Part D. Section 8: Food Safety and Technology

Introduction

The 2005 Dietary Guidelines for Americans emphasized the importance of food safety. Since the release of the Guidelines, food safety concerns have escalated, with the apparent increase in voluntary recalls of foods contaminated with disease-causing bacteria and adulterated with non-food substances. These food safety issues affect commercial food products and food preparations in the home.

The basic four food safety principles identified to reduce the risk of foodborne illnesses remain unchanged. These principles—Clean, Separate, Cook, and Chill—are cornerstones in the Fight BAC!® (www.fightbac.org) educational messages developed by the Partnership for Food Safety Education, a collaboration with the Federal government. These messages are reinforced in the United States Department of Agriculture's (USDA) *Be Food Safe* (www.befoodsafe.gov) efforts to reduce foodborne illnesses. Other food safety education programs include the USDA's *Is It Done Yet?* (www.isitdoneyet.gov) and *Thermy*™ (http://origin-www.fsis.usda.gov/food_safety_education/thermy/index.asp) initiatives, which outline key elements in thermometer use and placement to ensure proper cooking of meat, poultry, seafood, and egg products. The primary food safety message from these education programs is "It's Safe to Bite When the Temperature is Right." This "temperature" message receives attention in this chapter. Additional consumer-friendly information on food safety is available at www.foodsafety.gov. In addition to the principles of Fight BAC!®, the importance of "avoiding risky foods[1]" is another relevant food safety education construct addressed (Medeiros, 2001).

Heightened food safety concerns have contributed to the development of new technologies and research directed at reducing the risk of microbial foodborne illness outbreaks and food contamination, while assisting the consumer in controlling the home food preparation and storage environment. Food technology is the application of food science to the processing of food materials into safe, wholesome, and nutritious food (IFT, 2009). Thus, the 2010 Dietary Guidelines Advisory Committee (DGAC) was compelled to provide additional food safety guidance to the American public while introducing and discussing technological developments. The name of the subcommittee changed from the Food Safety to the Food Safety *and Technology* subcommittee.

This chapter updates the 2005 Report content related to risks from exposure to methyl mercury from the consumption of seafood, and, in addition, addresses the impact of exposure to persistent organic pollutants (POPs). The benefit-risk ratios are presented, weighing the benefits of consuming

[1] The DGAC defines a "risky food" as a food consumed in such a way (e.g., undercooked) that it poses a microbiological hazard for human health.

seafood against the risks on health, including reducing the risk of cardiovascular disease (CVD) and supporting child neurological development. The evidence assessment was particularly important in providing information about populations vulnerable to methyl mercury exposure, such as pregnant and nursing women and young children. What is known regarding the interaction of methyl mercury and selenium from seafood sources is briefly addressed, as is the influence of aquaculture practices on a safe and nutritious food supply.

During the deliberations of the DGAC, organic produce emerged as a topic of discussion. The DGAC agreed that current scientific evidence did not warrant a question on this topic, but that some clarification for the public was needed as to what "organic" means. Therefore, a short review of the topic by the Food Safety and Technology subcommittee is available online at www.dietaryguidelines.gov.

Lastly, food allergens were identified by the DGAC as an important food safety issue. The National Institute of Allergy and Infectious Disease (NIAID) of the National Institutes of Health established a Coordinating Committee to oversee the development and approval of *Guidelines for the Diagnosis and Management of Food Allergy*. The Coordinating Committee used an Expert Panel of specialists from a variety of clinical, scientific, and public health arenas relevant to this topic. The Expert Panel used an independent systematic literature review, as well as expert opinion, when needed, to develop the guidelines. Due to the extensive literature review conducted through this NIAID initiative, the DGAC deferred completing an evidence review on food allergy. A draft report of the *Guidelines for the Diagnosis and Management of Food Allergy* was released by NIAID in March 2010 (www.niaid.nih.gov). A short review of the topic by the Food Safety and Technology subcommittee is available online at www.dietaryguidelines.gov.

List of Questions

BEHAVIORS MOST LIKELY TO PREVENT FOOD SAFETY PROBLEMS AND THE EXTENT TO WHICH US CONSUMERS FOLLOW THESE BEHAVIORS

1. CLEAN: What techniques for hand sanitation are associated with favorable food safety outcomes and to what extent do US consumers follow them?

2. CLEAN: What techniques for washing fresh produce are associated with favorable food safety outcomes and to what extent do US consumers follow them?

3. CLEAN: To what extent do US consumers clean their refrigerators?

4. SEPARATE: What techniques for preventing cross-contamination are associated with favorable food safety outcomes?

5. COOK AND CHILL: To what extent do US consumers follow adequate temperature control during food preparation and storage at home?

6. AVOID RISKY FOODS: To what extent do US consumers eat raw or undercooked animal foods?

7. To what extent do specific subpopulations practice unsafe food safety behaviors?

FOOD SAFETY TECHNOLOGIES

8. To what extent are recently developed technological materials that are designed to improve food safety, effective in reducing exposure to pathogens and decreasing the risk of foodborne illnesses in the home?

SEAFOOD

9. What are the benefits in relationship to the risks for seafood consumption?

Methodology

The information used to develop the Food Safety chapter written for the 2005 DGAC was gleaned from a literature review and review of educational tools for conveying messages to consumers about safe food handling and preparation. The Committee emphasized information from the national food safety education campaign Fight BAC!®. Thus, unlike other chapters in the 2005 DGAC Report, which reflected evidence-based reviews, the food safety recommendations stemmed primarily from educational tools developed by the USDA. The 2010 DGAC emphasized systematic evidence-based assessments for all aspects of the Report, and leveraged, for the first time, the systematic review process using the Nutrition Evidence Library (NEL) and the careful quality weighing of that evidence. A description of the NEL evidence-based systematic review process is provided in ***Part C: Methodology***.

Using the NEL system for the first time for the Food Safety and Technology chapter provided a platform for evaluating evidence that has not been previously available and sets the standard for future Committees. Through this process, research strengths and weaknesses were identified, thus providing significant direction for national policy development and guidance for future investigations in food safety and food technology.

The Food Safety and Technology subcommittee assessed the quality of the available evidence pertinent to the three primary families of questions focused on a) in-home food safety behaviors, b) new technologies related to food safety in the home, and c) risks and benefits associated with seafood consumption. All NEL systematic evidence-based review materials are available at www.nutritionevidencelibrary.com.

For both the 2005 and the 2010 DGAC Reports, questions involved reviewing evidence on food safety techniques for application in the home, including those on food storage, food preparation and handling, personal hygiene, and management of cooking utensils. In addition, the food safety questions in the 2010 DGAC Report went further to review substantive evidence on consumer behaviors related to favorable techniques for preventing foodborne illness. The literature search generally covered 2004 through 2009, with slight variations in date ranges by topic that can be found online in the NEL. For in-home food safety behaviors, an original set of nine subquestions was drafted for the literature search and sort plans. Some of these subquestions were worded very generally with the intention to cast a wide net on the available literature. However, after searches were completed, the questions were refocused where the evidence was most plentiful, resulting in the overarching in-home food safety question and seven subquestions as noted above. For the original list of research questions on in-home food safety, see Table D8.1[2].

