Review

Hygiene in the home kitchen: Changes in behaviour and impact of key microbiological hazard control measures

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A R T I C L E   I N F O
Article history:
Received 20 February 2013
Received in revised form 12 July 2013
Accepted 20 July 2013

Keywords:
Consumer behaviour
Home kitchen
Food safety

A B S T R A C T

This review first examines the societal evolutions which may impact negatively on food safety at home as well as the knowledge and perceptions of consumers with respect to food hygiene. In its second section, this paper gives a general overview of measures to control microbiological hazards in the domestic kitchen and their effectiveness. The measures described are those that aim to (i) decrease cross contaminations, (ii) hinder microbial growth (storage temperature), (iii) decrease microbial load (cooking, cleaning of hand, dishes, dish cloths, sponges, towels, equipment and utensil surfaces). The necessity to clean hands is unanimously recognized but for other measures this is not the case and they therefore deserve to be further studied to establish the most relevant recommendations for consumers. Some views on how to communicate these recommendations to consumers are presented, which make it possible to conclude that improvements could to be obtained through motivating the youngest consumers.

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0956-7135/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.foodcont.2013.07.026
1. Introduction

The yearly incidence of foodborne infectious diseases in France in the 1990s was estimated at between 238,836 and 269,085, that is around 450 cases per 100,000 persons (Vaillant, De Valk, & Baron, 2004). Estimates for hospitalizations and deaths were between 10,188 and 17,771 and 228 to 691 respectively (Vaillant et al., 2004). Retrospectively, the estimate of incidence seems low in comparison with the 4100 cases per 100,000 persons per year in 2009 in the Netherlands (Havelaar et al., 2012). According to the European Food Safety Authority, 36% of the outbreaks in France in 2010 occurred in home settings (EFSA, 2012), which, taking into account the number of French inhabitants (65 million in 2012) and the Dutch estimated incidence, would correspond to about one million cases in 2012. An unknown percentage of these cases occur because of improper food manipulation, storage and preparation at home, that is in settings that are not under the control of the competent authority in charge of food safety. Many scientific papers (Doyle, Ruoff, Pierson, Weinberg, Soule, & Michaels, 2000b; Redmond & Griffith, 2003) highlight the role of consumer hygiene practices in their kitchen. This paper will focus on societal evolutions and on the knowledge, awareness and behaviour of consumers, in order to understand the significant elements to focus on for establishing a well-targeted communication strategy. However, one may note that some of the recommendations issued are divergent (e.g. on the cleanability of wooden chopping boards) or excessive (e.g. on the laundering conditions). Therefore, the present paper reviews home hygiene measures and, when available, their effectiveness, with the aim of providing elements appropriate for establishing or revising recommendations.

2. Societal evolutions and consumer studies

2.1. Impact of societal evolutions on home hygiene

In recent decades, lifestyle changes have had an impact on the eating habits of consumers, in industrialized countries, women are more likely to work outside home (Bloomfield et al., 2009). In France, although the model of the traditional meal (three meals a day at relatively fixed hours in the company of others) is stable, there is increased consumption of ready-to-eat foods with a decrease in the time spent on meal preparation (Étilévant, Bellisle, Étilé, Padilla, & Romon-Rousseau, 2012). Today production and preservation techniques make it possible to store food products longer, and frozen products are increasingly used in the preparation of meals (Heinzel, 2001; Terpstra, 2003). Also, more raw foods are consumed, such as meat and fish carpaccio and tartare, marinated fish, raw “sushi-type” fish (AFSSA, 2008). The high frequency of diseases related to the consumption of sprouts eaten raw, the “sproutbreaks” observed since 1973 in the United States and in other countries (Soon, Seaman, & Baines, 2013; Taormina, Beuchat, & Slutsker, 1999) are a reminder that new patterns of consumption should be taken into account in risk prevention. Raw products sometimes have distant or unknown origins. Thus, the European outbreak caused by sprouts contaminated with Escherichia coli O104:H4 in 2011 was most likely due to seeds imported from Egypt (EFSA, 2011). Similarly, a recent norovirus outbreak in Germany was most likely due to Chinese frozen strawberries (Richter, 2012).

