This paper on the basic four safe food handling practice areas was developed by Ellen Steinberg under contract to the non-profit Partnership for Food Safety Education. [January 2011] www.fightbac.org

Introduction

The purpose of this paper is to summarize the scientific literature behind the current Fight BAC!® campaign's four core home safe food handling messages of cook, chill, clean, and separate. The systematic search of published studies from 2005 onward was conducted utilizing the following seven databases: Medline, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Academic Search Complete, Educational Resources Information Centre (ERIC), Research Library, Department of Agriculture's National Agricultural Library (AGRICOLA), ProQuest Nursing and Allied Health Source. Key words were selected by general topic (e.g., food safety, food handling, food safety education, foodborne illness), food handling practices (e.g., cooking, food thermometer, thawing, cross-contamination, hygiene), target audiences (consumers, food handlers, students, pregnant women), "risky" foods (e.g., raw or unpasteurized milk and raw or undercooked eggs, meat, fish, poultry), and foodborne pathogens (e.g., *Campylobacter jejuni*, *Listeria monocytogenes, Salmonella, Escherichia coli*). In addition, manual searches of the last five years of the *Journal of the American Dietetic Association, Journal of Food Science Education, Journal of Food Science,* and the *Journal of Extension* were performed. Any articles addressing consumers' attitudes, knowledge, or beliefs about food safety were limited to studies conducted in the United States. All articles were obtained from peer reviewed journals.

Cook

Cooking foods to the proper internal temperature is necessary to inactivate foodborne pathogens. It is not uncommon for consumers to judge the doneness of meat based on the color of the meat or expressed liquid; however, science shows that many factors, other than temperature, can influence the final color (e.g., pH, meat source, packaging conditions, freezing history, fat content, added ingredients, irradiation) (King and Whyte 2006). Therefore, the color of cooked meat is not considered a reliable indicator of adequate cooking and the use of food thermometers is recommended to insure that meat reaches a safe internal endpoint temperature. Unfortunately, there is strong and consistent evidence that consumers in the United States do not own and/or use a food thermometer when cooking foods of animal origin (Abbot, 2009; Cates, 2009; DeDonder, 2009; Hoffman, 2005; Scott, 2010; Sellers, 2006; Shapiro, 2010; Takeuchi, 2006; Tropeka, 2006; Wilson, 2009). For example, in the FDA/FSIS Food Safety Survey, 67% of respondents indicated that they owned a food thermometer; yet, very few respondents indicated that they always used it when cooking ground beef (8%), poultry (15%), or egg dishes (3%). Further evidence of consumers' reluctance to use food thermometers is illustrated by the fact that respondents indicated that they were less likely to check cooking temperatures after the 2006 *E. Coli* outbreak than they were before the outbreak (Brady, 2009). Even when safe handling instructions were provided on product labels, participants in one study were not compelled to use a food thermometer (DeDonder, 2009). This lack of compliance may be due, in part, to the fact that, while consumers know the importance of cooking foods thoroughly, they lack the knowledge, skill, and/or motivation to use food thermometers (Abbot, 2009; DeDonder, 2009; Shapiro, 2010; Stein, 2010). Even when consumers associate specific pathogens, such as *Campylobacter* and *Escherichia coli,* with cooking foods thoroughly, this awareness does not translate into safer practices, especially when it may alter the taste of food (Lin, 2005). Unfortunately, research suggests that even when foods are cooked to the recommended temperature, some pathogens may not be destroyed. For example, Ou and Mittal (2007) demonstrated that the required final cooking temperature of pan fried frozen hamburgers was sufficient to inactivate *E. coli* but not *Salmonella* and *Listeria,* where higher process times were needed. Anaya and colleagues (2008) tested the survivability of *Salmonella* in popcorn prepared in the microwave oven and with conventional cooking. While salmonellosis from popcorn is not likely, the researchers showed that, if the initial count of *Salmonella* cells is relatively high, the cells are able to survive conditions of microwave and conventional cooking. Also, Rodriguez-Palacios and colleagues (2010) found that *Clostridium difficile* spores, in ground meat, were able to survive a cooking temperature of 71°C (160°F), which is normally recommended to eliminate foodborne pathogens. Lastly, when the accuracy and reliability of consumer food thermometers were assessed, results indicated that instant-read and digital thermometers were poor indicators of accurate temperatures as they did not match calibrated controls at the recommended insertion times (Liu, 2009). Thus, while it is known that heat kills bacteria, there is evidence to support that, in addition to cooking temperature, it is important to consider the product and process parameters that can affect the overall safety outcome of the product (Anaya, 2008).