The food safety questions of the 2005 DGAC Report evaluated topics that were not an integral part of Fight BAC!®, yet warranted attention. Since the 2005 Report, Fight BAC!® has further developed its guidance, and additional food safety materials from the Food and Drug Administration (FDA), and USDA's educational campaigns, www.isitdoneyet.gov and www.befoodsafe.gov, have greatly expanded the food safety messages available to consumers. Therefore, in the 2010 food safety discussion, information available from several USDA and HHS food safety educational programs are identified as points of reference to the findings of the literature reviewed. However, a research question did not specifically address these programs. In addition to the NEL evidence, the DGAC also used data summarized from the FDA and Food Safety and Inspection Service (FSIS) Food Safety Survey (2006).

While the basic pillars of food safety in the home remain unchanged, the Committee considered recent technological developments that may assist consumers in their food management practices. Thus, the second area of formal review encompassed common and emerging technologies associated with items such as thermometers, food contact surfaces, and sanitizers. This topic was not previously addressed by the 2005 DGAC, and the 2010 DGAC's literature search covered only 2004 through 2009 because information has emerged only recently. In addition to the questions stated previously, the 2010 DGAC conducted literature searches for two other questions on aspects of in-home technologies, 1) technological materials that may be effective in increasing the shelf life of foods, and 2) the accessibility and economical practicality of effective technological materials that are designed to improve food safety or increase shelf life. However, the evidence in these two areas was insufficient to draw any conclusions, and, therefore, they will not be discussed in the evidence review.

[2] Tables D8.1 through D8.8 can be found at the end of this chapter.

Originally presented in the 2005 DGAC Report, the current content also updates the evidence on methyl mercury exposure from seafood through a review of new evidence on the benefit-risk ratios associated with seafood consumption and health outcomes published since 2007. The impact of exposure to POPs also is addressed in the review of the literature for this question. A formal search of the evidence-based literature began in 2007 because a report published that year from the Institute of Medicine, *Seafood Choices–Balancing Benefits and Risks* (IOM, 2007), provided an evidence-based assessment of the methyl mercury and POPs issues from the 2005 Report through 2007. A second search on POPs alone was also done from 2004 to 2009. The Environmental Protection Agency (EPA)/FDA advisory, *What You Need to Know about Mercury in Fish and Shellfish* (EPA/FDA, 2004), the current Federal guidance at the time this Report was submitted, and analyses in food pattern modeling to explore the role of seafood in the total diet, were taken into consideration.

The subcommittee considered food safety-related information submitted by the public through the public comments process. Many of these topics were addressed through the evidence-based review. Other topics were not formally reviewed by the Committee, due, in part, to the complexity of the issue or the apparent limited availability of evidence related to the subject. To support the continued consideration of these topics for future DGACs and for public policy, the following are addressed through a review of contextual references:

- Seafood: Implications of dietary selenium and the potential health risks of methyl mercury exposure from seafood
- Seafood: Implications of aquacultural practices and a safe, nutritious food supply
- On-line resource (accessible at www.dietaryguidelines.gov): Implications of food allergens and a safe food supply
- On-line resource (accessible at www.dietaryguidelines.gov): Conventional and organically produced foods

BEHAVIORS MOST LIKELY TO PREVENT FOOD SAFETY PROBLEMS AND THE EXTENT TO WHICH US CONSUMERS FOLLOW THESE BEHAVIORS

Annually, foodborne illness affects more than 76 million individuals in the US leading to 325,000 hospitalizations and 5,200 deaths at a cost of $7 billion to the nation (IOM, 2006). Because foodborne illness outbreaks are difficult to trace and characterize, the proportion of outbreaks that can be attributed to unsafe food safety practices at home remains unknown, although it is believed to be substantial (Redmond, 2003; Roseman, 2007). An indirect way of assessing this risk is by documenting consumers' food safety practices at home. This topic is of relevance as the vast majority of consumers has a refrigerator and a stove or microwave at home, and prepare and/or consume at least some of their meals at home (FDA/FSIS, 2006).

Foodborne illness continues to be a major public health threat to US consumers who are aware of the importance of food safety for human health (Mead, 1999), but they do not believe that their home kitchens are an actual source of foodborne outbreaks (Levy, 2008; Miles, 2003; Redmond, 2004). Risky food safety behaviors at home are likely to translate into home-based foodborne illness outbreaks.

On the one hand, consumers are not aware, or they lack specific knowledge regarding pathogens (e.g. *Listeria*, *Campylobacter*) (Cates, 2006), food contamination vehicles and potential transmission routes (e.g. cross contamination) (Dharod, 2004), and proper cold storage temperatures and refrigerator cleaning (Bryd-Bredbenner, 2008; Godwin, 2006; Kilonzo-Nthenge, 2008; Kosa, 2007; Towns, 2006). For example, research conducted among Hispanic women in Connecticut has shown that few consumers are aware of the term “cross-contamination,” even after exposure to the Fight BAC!® campaign (Dharod, 2004). This is a cause of public health concern because the risk of cross-contamination in home kitchens in some Hispanic (Dharod, 2007a) and other (FDA/FSIS, 2006) communities is substantial. Hands play a central role in the chain of transmission of microbial pathogens through food and other vehicles. Thus, proper hand hygiene before, during, and after food preparation is one of the key measures for preventing foodborne diseases. Hand hygiene can be based on hand washing with plain soap (i.e., detergents that do not contain antimicrobial agents or contain low concentrations of antimicrobial agents that are effective solely as preservatives, CDC, 2002) and water (physical removal of microbes) and/or the use of rinse-free alcohol-based hand sanitizers (killing of microbes).

On the other hand, consumers often do not translate their food safety knowledge into safe practices (Abbot, 2009; Byrd-Bredbenner, 2007; Cates, 2006; Dharod, 2004; Dharod, 2007a; Godwin, 2006; Kwon, 2008; Patil, 2005; Redmond, 2003; Towns, 2006; Trepka, 2007; Yarrow, 2009). This is perhaps explained at least in part by the “not in my kitchen” optimistic bias (Cates, 2006; Levy, 2008; Miles, 2003; Redmond, 2004; Roseman, 2006) and the lack of consumers’ internal locus of control with regard to food safety, namely the belief that its mainly the responsibility of industry and government to prevent foodborne illness (Cates, 2006). Improvements in consumers’ knowledge and also their attitudes and intentions toward reducing home-based food safety risks are needed.

Higher socio-economic status has been associated with more food safety knowledge, but often with the worst food safety behaviors (Patil, 2005). Being a member of a racial/ethnic minority group has been associated with better food safety behaviors (FDA/FSIS, 2006; Patil, 2005). Improper home food safety behaviors have been identified in different stages of the life cycle, such as pregnancy (Kwon, 2008; Trepka, 2007), college students (Abbot, 2009; Byrd-Bredbenner, 2007; Byrd-Bredbenner, 2008; Yarrow, 2009), older adults (Almanza, 2007; Kosa, 2007; Roseman, 2007). Overall, men are more likely than women to practice risky food safety behaviors at home. Thus, all segments of the US population could benefit from improved food safety education based on effective behavioral change theories.