Food safety and the quality of marketed food have improved overall since the various crises of the last century, in part thanks to regulatory changes and technological advances. Thus, in France the incidence of listeriosis was divided by 4.5 from 1987 to 1997 (Goulet, de Valk, Pierre, Stainer, Rocourt, Vaillant, Jacquet, & Desenclos, 2001) and in the European Union salmonellosis incidence has been declining for six years (EFSA, 2012). However this impression of improvement felt by the population (Rohr, Luddecke, Drusch, Muller, & Alvenslieben, 2005) does not exactly reflect the reality of the situation. In fact, the incidence of listeriosis increased in Europe between 2002 and 2009 (AFSSA, 2009b). Its incidence decreased slightly in 2010, but Campylobacter and verotoxic E. coli infections have been increasing in Europe for several years (EFSA, 2012). Yet, increased awareness and improved surveillance may have played a role in the evolution of the reported number of foodborne diseases.

In addition, the highly publicized “hygiene hypothesis” might also be the cause of a certain disregard for hygiene. This hypothesis issued in 1989 (Strachan, 1989), suggested there may be a link between decreased exposure to pathogens and the increase in allergic diseases in recent years. However, some experts agree that further changes in environment and lifestyle, including dietary changes, lack of exercise, certain pollutants, and increased exposure to allergens, might cause a greater predisposition to atopy (Strachan, Warner, Schweiger, Pennington, Stanwell-Smith, & Jones, 2003). Thus, some authors assume the increase in allergies cannot be explained only by changes in domestic hygiene practices (Bloomfield, Stanwell-Smith, Crevel, & Pickup, 2006).

Alongside these developments, the demographics trend in the European countries tends towards an augmentation of at-risk populations, particularly the elderly with chronic diseases that require a high level of hygiene (Avdeev et al. 2011). Mainly because of the rising cost of care in nursing homes. Western governments advocate home care of the elderly as long as possible (Villéz, 2007). The decrease in sensory acuity and mobility of these people makes cleaning operations more difficult for them, causing an increase in risks linked to poor hygiene (Heinzel, 2001; Terpstra, 2003).

The environmental awareness of the public is another factor that may influence consumer practices. Environmental concerns such as natural resource depletion, ecosystem pollution and biodiversity degradation can have a detrimental effect on household behaviour. For example, the shortened cycles, lower temperatures and less water used in the “eco” programmes of washing machines could have a detrimental impact on hygiene (Terpstra, 2001).

The goal of waste reduction may also play a role. European Directive 2008/98/EC of 19 November 2008, which establishes measures to reduce wastes, provides in Article 9 for the implementation of preventive action plans aiming, in particular, to change current consumption habits (EC, 2008). A European Parliament resolution calling for halving food waste by 2025 and improving the access to food for poor people was adopted on 19 January 2012 (EU Parliament, 2012). As described in the popular press, actions are being implemented such as home cooking workshops, advice on recipes for cooking leftovers and tips to be displayed on retail shelves explaining how to keep food as long as possible. New practices are also emerging as regards the discounting of products with imminent expiry dates. These actions may lead to risky behaviour such as non-compliance with sell-by dates, encouraged by growing poverty in many Western countries since the economic crisis in 2008. Also, the risk linked to cooking in the just boiled water from a kettle (Derenne, 2010) sometimes recommended in the popular press for people who are poor, and do not possess cooking utensils, should be evaluated.

2.2. Knowledge, risk awareness and consumer behaviour

2.2.1. Knowledge

As reported below, many studies show that public knowledge regarding risks related to food is insufficient and varies from one European country to another: for example E. coli O157:H7 is better known in Britain than in Spain, Denmark or Poland (Hall, 2010). In a
survey of French women, Marrackchi et al. (2002) reported that the word “hygiene” referred to food hygiene for only 3% of them. In Germany, according to a telephone survey, 58% of respondents did not know that salami is a raw product (Bremer et al., 2005). In contrast, Redmond and Griffith (2003), in a review of studies on food safety at home, reported that 75% of respondents (British and American) knew that hand washing is essential to the prevention of contamination, although one fifth of the respondents were not familiar with the most effective methods for washing and drying hands.

A lack of knowledge about foodborne illnesses is a barrier to changing the high-risk practices of consumers (Angellillo, Foresta, Scozzafava, & Pavia, 2001), since this means they have little incentive to change their behaviour due to poor understanding of the nature, source and frequency of these diseases (Unusan, 2007). A study on the hygiene of domestic refrigerators in Ireland showed that the rate of bacterial contamination on the inner surfaces of refrigerators was lower among respondents who scored better in terms of food safety knowledge (Kennedy, 2005). Kennedy et al. (2011) suggested that poor practices of young consumers can be explained by the fact that they are generally less involved in the preparation of family meals. Thus, it is likely that ignorance led to a fatal case of poisoning caused by a Bacillus cereus toxin (Naranjo et al., 2011). The victim, aged 20, had consumed the remains of a plate of spaghetti with tomato sauce, prepared five days earlier and left at room temperature. Similarly, at a university festival in Japan, an outbreak of foodborne Staphylococcus aureus infection has been attributed to the consumption of pancakes prepared by young students Kitamoto et al. (2009).

