almost impossible to keep it from contaminating certain foods. The bacterium has been isolated from dried beans, cereals, dried foods (including spices and seasoning mixes) and potatoes. *B. cereus* is able to form spores that can survive long periods of dryness and mild heat treatments such as cooking. Hence, since *B. cereus* bacteria are common and widespread, preventing contamination of food with spores is virtually impossible. Consequently, effective prevention and control measures depend on inhibiting spore germination and preventing the growth of vegetative cells in cooked, ready-to-eat foods. Steaming under pressure, thorough roasting, frying and grilling are most likely to destroy cells and spores. Temperatures under 100°C will allow for the survival of some spores. Not all strains of *B. cereus* are able to cause foodborne illness. Only those strains that are able to produce toxin(s) are able to cause illness. The toxins are actually destroyed by heating, but if the food, e.g. rice that is most commonly found contaminated by this bacterium, is just briefly reheated, then the heat may not be sufficient to destroy all toxins. The bacteria cannot produce the toxin at refrigeration temperature. Therefore, if the food is cooked ahead of time, it should be cooled as quickly as possible (USDA, 2003).

Staphylococcus aureus

Staphylococcus aureus is among the longest recognised of the pathogenic bacteria. This species constitutes a normal part of the microflora of the human and the animal body, as it is found on skin surfaces and hair, and in the nose, mouth and throat. Staphylococcal food poisoning occurs as a result of the ingestion of a heat-stable, preformed enterotoxin, produced by the organism during growth. *S. aureus* multiplies in food that is left out at room temperature. The products that are most often affected by *S. aureus* are high protein and fat content products with low numbers of competitive microorganisms including milk, cream, smoked fish, poorly fermented meat products such as salami, ready-made chicken and meat sandwiches. In general, *S. aureus* growth is repressed in the presence of competing microorganisms. The presence of a large number of *S. aureus* organisms in a food may indicate poor handling or sanitation due to human contact or cross-contamination. However, it is not sufficient evidence to incriminate a food as the cause of staphylococcal food poisoning. The isolated *S. aureus* must be shown to produce enterotoxins. Conversely, small staphylococcal populations at the time of investigation may be remnants of large populations that produced enterotoxins in sufficient quantity to cause food poisoning (USDA, 2003).

In general, foodborne disease may occur when a susceptible individual consumes a food contaminated by viable microbial pathogen(s) and/or its toxin(s). However, not every exposure to a pathogen in food will result in infection or illness, and not all individuals in a given population are equally susceptible to all pathogens. The risk of foodborne disease is a combination of the likelihood of exposure to a pathogen in a food, the likelihood that exposure will result in infection or intoxication and subsequent illness and the severity of the illness. Therefore, rational decisions about the kind of interventions, which would be most effective in reducing the impact of pathogens on human health, need a scientific-based approach facilitating estimation of the probability and severity of a health disturbance as a consequence of consumption of food (Lammerding and Fazil, 2000).

Risk assessment approach in the household environment

The essence of microbial risk assessment is describing a system in which a microbial hazard reaches its host and causes harm. Risk assessment is a process that provides estimation of the probability and impact of adverse health effects attributable to potentially contaminated foods, or simply, risk assessment is a measure of risk and the identification of factors that influence it (Lammerding and Fazil, 2000). This approach includes hazard identification, hazard characterization, exposure assessment and risk characterization. Due to the structured approach, various options can be evaluated to assess the influence on the risk estimate. Mathematical modelling offers many possibilities in the quantitative estimation of the risks. Modelling should help to improve estimates and thereby allow quantification of food safety risks (Foegeding, 1997). Moreover, development of a model, although simplified and partially incomplete, can be a helpful tool to evaluate the relationship between risk and a factor that may be used to mitigate this risk (Lindqvist and Westöö, 2000). Once the model has been developed, the impact of various control strategies and trends can be simulated (Lammerding and Paoli, 1997).

In developing suitable guidelines or control interventions for home hygiene, a structured approach is needed. A detailed risk assessment can be used to identify critical gaps in our knowledge base, to characterise the most important risk factor and to help identify strategies for risk reduction in this environment (Lammerding and Paoli, 1997). In providing guidance to determine risk prevention, a number of factors need to be taken into account. For example, reviews of microbial contamination of the home may enable the identification of sites and surfaces that most likely contribute to infection risks. However, as the risks associated with environmental contamination depend not only on whether the site is contaminated, but also on the probability of transfer either to food, to other surfaces or directly from hand to mouth, and whether the numbers exceed the level that can result in infectious disease, a total approach to home hygiene has additional benefits. It creates an understanding of the relative risks for different aspects of home hygiene (Beumer *et al.*, 1999).