Specific to cooking and the prevention of illness from *Listeria monocytogenes,* it is recommended that vulnerable populations (e.g., pregnant women, the elderly, immunocompromised individuals) avoid hot dogs and deli meats unless they are reheated until steaming hot (Centers for Disease Control and Prevention). However, research suggests that this simple message may not be adequate to ensure protection from *Listeria monocytogenes* due to the evasive nature of this pathogen (Rodriguez-Marval, 2009; Sergelidis and Abrahim, 2009). Sergelidis and Abrahim (2009) studied the adaptive response of *Listeria* to heat as it relates to the induction of thermally processed foods. The authors concluded that milder thermal processes alter thermal resistance and destruction of pathogens; hence, additional research is needed to understand how *L. monocytogenes* adapts to overcome heat and other stresses. In another study, researchers tested several microwave oven heating scenarios for inactivation of *L. moncytogenes* in hotdogs (Rodriguez-Marval, 2009). The authors concluded that, to ensure a safe product, reheating instructions must consider variations in the power output of the microwave, the amount of food to be reheated, the age of the product, and whether or not antimicrobial compounds are present in the food. With regard to consumer behavior, many at-risk consumers are not even aware of *Listeria* (Cates, 2007; Cates, 2009; FDA-FSIS, 2006; Lin, 2005; Trepka, 2006) or that special reheating precautions are needed to help protect themselves from listeriosis (Cates, 2007; Cates, 2009). For example, Cates (2009) found that out of 1,140 older adults, 81.9% did not follow the recommendation to reheat hot dogs and deli meats to steaming, and 61.9% did not even know about the recommendation. In addition, after receiving information about this particular risk, some vulnerable individuals still expressed doubt as to whether or not they would reheat hot dogs and deli meats in the future (Cates, 2007; Cates, 2009; Hoffman, 2005).

Lastly, considerable evidence shows that consumption of raw or undercooked animal products is relatively common in the United States, even among vulnerable populations (Abbot, 2009; Byrd-Bredbenner, 2008; Cates, 2009; Hoffman, 2005; Samuel, 2007; Trepka, 2006). Trapeka and colleagues (2006) found that among WIC clients (50% of who had a high school education or less), many individuals prefer "pink meat" and undercooked eggs and are unaware of the recommendation to cook eggs until the yolk is firm. Similarly, Samuel and colleagues (2007) indicated that undercooked meat and runny eggs are among the most commonly eaten risky foods, and Byrd-Bredbenner (2008) found that out of 4,548 young adults, 53% consumed raw cookie dough; 33% ate eggs with runny or soft yolks; 11% ate raw oysters, clams, or mussels; and 7% consumed rare hamburgers.

Chill

For the purpose of this review, "chill" incorporates thawing practices, cold food storage, and handling of leftovers (2-hour rule). Specific to thawing frozen food, the Food Safety and Inspection Service of the United States Department of Agriculture (USDA-FSIS) discourages thawing at room temperature and alternatively recommends thawing in the refrigerator, in cold water that is changed regularly, in the microwave oven, or as part of the cooking process. In a study by Lianou and Koutsoumanis (2009), the effects of these thawing practices was tested using ground beef artificially inoculated with *Listeria monocytogenes* and *Salmonella* Enteritidis. The study revealed that *L. monocytogenes* and *S*. Enteritidis populations were not greatly affected when the ground beef was thawed by the recommended methods. However, the thermotolerance of *L. monocytogenes* was enhanced when overnight countertop defrosting was simulated. Another study illustrated that proper thawing of frankfurters did not have a significant effect on populations of *L. monocytogenes,* and, in fact, defrosting in the microwave resulted in slightly lower pathogen populations when compared to the other methods (Beauchamp, 2010). Lastly, when boneless chicken breasts were rapidly thawed by submersion in hot water (140°F), researchers found this process to be safe in terms of *Salmonella* growth and equal in safety to that of microwave thawing (Shrestha, 2009). Research addressing thawing practices of consumers in the United States is scarce; however, the information from limited research is encouraging. For example, 87% of 390 adult/elderly caregivers in Nevada indicated that they do not thaw meats, chicken, or fish on the kitchen counter at room temperature and instead thawed foods using the microwave (36%), under cold running water (46%), in the refrigerator (86%), or in cold water changed every 30 minutes (81%) (Wilson, 2009). Also, 85% of 220 high school and transitional teachers disagreed that it is safe to leave meat on the counter to thaw (Pivarnik, 2009). Lastly, 76% of 136 older adults indicated that, in the past month, they always defrosted foods either in the refrigerator, in cold water, or in the microwave oven (Sellers, 2006). Unfortunately, Trepka (2006) found that among 32 WIC clients, many did not know that it was unsafe to thaw food simply by leaving it outside of the refrigerator. Also, 30% (n=30) of adults indicated they did not think thawing frozen beef at room temperature for over 12 hours was very risky (Scott, 2010).