2.2.2. Perception

2.2.2.1. The optimistic bias. In recent decades, improvement of the microbiological quality of food probably explains the optimistic bias or feeling of invulnerability of consumers which is described in several studies (Hillers, 2003; Redmond & Griffith, 2004; Wright, Canham, & Masrani, 2011). A survey conducted in Germany in 2002 showed that consumers perceived an improvement in food quality and reduced risk in food (Rohr et al., 2005). Thus, German consumers believe that prevention of food risk is up to the authorities, industry and the agri-food trade, resulting in a loss of a personal sense of responsibility (Heinzel, 2001). In addition, individuals tend to concentrate on the superficial, “visual” aspects of housework rather than the actual hygienic aspects, which results in a lack of clear understanding of the risk of infection (Marrackchi et al., 2002).

Fein, Lin, and Levy (1995) in two telephone surveys conducted in the U.S. in 1988 and 1993 described the perceptions of consumers who felt they had recently been victims of foodborne illness: these “had greater awareness of foodborne microbes and concern about food safety issues, were more likely to eat raw protein foods from animals, and were less likely to practice safe food handling than were those who did not perceive that they had experienced such an illness”. A British case-control study of sporadic Salmonella poisoning revealed that optimistic bias was lower in households that had already experienced a foodborne infection, although it had not completely disappeared (Parry, Miles, Tridente, & Palmer, 2004).

2.2.2.2. Influence of the degree of risk perception on consumer behaviour. While food safety knowledge appears necessary to apply good hygiene practices, several studies showed that this knowledge is not sufficient for consumers to perceive the risks associated with foods. Thus, Debucquet, Fischler, and Merdji (2007) observed a mismatch between consumer practices and their still often archaic “beliefs” regarding food hygiene. For instance, poultry is considered to be less of a risk because it contains less blood than red meat. Similarly Fischler, Fuls, Dail, Duran, Rodgers, and Waggoner (2007) and Phang andBruhn (2011) reported that while most people were well informed that cross contamination is a major cause of foodborne illness and of the importance of cooking in its prevention, this knowledge did not necessarily translate into behaviour. It is interesting to note, however, that awareness of the risks associated with foods affects people’s behaviour. Respondents of the U.S. study by Chen, Godwin, and Kilonzo-Nthenge (2011) who “worry about” food safety at home were more likely than others to have low bacterial counts on their sinks. Fischer et al. (2007), following a study combining observations and microbiological investigation, concluded that motivation had more influence on consumer behaviour than knowledge of food safety.

2.2.3. Behaviours

Refrigeration, cooking and cleaning practices have been widely studied. Regarding refrigeration, Marklinder, Lindblad, Eriksson, Finnsson, and Lindqvist (2004) revealed in a Swedish survey, that, even if they knew the recommended storage temperatures for products, 74% of the respondents did not know the temperature of their refrigerator and for many, the location of foods in the refrigerator was based on convenience more than on hygiene considerations. The French survey by Lagendijk, Asséré, Derens, and Carpentier (2008) showed that only 37% of those surveyed using an anonymous self-administered questionnaire had checked that their refrigerator’s “cold zone” met the 4 °C recommendation. The results of the second French National Individual Survey on Food Consumption (INCA 2) showed that 43% of those surveyed reported storing raw food “where there is room” in their refrigerator (AFFSA, 2009a). Debucquet et al. (2007) filmed consumers and reported that they placed the red meat in the coldest refrigerator location while other meats (white) were placed there only if space was available. James, Evans, and James (2008) observed also that the temperatures of refrigerators around the world were often higher than recommended. Outbreaks due to E. coli O157:H7 in hamburgers incited the U.S. health authorities to strongly encourage the use of a thermometer to check that the burgers reach an internal temperature of 160 °F (71 °C) before serving. However, Anderson, Shuster, Hansen, Levy, and Volk (2004) studied the behaviour of 99 subjects: only 31 reported the correct cooking temperatures for meat, and only five used a food thermometer. Another study published in 2011 showed that American consumers who possess a kitchen thermometer are reluctant to use it, even if they are aware of the importance of thorough internal cooking (Phang & Bruhn, 2011).