The 2010 DGAC's evidence-based review of behaviors that are likely to prevent food safety problems and US consumers' actions in this regard has led it to one overarching Conclusion, which has Implications for current and future consumer education efforts. The sections that follow present specific Conclusions and evidence reviews for each of the four Fight BAC!® constructs (i.e., clean, separate, cook and chill), plus the "avoiding risky foods" construct.

Overarching Conclusion

Evidence shows that proper hand sanitation techniques, proper washing of vegetables and fruit, prevention of cross-contamination, and appropriate cooking and storage of foods in the home kitchen are most likely to prevent food safety problems. Food safety behaviors least practiced by consumers are hand sanitation, cross-contamination prevention, and use of cooking, refrigerator, and freezer thermometers. Food safety knowledge of US consumers is not being translated into improved food safety practices at home.

Implications

All segments of the US population could benefit from improved food safety education based on effective behavioral change theories. Food safety education is needed to not only improve consumers' knowledge, but also their attitudes and intentions toward reducing home-based food safety risks. In particular, consumers need to take more responsibility regarding food safety. Together, with sound government policies and responsible food industry practices, foodborne illness can be prevented.

Food safety behaviors that particularly need additional promotion are hand sanitation, use of cooking and refrigerator/freezer thermometers, and prevention of cross-contamination. Produce washing practices can vary significantly for different vegetables and this behavior needs to be substantially improved. Additional guidance is needed to provide detailed recommendations on the frequency of refrigerator cleaning to decrease pathogen growth and potential for cross-contamination. It is important to educate consumers on appropriate cooking temperatures and the reasons to avoid consuming raw or undercooked animal protein products. The consumption of certain risky foods (e.g., cookie dough containing raw eggs) is likely to occur at home, but the consumption of other foods (e.g., raw seafood) is more likely to occur outside the home. Thus, consumer food safety education in this area needs to address safe food practices in the different environments in which individuals are likely to consume the different products. Education should also address food safety issues that have emerged due to trends toward local- and regional-based food production.

Of subpopulations in the US, older adults may be at greater risk because of the age-related reduction in immunity. Pregnant women also have altered immune status which may render the fetus more susceptible to infection. Foodborne illnesses affecting pregnant women can have extremely serious consequences for the fetus as illustrated by the still births resulting from listeriosis. Foodborne illness outbreaks among college students have the potential to rapidly spread within the student body as a result of the group arrangements in which they often live.

Question 1. CLEAN: What Techniques for Hand Sanitation are Associated with Favorable Food Safety Outcomes and to What Extent Do US Consumers Follow Them?

Conclusion

Strong, clear, and consistent evidence shows that hand washing with plain soap for 20-30 seconds followed by proper hand drying is an effective hand hygiene technique for preventing cross-contamination during food preparation. Strong, clear, and consistent evidence shows that alcohol–based, rinse-free hand sanitizers are an adequate alternative when proper hand washing with plain soap is not possible. Moderate, consistent evidence shows that US consumers do not follow recommended hand sanitation behaviors.

Review of the Evidence

The conclusion on recommended techniques for hand sanitation is derived from 17 studies, including four meta-analyses or literature reviews (Aiello, 2007; Aiello, 2008; Haas, 2005; Meadows, 2004), six randomized controlled trials (Aiello, 2004; Fischler, 2007; Larson, 2004; Sandora, 2005; Sandora, 2008; Vessey, 2007), five quasi-experimental studies (Brown, 2007; Schaffner, 2007; Thorrold, 2007; Tousman, 2007; White, 2005), and two observational prospective studies (Dharod, 2009; Lee, 2005). Studies were conducted in schools and other community settings as well as in homes and under laboratory simulation conditions.

Soaps with antimicrobial additives are not needed for proper hand hygiene at home and should be avoided due to possible microbial resistance to antibacterials associated with their long-term use (Aiello, 2004; Aiello, 2007; Thorrold, 2007). Under some circumstances involving the presence of highly vulnerable individuals at home, alcohol-based hand sanitizers after hand washing with soap may provide additional protection. It is essential that consumers not only practice adequate hand hygiene techniques at home and in the community, but that they also do it at the right times. Thus, hand hygiene education and promotion should seek to improve the consumers' understanding of the chain of transmission of pathogens from food sources and the risk situations (i.e., critical control points) before, during, and after food preparation and other human activities requiring proper hygiene, including toilet use and contact with pets. Hand washing procedures for consumers adapted from information from the Centers for Disease Control and Prevention (CDC) can be seen in Table D8.2.

The conclusion regarding consumers' adherence to recommended hand sanitation is derived from five cross-sectional studies (Abbot, 2008; Anderson, 2008; Comer, 2009; Dharod, 2007a; Thumma, 2009). The FDA/FSIS Food Safety Survey (2006) provided additional evidence. In the Food Safety Survey (FDA/FSIS, 2006) three-quarters of respondents indicated that they always washed their hands before starting food preparation. Gender did not influence the hand washing report, but this behavior was more likely to be reported by those with lower levels of education and by those who identified themselves as White. Close to 88 percent reported washing the cutting board after placing raw meat on it. This behavior was more common among those with lower levels of education, females, and non-Hispanics than among those in other population groups. Studies have consistently shown that proper hand washing associated with food preparation (Abbot, 2008; Dharod, 2007a; Thumma, 2009) and bathroom use (Anderson, 2008; Thumma, 2009) is far less than optimal and needs to be better promoted (Comer, 2009). Two studies involving direct observation of hand washing behaviors during food preparation among college students (Abbot, 2008) and Puerto Rican home meal preparers (Dharod, 2007a) found a high degree of over-reporting of desirable hand washing behaviors during food preparation. This finding may be explained by a social desirability bias and indicates that results derived from self-reported hand hygiene behaviors should be interpreted with caution.

Question 2. CLEAN: What Techniques for Washing Fresh Produce are Associated with Favorable Food Safety Outcomes and to What Extent Do US Consumers Follow Them?

Conclusion

A limited body of evidence has shown that washing vegetables and fruit by running water over them at home or under laboratory simulation conditions is associated with reduced produce microbial loads. Moderate, consistent evidence shows that US consumers are not following recommended produce washing techniques at home.

Review of the Evidence

The conclusion regarding techniques for washing fresh produce is derived from three studies, including two non-randomized trials (Kilonzo-Nthenge, 2006; Parnell, 2005), and one cross-sectional study (Dharod, 2007b). Washing fresh produce at home is the last opportunity that consumers have to reduce potential pathogen loads in these products before consuming them and is likely to help reduce food safety risks (Dharod, 2007b; Kilonzo-Nthenge, 2006; Parnell, 2005). One of the few studies that examined this issue among free-living individuals while preparing a family meal at home provides relevant insights. Dharod et al. (2007b) demonstrated a significant reduction in total microbial and coliform counts associated with washing lettuce and tomato under running water in Puerto Rican households' home kitchens during preparation of a "chicken and salad" meal. Guidance for consumers for washing produce, adapted from information available from the FDA, can be seen in Table D8.3.