It is well accepted that to assure safe cold storage of food, home refrigerators should maintain an air temperature of 40°F or below. Control of the psychotropic pathogen *Listeria monocytogenes* is of particular

concern due to its ability to survive and grow under proper refrigeration conditions. *L. monocytogenes* has often been isolated from food processing environments (Taormina, 2010) and is predominately associated with ready-to-eat foods (World Health Organization). Thus, proper handling of refrigerated foods is imperative for all consumers but especially for pregnant women and individuals with compromised immune systems. As mentioned previously, many consumers have never heard of *Listeria* (Cates, 2007; Cates, 2009; FDA-FSIS, 2006; Lin, 2005; Trepka, 2006) nor do they realize that refrigerator temperatures of 40°F or below are recommended (Stein, 2010). Even when consumers acknowledge that maintenance of proper refrigeration temperatures is important, they still do not follow the recommendation (Abbot, 2009; FDA-FSIS, 2006; Kuo, 2010; Stein, 2010). As an example, despite providing adults over the age of 60 with a fact sheet about prevention of listeriosis, some participants said they were unlikely to follow the guidelines even though they agreed it was important to monitor refrigerator temperatures (Cates, 2007). Participants in this study stated that distrust in the accuracy of refrigerator thermometers, the belief that refrigerator thermometers are not necessary, not knowing where to purchase refrigerator thermometers and lack of concern about contracting listeriosis or other foodborne illnesses were all barriers to following this recommendation.

The Two Hour Rule states that perishable foods should not sit at room temperature for more than two hours. Even though this recommendation appears short, simple, and self-explanatory, research suggests that consumers are inconsistent in their practices. For example, out of 1,122 college undergraduates, 82% knew that leftovers should be refrigerated within 2 hours but only 44% knew that the same rule was necessary to keep a packed lunch safe to eat (Stein, 2010). Among seniors in congregate-meal and home-delivered-meal programs, 22% indicated they would leave a casserole on the counter for over two hours before they would throw it away and almost 10% would eat it even if it had been left on the counter overnight (Roseman, 2007). Almanza and colleagues (2007) found that 37% of 833 seniors who received home-delivered meals did not eat meals immediately upon receipt and consequently did not follow adequate storage procedures.

Clean

The lessons of proper hand hygiene begin in childhood; thus, this particular behavior has been studied across age groups. For example, Snow, White, and Kim (2008) indicated that, among elementary school children, first graders demonstrated the highest rate of hand washing and that the rate declined as the ages of the children increased. Confirmation of this trend was seen in college students (Anderson, 2008) and young adults (Abbot, 2009) where both groups demonstrated poor hand washing behaviors despite prior acknowledgement of its importance. Also, in a convenience sample of 30 households, Scott (2010) found that 30% of participants did not wash their hands after handling raw meat, even though 100% reported it was important. Similarly, while 90% of young adults reported always washing their hands thoroughly after handling raw poultry, only 52% were observed washing their hands correctly after handling chicken in an observational study (DeDonder, 2009). In a study by Lee (2005), fewer than half of adults with children in day care stated that changing diapers or eating food prepared by a person with gastroenteritis played a role in the spread of illness. Fortunately, after receiving proper education, people show more positive attitudes toward hand washing and are more likely to adopt personal hygiene recommendations compared to other food safety behaviors (Shapiro, 2010). With the popularity of antibacterial hand gels, researchers are investigating the efficacy of these products. For example, Haas and colleagues (2005) used different antimicrobial hand gels to assess the pathogen risk reduction after handling ground beef. Not surprisingly, when compared to no hand washing, there was a greater reduction of risk when any hand washing protocol was used. However, the microbial reduction from triclosan-containing products was smaller than that of products containing alcohol or chlorhexidine as the active ingredient. However, Liu and colleagues (2010) found that alcohol-based hand sanitizers were relatively ineffective in reducing the level of human enteric viruses from contaminated hands.