The cleaning of household refrigerators has been studied in many surveys that show large differences in the frequency of cleaning. These differences are likely due to different wording of the questions. Thus, in France in 2006, when G. Debucquet and M. Merdji (personal communication) asked how often a complete cleaning of the refrigerator is made, the most frequent answer was once a year, whereas, when the term “complete” did not follow the term “cleaning”, (Lagendijk et al., 2008) noted that 64% of respondents reported cleaning at least once per quarter. These authors also showed in their report that bleach was often used incorrectly. Among the respondents 21% used it without prior cleaning, in which case proteins from food residues can combine with the bleach and reduce its disinfecting power. In addition, concentrated bleach was sometimes used, causing a risk of damaging the surfaces and creating crevices which could become microbial reservoirs.

Hand washing is widely regarded as a measure of utmost importance. Anderson et al. (2004) showed that most people in the U.S. did not comply with the observed hand washing instructions given by the authors of the study when handling raw meat products, poultry or seafood (washing with warm water and rubbing
with soap for 20 s before thorough rinsing). Kendall et al. (2004) found that hand washing was usually performed before meal preparation but infrequently or never during various food manipulations, including raw products.

Risk behaviours of consumers are not limited to the preparation and storage of food. As part of an educational campaign on food safety, the French Institute of Consumer Affairs evoked consumer responsibility when purchasing products. Reading labels and expiry dates, visual inspection of packaging, and transporting refrigerated and frozen foods in insulated bags, are all important basic rules which need to be followed. Jevsnik, Hlebec, and Raspor (2008) showed that consumers felt that they were personally less responsible than operators in the food sector for the safety of the food they consume. Therefore, while they generally checked the condition of product packaging and labels, half of respondents reported never using an insulated bag for transporting refrigerated or frozen foods.

2.2.4. Communication

Many experts believe that State authorities should be responsible for informing and educating consumers in order to initiate behavioural changes in the general public. Public education programmes in primary schools are also often recommended (Cerf, Eliaszewicz, & Labellec, 2006). It would seem that these recommendations have been heeded, as attested by the many leaflets made available via the Internet and other media, by organizations involved in public health such as the World Health Organization and the French Agency for Food, Environment and Occupational Health & Safety (AFSSA, 2006). A large-scale programme was initiated by eighteen European countries, within the framework of the European E.BUG project to create a fun “resource” Web page on microorganisms, hygiene, antibiotics use and vaccines. A website, designed for school children aged 9 to 15 and their teachers, is currently available in nine languages and will be available in twenty additional languages in the future. In conclusion, the 2009 health crisis involving influenza virus H1N1 led health authorities to boost their communication efforts on hand washing which, together with behavioural recommendations, was shown to reduce self-reported acute illness by Finnish office employees participating in an open cluster intervention trial (Savolainen-Kopra et al., 2012). Regarding other recommendations, while specific studies, such as the one by Trifletti, Crovato, Capozza, Visintin, and Ravarotto (2012) conducted with forty five Italian students, have shown the effectiveness of prevention messages in avoiding illness due to raw meat, the effectiveness of public communication campaigns remains to be established.

3. Main microbiological hazard control measures

This section gives a general overview of aspects relevant to microbial risk and hazard control measures applicable to the home kitchen. No detailed recommendations are given, as these can be found in publication of international and national agencies in charge or food safety (ANSES, 2013; FASPC, 2012; MPI Food Safety, 2009; USDAHHS, 2013a; WHO, 2013).

3.1. Cross contamination

It has long been known that foodborne infections can be caused by contamination of kitchen surfaces or hands when preparing food (De Wit, Broekhuizen, & Kampelmacher, 1979). Microorganisms may be introduced into the kitchen by the food itself: raw poultry meat is a major vehicle and microbiological studies have shown that a poultry carcass can carry up to 10⁶ Campylobacter cells (Humphrey, Martin, Slader, & Durham, 2001). The authors stated that bacteria could also be carried by the packaging of these products and survive in the kitchen environment. Gram positive bacteria are able to survive on dry surfaces, but wet places in the kitchen are those where bacteria are the most likely to survive or grow and the hands are the most effective vehicle for contamination transfer (Beumer & Humphrey, 2003; Cogan, Bloomfield, & Humphrey, 1999). Microorganisms can also be transmitted from wet or damp sponges used to clean surfaces where they are able to survive and then are transferred from these surfaces to food (Kusumaningrum, Riboldi, Hazeleger, & Beumer, 2003). A review of the literature on bacterial transfer to food highlighted that high levels of moisture, contact time and pressure could result in high transfer between surfaces (Pérez-Rodriguez, Valero, Carrasco, García, & Zurera, 2008).