The conclusion regarding consumer behaviors related to washing fresh produce is derived from two cross-sectional studies (Dharod, 2007a; Anderson, 2004) and an analysis of responses from the FDA/FSIS Food Safety Survey (2006). Dharod et al. (2007a) found that among Puerto Rican home meal preparers, 87 percent washed the lettuce and 85 percent washed the tomatoes under running water while preparing salad. In their direct observation study among 99 US college students, Anderson et al. (2004) found that 6 did not clean any of the vegetables used to prepare a salad, 70 rinsed the lettuce, 93 rinsed the tomato, 47 rinsed the carrots, and 55 rinsed the cucumber with water. This study also documented that average washing time ranged from 4.8 to 12.4 seconds, substantially shorter than the 60 seconds recommended by the author. These findings indicate that washing practices can vary significantly for different vegetables and that these behaviors need to be substantially improved.

The FDA/FSIS Food Safety Survey (2006) asked consumers about their behaviors for washing tomatoes, cantaloupe, and strawberries. Among participants who responded that they ever buy the product, a smaller proportion (57%, n=1806) reported usually washing cantaloupe compared to much higher proportions that usually washed tomatoes (97%, n=2029) or strawberries (98%, n=2001). Among participants who reported washing tomatoes, cantaloupe, or strawberries, the method reported for washing was analyzed. Washing produce by rubbing it under running water with a brush, cloth, or hands was considered a favorable behavior. Also reported was use of any type of cleaner to wash produce. Although this is not an encouraged behavior, it is also not necessarily undesirable if a cleaner intended for produce is used. Respondents of lower incomes consistently reported more favorable behaviors than their higher income counterparts for washing tomatoes, cantaloupe, and/or strawberries. Adults ages 18 to 59 years were significantly more likely to practice the desirable behavior of rubbing tomatoes (76%) and strawberries (49%) under running water compared to adults ages 60 years and older (71% and 36%, respectively) ($p < 0.05$). Respondents with children younger than age 5 years were more likely to rub cantaloupe (79%) and strawberries (61%) under running water compared to those without children younger than age 5 years (69% and 40%, respectively) ($p < 0.05$). Women were significantly more likely to use a cleaner to wash tomatoes, cantaloupe, and strawberries (8%, 10%, and 5%, respectively) compared to males (6%, 4%, and 3%, respectively) ($p < 0.05$).

Question 3. CLEAN: To What Extent Do US Consumers Clean Their Refrigerators?

Conclusion

Moderate, consistent evidence shows that US consumers do not clean their refrigerators following available guidance.

Review of the Evidence

This conclusion is derived from four cross-sectional studies (Bryd-Bredbenner, 2007; Godwin, 2006; Kilonzo-Nthenge, 2008; Kosa, 2007). The DGAC also reviewed a case-control study from the United Kingdom (Parry, 2005) to obtain additional contextual information on this question.

The four cross-sectional studies all reported cleanliness and sanitation of refrigerators as a problem. Bryd-Bredbenner et al. (2007) found that young adults scored less than 60 percent on the appliance cleanliness and cold food storage scales. Kosa et al. (2007) found that among a large adult sample, 53 percent of participants had not cleaned their refrigerator for at least 1 month before the survey. Kilonzo-Nthenge et al. (2008) identified 19 different bacterial isolates including *Listeria innocua* in 4.4 percent of domestic refrigerators in a study in Tennessee. They also identified *Klebsiella pneumoniae* and *Enterobacter cloacae* in 23.4 percent and 20.5 percent of the refrigerators, respectively, and identified multidrug antibiotic resistance in *Klebsiella* and *Enterobacter spp*. Although most of the bacteria identified are nonpathogenic to healthy adults, they do serve as sanitation markers. Thus, findings indicate that proper food and refrigerator sanitation practices were not being followed in a significant proportion of households. Godwin et al. (2006) found in Florida and Tennessee households that 72 percent of swabs contained viable microbial populations, as assessed by way of adenosine triphosphate bioluminescence. The highest microbial loads were detected in the vegetable compartment and the meat sections. The microbial load in the vegetable compartment correlated significantly with the cleanliness score for that compartment. Only 5 percent of the respondents reported emptying and cleaning the entire refrigerator often or very often, with 78 percent reporting doing so occasionally or rarely. The UK case-control study (Parry, 2005) did not find an association between the presence of *Salmonella* in dishcloths and refrigerators and risk of salmonellosis. Findings are difficult to interpret as 65 percent of individuals who developed salmonellosis had eaten meals prepared outside the home kitchen 72 hours before the onset of symptoms. Godwin et al. (2006) documented that consumers' self-reports of vegetable compartment cleaning frequency did not correlate with microbial loads found in domestic refrigerators. Thus, proper refrigerator hygiene techniques may not be followed even when the behavior is practiced. Table D8.4 provides general guidance for consumers on refrigerator cleaning adapted from information available from FSIS.

Question 4. SEPARATE: What Techniques for Preventing Cross-Contamination are Associated with Favorable Food Safety Outcomes?

Conclusion

Moderate, consistent evidence indicates that preventing cross-contamination in the home kitchen may reduce exposure to foodborne pathogens among US consumers. Techniques associated with favorable food safety outcomes for preventing cross-contamination include proper cleaning of food preparation surfaces and/or cooking utensils, particularly cutting boards and cutlery, accompanied by hand washing.

Review of the Evidence

This conclusion is based on 12 studies, including five comprehensive risk analyses (Kusumaningrum, 2004; Luber, 2009; Mylius, 2007; van Asselt, 2008; Yang, 2006), two laboratory simulation studies (de Jong, 2008; Sharma, 2009), two home kitchen videotaped studies (Redmond, 2004; van Asselt, 2009), one systematic review (Stenberg, 2008), one randomized trial (Larson, 2004), and one case-control study (Parry, 2005).

Four quantitative risk assessments concluded that lack of proper cleaning of food preparation surfaces and/or cooking utensils used in the home kitchen is likely to increase enteropathogenic cross-contamination from poultry meats or eggs to ready-to-eat vegetables or salads (Kusumaningrum, 2004; Luber, 2009; Mylius, 2007; van Asselt, 2008). Laboratory simulation (de Jong, 2008, Redmond, 2004) and home-based inoculation (van Asselt, 2009) studies provide strong support for a link between cutting board and cutlery sanitation and the prevention of microbial cross-contamination during food preparation. Mylius et al. (2007) conducted a risk assessment analysis that illustrated the importance of properly washing food preparation surfaces to prevent cross-contamination from chicken to salad with *Campylobacter*. The key parameters of this simulation study were the transfer probabilities of *Campylobacter* colony forming units (CFU) between kitchen/food objects and the probability for different behaviors to be followed during food preparation. These probabilities were obtained from previously published studies or assigned when no data were available. Simulation results showed that the single most effective action for reducing risk of cross-contamination and corresponding infection risk was cutting-board washing followed by hand washing and salad rinsing. In spite of this consistent evidence, some studies have not been able to empirically document a link between good environmental kitchen hygiene and decreased risk of gastrointestinal infections (Larson, 2004; Stenberg, 2008). Sharma et al. (2009) found that microwaving and dishwashing treatments significantly lowered aerobic bacterial counts (<0.4 log and 1.6 log CFU/sponge, respectively) more than any chemical treatment or control (7.5 CFU/sponge) ($p < 0.05$). This study suggests that microwaving or dishwashing treatments of kitchen sponges may be effective methods to kill foodborne pathogens in sponges to lessen chances of cross-contamination from sponge to other home kitchen surfaces where food is placed (Sharma, 2009).