Specific to cleanliness in the kitchen, it is well accepted that sponges are not recommended for cleaning food preparation areas because they can harbor bacteria. However, Sharma (2009) demonstrated that microwaving (1.30kW for 1 min) and dishwashing (normal cycle) treatments are capable of killing foodborne pathogens in kitchen sponges, with microwaving being the more effective method and dishwashing being significantly more effective than 10% bleach. Also, it is a positive sign that in a convenience sample of 30 households, 63% answered that it is very important to use paper towels instead of sponges on kitchen counters (Scott, 2010). Also, WIC participants were aware that sponges could allow for bacterial growth, so they used paper towels or wet-wipes for cleaning kitchen surfaces. Finally, if consumers use antibacterial cleaning products, research shows that these

products are effective at reducing bacteria on food contact surfaces provided they are used as directed (DeVere and Purchase, 2007).

Thorough washing of fresh produce is paramount for lessening one's risk of foodborne illness from consumption of contaminated fresh fruits and vegetables. Brandl (2008) found that plant tissue damaged from harvesting and processing of lettuce can promote significant multiplication of *E. coli* 0157:H7. In addition, Brandl and Amundson (2008) found that young lettuce leaves, which are rich in nitrogen and carbon, may be associated with a greater risk of contamination from *E. coli* 0157:H7 and *Salmonella enterica*. Yet, if leafy greens are processed, packaged, and sold as "washed" or "ready-to-eat", experts indicate that additional washing is not likely to enhance the safety of the product (Palumbo et al., 2007). However, if produce is not intended to be ready-to-eat, consumers are advised to wash fruits and vegetables under running tap water and, when possible, scrub firm produce with a brush. For example, Parnell and colleagues (2005) found that when cantaloupe and honeydew melons were scrubbed with a clean brush under running water, optimal microbial removal was achieved. The authors warned, however, that to ensure the benefits of scrubbing produce, consumers should receive instructions for properly cleaning and sanitizing brushes to prevent possible cross-contamination. Research addressing consumer behavior shows that consumers tend to overestimate their compliance of this recommendation. For example, the FDA/FSIS Food Safety Survey (2006) indicated that, among those who bought tomatoes (n=2275) and strawberries (n=2001), 97% of participants said they washed them before cooking or eating. However, only 57% (n=1806) washed a cantaloupe before cutting it. Scott (2009) found that, after delivery of a fresh produce safety education program, participants reported a significant increase in washing fresh produce with running tap water but only a slight increase in using a vegetable brush to scrub firm produce. In a later study by Scott (2010), 93% of participants said it was important to wash raw vegetables, but it was observed that only 60% washed lettuce and 73% washed tomatoes before consumption. As a side note, it is unfortunate that 83% of participants in the same study also believed that washing raw chicken was very important.