Van Asselt, de Jong, de Jong, and Nauta (2008) provided data to quantify the risk of campylobactersiosis due to bacterial transfer between foods, hands, knives and cutting boards when preparing a salad with chicken. The high decrease of bacterial transfer observed in this study when hand washing is performed during the meal preparation showed that reducing handling can be crucial to reduce cross contamination. The same research group showed that a simple rinsing of hands only slightly reduced the transfer rate while rinsing cutting boards with hot water at 68 °C for 10 s reduced it significantly (De Jong, Verhoef-Bakkenes, Nauta, & De Jonge, 2008). Knowing that more conventional washing with cooler water was not effective (Cogan, Bloomfield, & Humphrey, 1999), these authors concluded that to reduce the risk, cutting boards should be dedicated to one type of food (one board for raw food, another one for ready-to-eat food).

Materials containing antimicrobial compounds had been put on the market with the aim of decreasing cross contamination. For example cutting boards containing Triclosan (Moretro, Høiby-Pettersen, Habimana, Heir, & Langsrud, 2011) or refrigerators surfaces containing silver (Ilg, Bruckner, & Kreyenschmidt, 2011). Although such materials have some efficiency they are often criticized. Triclosan is suspected to be toxic (Bedoux, Roig, Thomas, Dupont, & Bot, 2012) and to develop cross resistance to antibiotics (Yazdankhah, Scheie, Høiby, Lunestad, Heir, Fotland, Naterstad, and Kruse, 2006). Silver, discharge in the environment should also be avoided (Ilg et al., 2011).

3.2. Storage temperature

From production through to consumption, food quality and safety are highly dependent on temperature. Among the various means of preservation, cold, whether above or below freezing, is the most common. Redmond (2009) pointed out that after cooking, the time during which a food is exposed to a temperature that allows bacterial growth must be reduced. Thus, the World Health Organization recommends that the dividing of a meal into small portions before storing in the refrigerator or freezer be done within 2 h after cooking (WHO, 2006). Although to our knowledge there are no quantitative risk assessment studies justifying this time, several studies modelling the behaviour of spore-forming bacteria during cooling are available (Cevallos-Cevallos, Akins, Friedrich, Danyluk, & Simonne, 2012; Jaloustre, Cornu, Morelli, Noël, & Delignette-Muller, 2011) and show very little bacterial growth when cooling is done promptly. There is a similar lack of risk assessment to establish storage times of food from the catering trade. This should be done in order to provide science-based recommendations.

But risks can also arise from a misinterpretation of storage instructions. Mazuet, Bouvet, King, and Popoff (2011) reported that a botulism outbreak involving two severe cases in a French family resulted from the consumption of a commercial preparation sold as “enchiladas”, a type of Mexican crepe with a filling of chicken and vegetables. This food had been stored for at least two weeks before consumption at room temperature instead of at 4 °C.
To help the consumer, temperature indicators within refrigerators have become mandatory in France (Premier Ministre, 2002). In addition, to inform the consumers about the refrigeration conditions undergone by foods along the distribution chain and provide them with new tools to make decisions regarding food safety, time temperature integrators are more and more frequently included in the packaging of refrigerated foods of extended durability (Ellouze & Augustin, 2010; Giannakourou, Koutsoumanis, Nychas, & Taoukis, 2005; Labuza & Bin, 1995).

3.3. Cooking temperature

Cooking is critical to preventing risks. In a British epidemiological study Ryan, Wall, Gilbert, Griffin, and Rowe (1996) showed that the inappropriate heat treatment of foods during meal preparation was a contributing factor in 35% of poisonings recorded in Britain. *E. coli*-producing Shiga toxins (STEC) are considered since the 1980s to be a major pathogen in the United States where many infections were linked to the consumption of undercooked hamburgers. Grilling technique and modelling studies have been conducted to determine the most effective way to reduce the concentration of *E. coli* O157:H7 in ground beef patties cooked at home. Hawronslyj and Holah (1997) showed that hamburgers cooked in a skillet and turned every 45 s during cooking reached the internal temperature of 166 °F (74.4 °C) within 4 min. This cooking practice does not seem to be common among French consumers and temperature measurements during the typical French cooking of a frozen hamburger, i.e. in a frying pan turned once halfway through cooking, showed that more than 10 min were needed to reach 65–70 °C (AFSSA, 2007).