Two studies had findings that were not consistent with the majority of the studies that led to the conclusion on cross-contamination. In a study by Yang et al. (2006), cross-contamination via refrigerators and hands did not substantially increase the mean level or prevalence of *L. monocytogenes* contamination in deli meats handled in the study. The UK case-control study (Parry, 2005) did not find an association between the presence of Salmonella in dishcloths and refrigerators and risk of salmonellosis. Findings are difficult to interpret, as 65 percent of individuals who developed salmonellosis had eaten meals prepared outside the home kitchen 72 hours before the onset of symptoms.

Recommended techniques for consumers for preventing cross-contamination adapted from information available from FSIS can be found in Table D8.5.

Question 5. COOK AND CHILL: To What Extent Do US Consumers Follow Adequate Temperature Control During Food Preparation and Storage at Home?

Conclusion

Strong, consistent evidence shows that the great majority of US consumers do not use food thermometers to properly assess the internal cooking temperature of meat and poultry while cooking. Moderate, consistent evidence shows that US consumers lack refrigerator and freezer thermometers in their homes.

Review of the Evidence

The conclusion regarding food thermometers is derived from eight studies, including one systematic review (Redmond, 2003), one laboratory simulation study with a cross-sectional study component (Bergsma, 2007) and six cross-sectional studies (Abbot, 2009; Byrd-Bredbenner, 2007; Dharod, 2004; Dharod, 2007a; Kwon, 2008; Trepka, 2007). The FDA/FSIS Food Safety Survey (2006) provided additional evidence for this conclusion. Table D8.6 shows the safe minimum internal cooking temperatures for meat, poultry, and seafood recommended for consumers by FSIS and FDA.

Inadequate cooking represents a food safety hazard that can easily be avoided with the use of food thermometers widely available to consumers and effective dissemination of recommended internal cooking temperatures for different food products. In the FDA/FSIS Food Safety Survey

(2006), 34 percent of respondents who reported preparing chicken indicated that they ever use a meat thermometer when cooking chicken. Those with lower levels of education, males, and White and Asian respondents were more likely to report using a meat thermometer when cooking chicken. Seven studies (Abbot, 2009; Byrd-Bredbenner, 2007; Dharod, 2004; Dharod, 2007a; Kwon, 2008; Redmond, 2003; Trepka, 2007) found that few households reported owning and/or using a food thermometer to check for the doneness of meats. Dharod et al. (2004) found that, among Latino parents, the use of meat thermometers was very rare both before and after exposure to the Fight BAC!® campaign. Redmond and Griffith (2003) found that only 12 percent to 24 percent of consumers regularly used meat thermometers. Using a cross-sectional survey, Bergsma et al. (2007) found that while thorough heating of chicken was considered very important by the study participants, generally those participants only visibly checked chicken meat for doneness and did not use meat thermometers. In the laboratory simulation component of that study, the authors suggested that cooking chicken for recommended periods of time and visually inspecting it for doneness could result in chicken which may not be sufficiently cooked to reduce levels of harmful bacteria (Bergsma, 2007). It is notable that, although just as important as for meat and poultry, no evidence was identified on consumer use of thermometers for ensuring the adequacy of cooking for seafood. Table D8.7 provides information on recommended techniques for consumers for thermometer use adapted from information available from the FSIS and FDA.

The conclusion regarding refrigerator and freezer thermometers is derived from two cross-sectional studies (Kosa, 2007; Towns, 2006). Additional evidence was gathered from the FDA/FSIS Food Safety Survey (2006). The two cross-sectional studies found that subjects reported a lack of thermometers in refrigerators and/or freezers in their homes (Kosa, 2007; Towns, 2006). Towns et al. (2006) concluded that their well educated survey participants failed to follow proper refrigeration and freezer storage practices, in spite of being aware of the importance of doing so to prevent foodborne illness. These findings are supported by findings from the FDA/FSIS Food Safety Survey (2006). Techniques for consumers for using refrigerator and freezer thermometers adapted from information available from the FSIS can be found in Table D8.8.

Question 6. RISKY FOODS: To What Extent Do US Consumers Eat Raw or Undercooked Animal Foods?

Conclusion

Moderate, clear, and consistent evidence shows that the consumption of raw or undercooked animal-source food products is relatively common in the US, especially for eggs and egg-containing products, and ground beef products.

Review of the Evidence

This conclusion is derived from eight studies, including one meta-analysis (Patil, 2005) and one systematic review (Redmond, 2003), and six cross-sectional studies (Anderson, 2004; Byrd-Bredbenner, 2008; Dharod, 2007b; Kaylegian, 2008; Lopez Osornio, 2008; Trepka, 2007). Additional evidence was gathered from the FDA/FSIS Food Safety Survey (2006). In their direct observation study of US household meal preparers, Anderson et al. (2004) found that 61 percent of those who prepared a chicken entrée undercooked the chicken. In this study 46 percent of those who chose to prepare meatloaf undercooked the ground beef. A direct observation study involving videotaping of a small sample of home meal preparers in the Netherlands found that one-third of the participants undercooked the chicken (van Asselt, 2009). Undercooking was estimated based on an eight minute chicken boiling time cut-off. These findings are in contrast with those of Dharod et al. (2007b) who documented that almost none (7%) of the Puerto Rican household meal preparers included in their study undercooked the chicken. In the FDA/FSIS Food Safety Survey (2006), about 38 percent reported eating foods containing raw eggs, with this behavior being less common among those with lower levels of education, Blacks, and Asians. Studies have found that among diverse US study populations, raw or undercooked animal-derived products are widely consumed (Bryd-Bredbenner, 2008; Patil, 2005; Trepka, 2007; FDA/FSIS, 2006). Bryd-Bredbenner et al. (2008) reported that among a large sample of college students, a substantial number reported consuming a variety of risky foods, such as cookie dough containing raw eggs (53%), fried eggs with runny or soft yolks (33%), sushi (29%), raw sprouts (29%), raw oysters, mussels, or clams (11%), and rare hamburgers (7%). Trepka et al. (2007) found that among female African-American WIC clients, 24.7 percent reported usually eating undercooked eggs, 51.6 percent of pregnant women reported "sometimes," or "frequently," eating hot dogs or deli meats since becoming pregnant without first reheating them, and 35.5 percent reported eating soft cheeses and blue-veined cheeses sometimes or more frequently since becoming pregnant. In addition, almost 12 percent reported consuming hamburgers with pink/red color inside, and only 62 percent reported always using boiling water before preparing infant formula. The prevalent consumption of undercooked eggs detected in localized studies is confirmed by a systematic review (Redmond, 2003) and the meta-analysis by Patil et al. (2005). Based on US surveys conducted between 1977 and 2000, Redmond and Griffith (2003) report that the prevalence for this practice has ranged from 5 percent to 56 percent, with the most recent surveys suggesting that as many as half of the US population may consume undercooked or raw eggs. Lopez Osornio et al. (2008) found that the US consumers were more likely than Argentinean and Spanish consumers to prefer beef steaks to be cooked rare. However, Trepka et al. (2007) found in their study that only 3.5 percent of WIC participants liked their meat cooked medium-rare or rare.