Separate

Cross contamination is multifactorial; hence, there are several consumer recommendations for preventing the transfer of pathogens from one food to another. Due to the complexity of the problem, it is not surprising that many consumers do not consider the various ways food can become contaminated. One relatively common misconception is the "five-second rule", which implies that if a food is dropped and picked up quickly there is not enough time for the food to become contaminated. Dawson and colleagues (2007) tested this concept by determining the survival and transfer of *Salmonella* Typhimurium from wood, tile or carpet onto bologna and bread. The results indicated that *Salmonella* Typhimurium can be transferred to food almost immediately on contact, and the bacteria can survive for up to 4 weeks on dry surfaces in populations high enough to contaminate food. Mylius, Nauta and Havelaar (2007), developed a model for bacterial cross-contamination during food preparation and applied it using *Campylobacter*-contaminated chicken breast. The researchers found that cross-contamination of salad is most likely to occur from the contaminated hands of the cook than via the cutting board, but that it was unlikely to occur from the water tap. Ravishankar, Zhu, and Jaroni (2010) assessed the transfer rates of *Salmonella enterica* from chicken to lettuce utilizing three different food-handling scenarios. As described by the authors, in scenario 1, the cutting board and knife used to cut chicken were also used for cutting lettuce, without washing; in scenario 2, the cutting board and knife were washed with water after cutting chicken, and subsequently used for cutting lettuce; and in scenario 3, the cutting board and knife were thoroughly washed with soap and hot water after cutting chicken, and before cutting lettuce. When samples were taken to detect *S. enterica,* the researchers found that scenario 3 resulted in contamination levels <1 log CFU/g as opposed to 3 logs CFU/g in scenario 1 and 2.4 logs CFU/g in scenario 2. Thus, the authors concluded that the FDA's recommendation for cleaning cutting boards and utensils is adequate for preventing cross contamination of *S. enterica*. With regard to consumer behavior, results from a home self-inspection food safety quiz indicated that 33% of respondents do not store raw meat below all other foods in the refrigerator (Kuo, 2010) and, in another study, 34% of young adults stated that they do not keep raw animal products separated from ready-to-eat food (Abbot, 2009). Also, 29% (n=1,400) of older adults indicated they do not wash their hands for 20 seconds with soap and warm water after handling raw animal products (Cates, 2009). Finally, some WIC clients stated that it is inconvenient to wash cutting boards after cutting meat and that lack of a dishwasher is the primary barrier to properly cleaning kitchen utensils (Trepka, 2006).

Conclusion

The research presented in this review is not all encompassing; however, it provides the information necessary to draw some conclusions about the current Fight BAC!® campaign's four core home safe food handling messages of cook, chill, clean, and separate.

There is considerable evidence to support that current recommended cooking times and temperatures may not be sufficient to eliminate all foodborne pathogens that could be present in foods of animal origin. Furthermore, there is strong and consistent evidence indicating that consumers in the United States do not own and/or use a food thermometer when cooking foods of animal origin. Based on these findings, it is possible that the current food safety messages that address cooking may need to be reviewed.

There is moderate, consistent evidence illustrating that the current recommendations for thawing frozen foods are effective in controlling the population growth of *Listeria monocytogenes* and *Salmonella* Enteritidis. However, there is limited, mixed evidence as to whether or not consumers are aware of and/or practicing safe thawing behaviors. Specific to cold storage and the control of *Listeria monocytogenes*, limited, consistent research indicates that innovative processing techniques may alter the survivability characteristics of *Listeria monocytogenes;* thus, the current chill recommendations may not be adequate. In fact, Doyle and Erickson (2006) assert that behaviors related to chill may have the greatest impact on reducing foodborne listeriosis and that consumer messages should focus on "high risk" foods which possess the following properties: ready-to-eat foods that support the growth of *Listeria monocytogenes*; foods that have the potential for contamination during processing; and, refrigerated foods that are typically stored for extended periods of time.

With regard to hand sanitation and environmental cleanliness, clear and consistent evidence shows that the current messages related to clean are appropriate for hand hygiene, cleaning of produce, and prevention of cross contamination. Consistent research illustrates that alcohol-based hand gels and properly applied antibacterial cleaning products effectively control the transmission of bacterial contaminants. However, one study shows that alcohol-based hand sanitizers are relatively ineffective in reducing the level of human enteric viruses. In terms of consumer behavior, strong and consistent evidence shows that consumers acknowledge the importance of the behaviors related to clean; however, their reported and observed behaviors are not congruent.

Moderate, consistent evidence illustrates that the current recommendations for preventing cross contamination are effective in reducing exposure to foodborne pathogens. Yet, limited, consistent research shows that consumers do not practice these recommendations.

Regardless of the food safety recommendation being delivered, consumers' knowledge, attitudes, and beliefs are a constant variable in terms of how the message is received and whether or not it is adopted. Gaps between knowledge and behavior are common (Shapiro, 2010) and research indicates there is often a clear discrepancy between self-reported behavior and what is actually practiced (DeDonder, 2009; Levy, 2008). As Levy indicates, "practice-specific risk perceptions are the primary cognitive antecedents of safe food behavior." Hence, in addition to the scientific validity of food safety recommendations, the complexity of human behavior needs to be considered in the design of future food safety messages.

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