Due to its ease of use, the microwave oven is widely utilized in homes and plays an important role at mealtime. According to the French National Institute of Statistics and Economic Studies, 82.3% of French households were equipped with a microwave in 2007 and according to the Department of Agriculture of the United States (USDA), more than 90% of American homes had one in 2011. But, because of the heterogeneity of heating in these ovens, the temperature required to reduce the microbial load is not always reached evenly throughout the entire food. Because of this, the heating time should not be too short. In the United States it is recommended to heat food in a covered container until steam escapes, wait a few minutes (during which time the temperature continues to rise) and then measure the temperature of the food to check that it has reached at least 74 °C (165 °F) (USDA, 2011). Yet, as regards meats of different type, temperatures from 60 °C (140 °F) to 74 °C (165 °F) are recommended (USDHHS, 2013b), making difficult for the consumer to remind and apply correctly. In fact, the use of a thermometer for cooking at home is considered an important measure in the United States (Hillers, 2003). But this recommendation, usually applied by professional caterers, requires expertise and is difficult to implement at home (Snyder, 1997).

3.4. Cleaning and disinfection

Microorganisms are capable of adhering to surfaces. Surface conditions which promote bacterial growth – including the presence of water (even intermittently), nutrients and a favourable temperature – bacteria can multiply and may form a biofilm, a microbial community of attached bacteria adhering to each other in a matrix of extracellular polymeric substances (Costerton, Stewart, & Greenberg, 1995). Such conditions may exist in different areas of the kitchen: the sink, including the area around the drain, the sponges, the garbage can, etc. Certain bacteria such as *Lysteria monocytogenes* grow at low temperatures, a property that most likely contributes to the presence of this bacterium on the internal surfaces of approximately 2% of domestic refrigerators (Beumer, Te Giffel, Spoorenberg, & Rombouts, 1996; Jackson, Blair, McDowell, Kennedy, & Bolton, 2007; Sergelidis et al., 1997). If wet zones are not cleaned regularly, they become reservoirs for bacteria, some of which may be unwanted species. In addition to these wet zones, that include cleaning cloths and sponges, all kitchen surfaces, utensils, dishes, taps, etc. are also possible places where microorganisms may accumulate. Therefore it is very important to clean them after use as well.

3.4.1. Dishes

Mattick, Durham, Hendrix, et al. (2003) were interested in the microbiological quality of the water used for dish washing and in the transfer of bacteria during washing in domestic and professional kitchens. They showed that water temperature, detergent concentration and drying played a role in the survival of microorganisms. Conventional methods of washing dishes did not enable the complete elimination of bacteria. However, after drying, the transfer of bacteria from plates to food was rarely detected (Mattick, Domingue, et al., 2003).

The arrival of the dishwasher in the kitchen has surely contributed to improving household hygiene. The effectiveness of washing increases when the pH is alkaline and at high washing temperatures. But these pH and temperature conditions can also create an alternative habitat for species of mycotoxin-producing fungi (Zalar, Novak, de Hoog, & Gunde-Cimerman, 2011). Also, overloading, poor maintenance or lack of maintenance of the dishwasher may decrease the effectiveness of cleaning.

3.4.2. Hands

Hands have for long been regarded as a crucial vector for microorganisms. In a report on the impact of hand hygiene in reducing the transmission of infectious diseases, Bloomfield, Aiello, Cookson, O’Boyle, and Larson (2007) emphasized that this is a key factor of the incidence of gastrointestinal infections. Recently, Aldabe et al. (2011) reported a case of household transmission of haemolytic uraemic syndrome which occurred in the South West of France. It is likely that *E. coli* O104:H4 was transmitted to two individuals from the infected person who prepared their meals. Doyle, Ruoff, Pierson, Weinberg, Soule, and Michaels (2000b), with data from the U.S. Center for Disease Control and Prevention, considered that proper hand washing is one of the most effective ways to fight against infections in the home. Todd, Michaels, Smith, Greig, and Bartlestone (2010) reviewed the bibliographic data for hand cleaning and disinfection. They concluded that the time spent at washing hands, as well as the method used, were more important than the temperature of the water. Soaps containing a biocide were more effective on enteric bacteria than regular soaps but if the amount of ordinary soap and the washing time were increased, efficiency was comparable to that of antiseptic soaps (Fischler, Fuls, Dail, Duran, Rodgers, & Waggoner, 2007). Kennedy et al. (2011) highlighted the relationship between *Campylobacter jejuni* on hands and on refrigerator door handles and countertops when preparing a meal. Phang and Bruhn (2011) showed that water taps were most commonly involved in bacterial transfer via hands.