Raw milk consumption has been associated with serious foodborne outbreaks in the US. Kaylegian et al. (2008) examined raw milk consumption practices in a sample formed predominantly of dairy farmers from upstate New York. As many as 45.3 percent reported having consumed raw milk during the previous year. The main reasons for consuming raw milk were taste, convenience, and cost. Concerns related to health hazards associated with raw milk consumption were expressed by 38.2 percent of the raw milk and 73.2 percent of the pasteurized milk consumers.

Related Contextual Issues

Raw or Undercooked Eggs and Public Health Risks

Historically, in the US, guidelines for handling and preparing eggs for human consumption have been issued by the Federal government, and food industry and dietetic associations. Those guidelines have been developed because salmonellosis, an egg-associated foodborne illness, is an important public health problem (Braden, 2006; CDC, 2005). A bacterium, *Salmonella enteritidis*, can be inside perfectly normal-appearing eggs, and if the eggs are eaten raw or undercooked, the bacterium can cause illness (CDC, 2005). A person infected with the *Salmonella enteritidis* bacterium usually has fever, abdominal cramps, and diarrhea beginning 12 to 72 hours after consuming the contaminated food, and the illness usually lasts 4 to 7 days without necessarily requiring antibiotics (CDC, 2005). However, the diarrhea can be severe, and the person may be ill enough to require hospitalization (CDC, 2005). The elderly, infants, and those with impaired immune systems may have a more severe illness in which the infection may spread from the intestines to the bloodstream, and then to other body sites and can cause death unless the person is treated promptly with antibiotics (CDC, 2005).

Therefore, fresh eggs and egg products should be handled, refrigerated, prepared, and stored properly, including the use of sell by dates, to reduce the risk that foodborne pathogens that may be present in those foods will cause foodborne illness in those eating the food. Research shows that shell eggs are a major vehicle for *Salmonella enteric* serotype Enteritidis (SE) infection in humans because eggs can be internally contaminated by transovarian transmission of SE in the laying hen (Braden, 2006). It has been estimated that of the 47 billion eggs consumed annually as shell eggs, 2.3 million are SE-positive, exposing a large number of people to the risk of illness (Potter, 1999). Through proper handling in the home (i.e., refrigeration, avoiding cross-contamination, and thorough cooking to kill pathogens that might exist in eggs and egg products), foodborne illness from eggs can be reduced. Adequate refrigeration prevents any *Salmonella* present in eggs from growing to high numbers (CDC, 2005). Although cooking reduces the number of bacteria present in an egg, an egg with a runny yolk still poses a greater risk than a completely cooked egg (CDC, 2005). Recommendations on in-home handling of eggs from the Federal government range from how to safely transport, handle, store, and sufficiently cook simple egg dishes to how to improve the safety of egg recipes involving food mixtures that include raw egg ingredients (such as homemade ice cream, eggnog, meringue shells, divinity candy, 7-minute frosting, meringue-topped pies, Hollandaise sauce, Caesar salad dressing, and other desserts) (HHS, 2010).

Raw or Undercooked Ground Beef and Public Health Risks

Raw and undercooked meats, such as hamburger meat, are potential sources of pathogenic bacteria that can result in foodborne illness which can have serious health consequences, including death. Since the 1980s, outbreaks of illness in the US have been reported as a result of consuming undercooked hamburgers from some fast food restaurants, in communities, and different facilities (Doyle, 1991; CDC, 1993). Over that period, manufacturers have conducted a series of national recalls by manufacturers of ground beef contaminated with harmful bacteria. Ground beef and hamburger meat can become contaminated with pathogenic bacteria, such as *Salmonella*, *Escherichia coli O157:H7*, *Campylobacter jejuni, Listeria monocytogenes*, and *Staphylococcus aureus*, at different points from the farm to the table (FSIS, 2009). Efforts have been made by the food industry and Federal government to reduce contamination of ground beef from beef production through consumption, but outbreaks still occur. For example, although FSIS has documented a decrease in *Salmonella spp.* in ground beef, from a baseline prevalence of 7.5 percent in 1996 to 1.6 percent of 30,984 regulatory samples collected in 2004 (CDC, 2006; USDA, 1996; USDA, 2006), outbreaks of human *Salmonella* infections associated with ground beef continue to occur (CDC, 2006).

One of the bacteria of special concern that could contaminate muscle meat at slaughter is *E. coli O157:H7*, a bacterial pathogen that has a reservoir in cattle and other similar animals (FSIS, 2009). *E. coli O157:H7* produces large quantities of a potent toxin that forms in the intestine and causes severe damage to the lining of the intestine (FSIS, 2009). Consumption of food contaminated with *O157:H7* can cause a severe and bloody diarrhea and painful abdominal cramps and, in 3 percent to 5 percent of cases, a complication called hemolytic uremic syndrome that can result in the development of temporary anemia, profuse bleeding, and kidney failure (FSIS, 2009). *E. coli O157:H7* bacteria survive refrigerator and freezer temperatures and once they get in food, they can multiply very slowly at temperatures as low as 44 °F (FSIS, 2009). The actual infectious dose is unknown, but most scientists believe it takes only a small number of this strain of *E. coli* to cause serious illness and even death, especially in children (FSIS, 2009). The bacteria are killed by adequate and proper cooking.

Because consumers cannot see or smell pathogenic bacteria that may be in ground beef, it is impossible for consumers to know if meat obtained from a food store is contaminated with such bacteria. Therefore, it is very important that consumers understand how to properly handle, transport, store, and prepare any raw meat that will be used in the home. The Federal government has issued recommendations on how to reduce risks of contracting foodborne illness from ground meat, including guidance on not eating any raw or undercooked ground beef, not tasting raw or undercooked ground beef during food preparation, avoiding cross-contamination from raw meat to ready-to-eat foods when transporting meat from the store and in the home, cooking food containing ground beef to ensure that any pathogenic bacteria are killed, proper storage in the refrigerator or freezer, and the importance of hand washing after handling raw ground beef (USDA, 1996).