The need for risk-informed decision making and planning is urgent in determining priorities in public health programs. In order to establish effective and acceptable decontamination for a public setting, including home setting, Raber *et al.* (2001) indicated that public perception of risk to health, public acceptance of recommendations based on scientific criteria, time constraints and economic concerns must all be addressed in the context of a specific scenario. A risk-based approach means that clean up or decontamination guidelines should be based on a defined, 'acceptable' level of risk to health, while key issues are to determine exactly what constitutes a safety hazard and whether decontamination is necessary or not for a particular scenario. This study indicates that clean up criteria are site dependent and population specific. Zero concentration of a biological agent and zero risk, in many cases, is clearly not a necessity. It is likely that economic drivers will also influence populations to accept higher risks. Furthermore, an important factor underlying each risk-based decision is the uncertainty and reliability of available data. Uncertainties in site-specific features and prediction of natural attenuation or potential dilution effects all need to be considered to get to the decision about whether appropriate decontamination levels have been reached (Raber *et al.*, 2001).

In order to provide a scientific basis for risk management strategies that minimise the level of undesirable bacteria on the hands and, therefore, reduce the risk of cross-contamination during food preparation, Montville *et al.* (2002) described a risk assessment of hand washing efficacy. The risks associated with different hand washing techniques were quantified, including FDA (Food and Drug Administration) food code, i.e. soaping for 20 seconds and rinsing thoroughly, followed by drying with a paper towel. Proper hand washing has been recognised as one of the most effective measures to control the spread of pathogens, especially when considered along with the restriction of ill workers and the controversial recommendation of no-bare-hand contact with ready-to-eat foods. Since foodborne pathogenic bacteria are transient in nature, with the exception of *S. aureus*, the models reflected hand washing efficacy with respect to the risk of bacterial contamination to a reasonable degree. The result indicated that when done properly, hand washing could reduce the risk of bacterial contamination on hands. The primary factors influencing final numbers of bacteria on the hand were sanitizer, soap and drying method (Montville *et al.*, 2002).

The risk assessment at household level will be useful in providing guidance to make rational decisions about the kind of interventions to control transmission of foodborne infectious diseases in this environment. As relevant and accurate data are often lacking, particularly in the exposure assessment, systematic studies are needed to provide quantitative data for risk management efforts in the domestic environment.

Recently, several quantitative studies dealing with the survival and transmission of foodborne pathogens were performed. For *Salmonella* Enteritidis, *Campylobacter jejuni* and *Staphylococcus aureus*, the survival against air-drying on surfaces was quantified. Even after a single contamination event, these pathogens survive on stainless steel surfaces for hours or days, depending on the species, initial counts and the presence of food residues. *S. aureus* is the most tolerant against air-drying on surfaces, followed by *S.* Enteritidis and *C. jejuni*. These pathogens are readily transmitted from wet sponges to stainless steel surfaces and from these surfaces to cucumber and chicken fillet slices. Therefore, effective cleaning and/or sanitizing of food preparation surfaces is apparently important to prevent the cross-contamination (Kusumaningrum *et al.*, 2003).

In another study, a quantitative analysis was carried out to estimate the probability of contamination and the levels of *Salmonella* and *Campylobacter* on salad as a result of cross-contamination from contaminated chicken carcass via kitchen surfaces. Data on prevalence and numbers of these bacteria on retail chicken carcasses and the use of unwashed surfaces to prepare food were collected from the literature. The rates of bacterial transfers were collected from laboratory experiments and from the literature. Monte Carlo simulations with input parameter distributions were used to estimate the contamination of the product. The results have shown that the probability of *Campylobacter* contamination on salads is higher than that of *Salmonella* since both the prevalence and the levels of *Campylobacter* on chicken carcasses are higher than those of *Salmonella*. It is realistic to expect that a fraction of human exposure to, particularly, *Campylobacter* originates from cross-contamination in private kitchens during food handling. The probability of illness caused by *Campylobacter* is generally three orders of magnitude higher than that caused by *Salmonella*. It is important to use separate surfaces or to properly wash the surfaces between preparation of raw and cooked foods or ready-to-eat foods to cut the cross-contamination route (Kusumaningrum *et al.*, 2004).

Concluding remarks

Domestic kitchen environments can potentially spread pathogenic bacteria, including *S.* Enteritidis, *C. jejuni* and *S. aureus*. However, foodborne disease outbreaks related to this environment are more often associated with specific incidents and practices rather than continuously present large populations of foodborne pathogens in the kitchen. As foodborne disease occurrence continues over time, prevention and control measures must be managed on a continuous basis. Hygiene procedures in the kitchen should be considered as a reason to reduce microorganisms to a level that is not harmful to health, but are not intended to achieve sterility.

It is also apparent that public awareness of hygiene alone may not be enough; what is needed is increased understanding, leading to improved practices. As with many issues of health, education is an important part of the fight against the spread of foodborne diseases. By learning what threats are posed by foodborne diseases and by changing behaviour, people can reduce the risk. It is important to remember that each individual can play a critical role in preventing and controlling illness. Basic personal and kitchen hygiene can greatly help to defend against harmful microorganisms.

The take-home message

Foodborne infectious diseases present old and new challenges. No matter how sophisticated and complex a measure and control system is, it will be never finished nor complete, because change is constant. Changing life styles, population demographic, and global food trade are a few examples of factors that relate to the occurrence of foodborne disease. As foodborne disease occurrence continues over time, prevention and control measures must be managed on a continuous basis. Continued research will improve our understanding of the complex factors that cause foodborne disease.

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