The presence of moisture on the hands promoted the transfer of bacteria to surfaces (Doyle, Ruoff, Pierson, Weinberg, Soule, & Michaels, 2000b). For hand drying, it is recommended to use paper towels instead of cloth towels for two reasons: their manufacturing process reduces or eliminates the microbiological load, and they are disposable (Doyle, Ruoff, Pierson, Weinberg, Soule, Michaels 2000a). Hand drying was also studied by professionals from different sectors, both in hospitals and the catering industry. Snelling, Saville, Stevens, and Beggs (2011) compared methods of drying hands which were naturally contaminated
through handling raw chicken. For these authors, wiping with paper towels was the most effective method compared to the use of hot air drying devices. However, the regular use of paper towels at home also needs to be considered with regard to its ecological footprint.

3.4.3. Cleaning clothes, sponges and towels

Several studies have shown that dish cloths, sponges and towels used daily in the kitchen contribute to the transmission of pathogenic microorganisms. A study of dish cloths showed that 37% of them were contaminated with L. monocytogenes and 18 of the 108 analyzed cloths were contaminated with this bacterium at levels ranging from 1000 to 10,000 CFU per cloth (Beuemer et al., 1996). Scott and Bloomfield (1993) studied the relationship between bacterial contamination of countertops and cleaning cloths. When used for cleaning in a professional caterer’s kitchen during working hours, detergent-soaked cloths were heavily contaminated within a few hours. After cleaning of the premises and equipment, their level of contamination and the contamination of the cleaned surfaces were found to be even higher, which indicates the transfer of bacteria from the cloths to the surfaces and vice versa. Hilton and Austin (2000), in a study on cleaning cloth contamination, confirmed that in both new and used cloths could play an important role in the transfer of bacteria to surfaces, there was no significant difference between the microbial load of wet cloths, dry cloths, those used for short and prolonged periods and cloths used for different activities. Gibson, Crandall, and Rike (2012) studied the role of the material used to make cleaning cloths in the removal of viruses from surfaces and in their spread to other surfaces. They found that cotton/cellulose cloths and microfiber cloths transferred less viruses to surfaces than “non-woven” and terrycloth towels.

Sponges are used frequently to clean surfaces. Lagendijk et al. (2008) in a survey of French consumers showed that 89% of respondents said they used a sponge to clean their refrigerator. Due to their large surface/volume ratio, their almost constant humidity and the nutrients for bacterial growth they can contain, sponges are an ideal habitat for bacteria (Rayner, Veeh, & Flood, 2004). Chaidez and Gerba (2000) studied the microbial quality of sponges used in domestic kitchens in Mexico. They showed that 9.8% of them were contaminated with Salmonella, and that 60% of cellulose sponges and 86% of natural sponges were contaminated with S. aureus. In contrast, in a North American study published the same year, only 4% of the sponges were contaminated by S. aureus and none by Salmonella or Campylobacter (Hilton & Austin, 2000).

Mattick, Hendrix, et al. (2003). found in a professional kitchen that using a hand towel during the preparation of a dish of raw chicken naturally contaminated with Campylobacter led to contamination of the towel by this bacterium. This study also showed that more effective detection methods enabled Campylobacter to be isolated from a dry cloth, although it was formerly believed that it was very difficult for this bacterium to survive after desiccation. Doyle, Ruoff, Pierson, Weinberg, Soule, and Michaels (2000a) also showed that pathogenic bacteria could survive in clean linen. Laboratory studies showed a reduction of the bacterial load of artificially contaminated clean linen after washing at 30 °C, but when the linen was soiled in real-life domestic conditions, microorganisms, protected in soil aggregates, survived the thermal and chemical stress of washing and higher temperatures were necessary to reduce the bacterial load (Terpstra, 2001). Doyle, Ruoff, Pierson, Weinberg, Soule, and Michaels (2000a) therefore recommend laundering at 74 °C (165 °F) with bleach and drying in a dryer as a highly effective decontamination method. However, the International Scientific Forum on Home Hygiene recommended using detergents containing oxidizing agents at only 30–40 °C for the routine washing of linen coming into contact with the body (underwear, socks, towels, etc.). For the decontamination of domestic non-metallic sponges, several teams evaluated the effectiveness of microwave heating. Because with this method heat is generated by the vibration of water molecules under the effect of the microwaves, the sponges must be fully wetted. Two minutes at maximum power (1000 W) inactivate more than 99% of the total viable count, coliforms, E. coli and MS2 phages but Bacillus cereus spores were undetectable only after 4 min when a temperature of 87.2 °C was reached (Park, Bitton, & Melker, 2006). Sharma, Eastridge, and Mudd (2009) showed that microwave treatment and the dishwasher were both effective ways to kill pathogenic microorganisms in sponges used in domestic kitchens. Because many homes are equipped with a microwave oven, its use can be an inexpensive alternative to the use of chemicals.