Raw Milk and Milk Products and Public Health Risks

Milk and milk products from cows, sheep, or goats contain a wide variety of important nutrients. However, raw milk and raw milk products (such as cheese and yogurt made from raw milk) have not been pasteurized to kill harmful bacteria (FDA, 2009). These products may contain harmful microorganisms that can cause serious foodborne illnesses, hospitalization or death. Pasteurization is a process that kills harmful bacteria by heating raw milk to a specific temperature for a set period of time (FDA, 2009). These harmful bacteria, which include *Brucella*, *Campylobacter*, *Listeria*, *Mycobacterium bovi*, *Salmonella*, Shiga toxin-producing *E. coli*, *Streptococcus pyogenes*, and *Yersinia enterocolitica* (CDC, 2009), can cause diseases such as listeriosis, typhoid fever, tuberculosis, diphtheria, and brucellosis. Pasteurization of milk became widespread in the US by 1950 and is recommended for all milk consumed by humans by the CDC, the FDA, and many other medical and scientific organizations (CDC, 2009).

From 1993 to 2006, 69 outbreaks of human infections resulting from consumption of raw milk were reported to CDC and these outbreaks included a total of 1,505 reported illnesses, 185 hospitalizations, and 2 deaths (CDC, 2009). Symptoms of foodborne illness that could develop after consuming raw milk include vomiting, diarrhea, and abdominal pain, and flulike symptoms such as fever, headache, and body ache (FDA, 2009). Although most healthy people will recover from an illness caused by harmful bacteria in raw milk, or foods containing raw milk, within a short period of time, some can develop symptoms that are chronic, severe, or even life-threatening (FDA, 2009). Pregnant women who consume raw milk or raw milk cheeses that may be contaminated with the bacteria *Listeria* run a serious risk of developing listeriosis which can cause miscarriage, fetal death, or the illness or death of a newborn (FDA, 2009). Table D8.9 provides guidance for consumers for ensuring milk and milk product choices are safe adapted from information available from the FDA.

Table D8.9. Guidance for choosing pasteurized milk and milk products

Read food labels to make sure that the word "pasteurized" is on the label of milk or milk products and, if unsure, ask a grocery store employee whether a milk or milk product contains pasteurized milk. Such foods made from unpasteurized milk could contain harmful bacteria.
Choose versions of these types of food made only with pasteurized milk:
• Milk
• Cream
• Yogurt
• Pudding
• Ice cream and frozen yogurt
• Cottage, cream, and ricotta cheeses
• Processed cheeses
• Soft cheeses such as Brie, Camembert, blue-veined cheeses, and Mexican-style soft cheeses such as Queso Fresco, Panela, Asadero, and Queso Blanco

Source: Adapted from http://www.fda.gov/Food/ResourcesForYou/Consumers/ucm079516.htm. Accessed April 20, 2010.

As with any animal food product, it is important to handle and store pasteurized milk and milk products properly to prevent the growth of possibly harmful bacteria that can multiply at room temperature. Thus, pasteurized milk and milk products should be stored in a refrigerator (preferably at the back of the refrigerator where it is cooler) kept at 40°F (4°C) or below, refrigerated promptly if used, and not left out at room temperature. Also, to reduce the possibility of contaminating milk with bacteria, unused milk poured out of its container should never be returned to its original container. Just because milk is pasteurized does not mean that it is safe to leave it at room temperature for an extended time.

Raw and Undercooked Seafood and Public Health Risks

Raw and undercooked seafood can be a cause of foodborne illnesses due to contamination by harmful bacteria, viruses, and parasites. Molluscan shellfish (oysters, clams, and mussels) and raw fish and crustaceans can be contaminated with pathogenic strains of the bacterium *Vibrio* (Butt, 2004; IOM, 2007). Some oysters are treated for safety after they are harvested but that information may or may not be disclosed (FDA, 2009a). However, post-harvest treatment of oysters does not necessarily remove all pathogens that can cause illness (FDA, 2009a). Therefore, oysters should not be eaten raw or undercooked by people at risk of foodborne illness, including pregnant women, young children, older adults, and persons with compromised immune systems or who have decreased stomach acidity (FDA, 2009a). Raw oysters contaminated with certain bacteria viruses can be life threatening, even fatal when eaten by someone with liver disease, diabetes, or a weakened immune system (FDA, 2009b).

Eating raw and undercooked oysters is an especially risky practice because the *Vibrio* bacteria in the food is not visible and may not be picked up by an off smell or unusual taste. The seriousness of symptoms that could develop after eating contaminated shellfish depends on many factors, including how much bacteria is ingested and the person's underlying health conditions (FDA, 2009b). In addition to *Vibrios*, a variety of potentially pathogenic bacteria (including *Salmonella spp*. and *Listeria monocytogenes*) have been associated with seafood safety risks, although actual occurrence is very rare or not reported due to lack of severity of symptoms (IOM, 1991; IOM, 2007).

Regarding viruses, contamination of water with human fecal matter on or near oyster beds has resulted in shellfish-borne "Norwalk-like" viruses and hepatitis A infections in consumers of raw oysters harvested from contaminated water (IOM, 2007; Kohn, 1995). Regarding parasites, consumption of raw or undercooked seafood products that have not been previously frozen has been implicated in certain parasitic infections, but incidence of those infections is more common in regions of the world where raw consumption is more common (IOM, 2007). Parasites that have been found in consumable seafood and have infected human beings include nematodes, trematodes, cestodes, and protozoa (Butt, 2004).

Adequate cooking of raw seafood is the safest method of preventing infections from harmful microorganisms that may be found in oysters, clams, mussels, other shellfish, or finfish. According to the FDA, consumers who choose to eat raw seafood despite the risks, should choose seafood that has been previously frozen (FDA, 2009a). However, although freezing will kill any parasites that may be present in certain seafood, freezing does not kill all harmful microorganisms and does not decrease the potency of some toxins that some bacteria may produce. Therefore, proper cooking of seafood to recommended temperatures is the best way to reduce the risk of foodborne illness.

Recommendations on proper handling of raw seafood from the Federal government range from how to safely transport, handle, store, and sufficiently cook, and serve all types of fish, shellfish, and mollusks to ways to determine whether seafood is cooked to a sufficient temperature to kill harmful contaminants that may be in the food (FDA, 2009a).

Additional guidelines have been issued for pregnant women, older adults, and people with weakened immune systems to reduce their risk of contracting listeriosis from seafood. Those guidelines specify to avoid refrigerated types of smoked seafood except in a cooked recipe. The types to be avoided include refrigerated smoked salmon, trout, whitefish, cod, tuna, and mackerel. They are usually labeled as "nova-style," "lox," "kippered," "smoked," or "jerky" fish and can be found in the refrigerated section of grocery stores and delicatessens (FDA, 2009a).

Question 7. To What Extent Do Specific Subpopulations Practice Unsafe Food Safety Behaviors?

Conclusion

Moderate available evidence, which focused on pregnant women, college students, and older adults, shows that these populations commonly practice unsafe food handling and consumption behaviors.

Review of the Evidence

This conclusion is derived from nine studies, including eight cross-sectional studies (Abbot, 2009; Almanza, 2007; Byrd-Bredbenner, 2007; Byrd-Bredbenner, 2008; Kosa, 2007; Kwon, 2008; Roseman, 2007; Trepka, 2007) and one non-randomized trial (Yarrow, 2009).