3.4.4. Equipment surfaces

The household refrigerator is a concern for hygienists because food may be stored there for very long periods of time. The microbiological cleanliness and hygiene practices involved in its use have therefore been studied. Carpentier et al. (2012) examined factors that can affect the bacterial load of the inner surfaces of domestic refrigerators. Cleaning frequency did not appear to have any significant effect. In contrast, the simultaneous presence of condensation and visible soiling was associated with higher bacterial loads. They concluded that it is best to recommend cleaning as soon as surfaces get dirty because of a food spill rather than recommending a cleaning frequency.

Holah and Thorpe (1990) evaluated the cleaning performance of different materials used for making domestic sinks and concluded that stainless steel was more resistant to impacts and shocks, and more hygienic than the other materials studied (enameled steel, mineral resin and polycarbonate). Other studies comparing stainless steel to plastic polyvinyl chloride and polyurethane showed that bacteria adhere less strongly to stainless steel (Khamisse, Firmesse, Chassaing, Christianes, & Carpentier, 2010; Midelet & Carpentier, 2002). But, like on any other material, microorganisms can survive on dry stainless steel surfaces (Kusumaniangrum et al., 2003), making them a risk of contamination as well.

Cleaning with detergent followed by rinsing and applying bleach effectively reduced the bacterial load of surfaces provided the contact time is sufficient (Medrano Félix et al., 2011). Yet, the benefits of using biocides (disinfectants) in domestic hygiene products are controversial. Chen et al. (2011) showed in a study in domestic kitchens in the U.S. that bacterial counts on sinks where raw chicken had been handled were not significantly different in respondents who used disinfectants (bleach or combined detergents-disinfectants) and those who did not. Mattick, Hendrix, et al. (2003) reached the same conclusion regarding dish washing liquid. Josephson, Rubino, and Pepper (1997) showed that when a combined detergent–disinfectant product was introduced with no specific recommendations in households where it had not been used previously, it did not affect the contamination levels of surfaces. However, just after using this product according to a strictly defined protocol (contact time of 5–10 min before wiping with a paper towel), the decontamination effect was clearly visible. These authors recommended using a detergent–disinfectant product from time to time, for example after handling raw meat or seafood. Cole et al. (2003) searched for bacteria that might be pathogenic to humans (Staphylococcus sp., S. aureus, Enterococcus sp., Pseudomonas sp., Acinetobacter sp., E. coli, Enterobacter, Klebsiella, Citrobacter, etc.) in the homes of users and non-users of biocidal products. The authors showed that the prevalence of these bacteria was slightly higher in households of non-users of biocide products. Larson, Lin, Gomez-Pichardo, and Della-Latta (2004) had reservations about the routine use of disinfectants in cleaning operations and recommended evaluating their impact on the environment.
Scientists are particularly interested in the effective cleaning and disinfecting of household cutting boards. In fact, the cuts and scratches made on their surfaces by using sharp utensils make them difficult to clean. Carpentier (1997) in a literature review of cutting board hygiene explained how drying, the presence of residual organic materials and cleaning techniques played an important role in the survival of microorganisms on these surfaces. Plastic cutting boards were considered more hygienic than wood by some authors (Gilbert & Watson, 1971; Gough & Dodd, 1998) because they can be placed in the dishwasher and can be decontaminated in the microwave oven, although this may be difficult to achieve. However, Ak, Cliver, and Kaspar (1994) and Park and Cliver (1996) suggested that wooden cutting boards are not less hygienic than plastic ones and they demonstrated that microwaves more effectively destroyed the bacterial flora found on wooden surfaces.

4. Conclusion

This literature review showed that societal changes are likely to result in an increase of microbiological hazards in food prepared at home. This study also showed that among the control measures used for microbiological hazards in the home, washing hands before preparing food as well as during its preparation is recognized by all authors as of primary importance. However, no consensus has been reached regarding several other measures studied. Should a disinfectant be added to the detergent for washing dishes and cutlery or kitchen equipment? Should a food thermometer be used? Should wooden or plastic cutting boards be used? Such questions deserve further analysis taking into account consumers’ behaviour and the recommendations issued should then be ranked following a risk-based analysis as performed by several authors (Rossvoll et al., 2012; Worsfold & Grif

Acknowledgements

The authors are very grateful to Dana Pottratz for English revision and to Olivier Cerf for helpful suggestions.

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