Pregnant Women

As reported previously as evidence on the consumption of "risky foods," Trepka et al. (2007) conducted a study in a sample consisting predominantly of African-American WIC participants. Pregnant women reported practicing risky food handling and consumption behaviors that could put them at greater risk for acquiring listeriosis. For example, pregnant women reported eating hot dogs or deli meats without first reheating and reported eating soft cheeses and blue-veined cheeses. Using a cooking thermometer, refrigerating foods within 2 hours, and thawing frozen foods safely were the least frequently reported recommended food safety behaviors. Primiparous women had lower food safety scores than their multiparous counterparts. Kwon et al. (2008) applied a food safety survey in 87 WIC offices in 31 states. The need for a meat thermometer to check doneness while cooking ground beef patties was acknowledged by 23.7 percent of respondents, but only 7.7 percent reported actually using it when cooking ground beef patties. Hispanic women were the least likely to have ever used a meat thermometer (25.4%), followed by Non-Hispanic Black women (36.2%) and Non-Hispanic White women (46.1%). More than 40 percent of respondents did not use adequate methods to thaw frozen foods, with the likelihood of this happening being much higher among Hispanic and Non-Hispanic Black individuals than among their White counterparts. The overall food safety knowledge score was significantly higher among those with higher levels of education, and White (vs. Hispanic) women. However, the food safety behavior score was not significantly different when comparing White women with their Hispanic counterparts. Black women had the lowest food safety behavior score.

College Students

Four studies agree that US college students do not engage in many recommended safe food-handling practices (Abbot, 2009; Byrd-Bredbenner, 2007; Byrd-Bredbenner, 2008; Yarrow, 2009). Participants in the study by Abbot et al. (2009) self-reported engaging in less than half of the recommended safe food-handling practices evaluated (i.e., cross-contamination, hygiene, cooking temperatures, food storage, risky food consumption). This was confirmed through direct observation of their food preparation behaviors in a laboratory kitchen. For example, only half of them practiced adequate hand and kitchen sanitation; one-third did not follow adequate procedures to prevent cross-contamination between raw chicken and ready-to-eat produce; and more than 70 percent did not follow recommended procedures for safe chicken cooking. Byrd-Bredbenner et al. (2007), audited the home kitchens of the same college students studied by Abbot et al. (2009), and found that their scores were lower than 60 percent on the kitchen appliance cleanliness (i.e., microwave oven, can opener, dishwasher) and cold food storage scales and that only 7 percent of kitchens had a food thermometer. Mean refrigerator temperature was 6.1°C (range: 0-16°C) which is higher than recommended (i.e., 4.4°C/40°F or below). Byrd-Bredbenner et al. (2008) found in an online survey among college students across the US that they reported consuming some "risky foods" including homemade cookie dough containing raw eggs (53%); fried eggs with runny or soft yolks (33%); sushi (29%); raw sprouts (29%), raw oysters, clams, or mussels (11%); and hamburgers cooked rare (7%). Male students ate significantly more "risky foods" than women ($p<0.0001$). While consumption of raw/undercooked animal source foods may be culturally or socially acceptable and/or desirable, consumers should be aware of the health risks associated with the consumption of these foods. Yarrow et al. (2009) found that non-health majors whose food safety beliefs and knowledge improved after exposure to a food safety educational intervention, showed no improvements in the practice of risky behaviors, including not using thermometers and eating "risky foods," as a result.

Older Adults

Three studies (Almanza, 2007; Kosa, 2007; Roseman, 2007) agree that older adults report partaking in risky food-handling behaviors. A study of Elderly Nutrition Program clients (Roseman, 2007) found that 22 percent reported not throwing away casseroles or other food dishes that had been left on the counter for 2 or more hours (41% of men vs. 18% of women, $p=0.004$). Fifty percent of the oldest group (≥ 91 years) and 36 percent of the ages 60 to 70 years group, kept all or part of their unconsumed meal on the counter instead of the refrigerator, and 16 percent were somewhat or not likely to wash hands before eating their meals. Whereas 93 percent of White respondents indicated that they would throw away a meal that was left on counter overnight, this was true for only 77 percent of their non-White counterparts. The risk of practicing this behavior was also lower among the less educated and those in younger age brackets. Almanza et al. (2007) report from a multi-state study that of the 35 percent of seniors who kept leftovers from a home-delivered meal program, only 15 percent ate the non-refrigerated leftovers within 2 hours. Also, 38 percent of participants who were delivered hot food and did not consume it right away left it on a counter or table. Kosa et al. (2007) found that only 16 percent of older adults participating in a nationally representative web-based survey had a refrigerator thermometer at home. Older adults who were not married and who lived alone were less likely to have refrigerator thermometers or have their refrigerators at a recommended temperature ($p < 0.05$).

Related Contextual Issues

Listeriosis

Listeriosis is an infection caused by *Listeria monocytogenes,* a pathogen that can grow at low temperatures. It is estimated that 2,500 cases of listeriosis occur annually in the US and that 500 people die of this disease each year. Individuals with compromised immune systems, including pregnant women and their unborn child, as well as older adults are at higher risk of listeriosis. Cates et al. (2006) conducted a nationwide representative web-based survey of food safety knowledge and practices among US adults (response rate=71%). Awareness was much lower for *Listeria* (43.8%) than for *E. coli* (94.2%) and *Salmonella* (93.9%). Slightly more than two-thirds of respondents indicated that they did not know which foods could transmit *Listeria* and less than 5 percent correctly identified likely sources. Indeed, only 3.2 percent identified deli meats and frankfurters as potential *Listeria* vehicles. The great majority followed recommended guidelines for frankfurter's cold storage time and temperature. However, they were less likely to do the same with deli meats. *Listeria* awareness was lower among those with lower socio-economic status but improper frankfurter cold storage was significantly more common among those with higher levels of education. Men were significantly more likely than women to store frankfurters and deli meats outside the recommended storage guidelines. Likewise, those ages 18 to 29 years and 60 years and older were more likely to mishandle deli meats compared with their counterparts in the intermediate age groups.

FOOD SAFETY TECHNOLOGIES

Question 8. To What Extent are Recently Developed Technological Materials that are Designed to Improve Food Safety Effective in Reducing Exposure to Pathogens and Decreasing the Risk of Foodborne Illnesses in the Home?

Conclusion

A limited body of inconsistent evidence describes and evaluates contributions to or advances of food safety modalities or practices in the home. These small studies indicate the correct usage of these kinds of products is critical for assessing proper cooking temperature and ensuring adequate reduction of microbial burden on food contact surfaces. Not all thermometers tested, wipes assessed, and sanitizers evaluated were accurate or effective in providing correct cook temperatures or assuring consistent safety against typical foodborne organisms.

Implications

New and emerging technologies over the past 5 years can assist consumers in preserving and protecting foods while encouraging safe food handling practices in the home; however, appropriate techniques for using products is essential in the efficacy of decreasing the risk for foodborne illness. The evidence supporting emerging food safety technologies in the home is limited, despite the emergence of commercial tools and appliances intended to improve safe food handling and management practices in the home. Consumers should adhere to food safety fundamentals in the home, which will remain foundational, even with future introductions of food safety technologies.

Review of the Evidence

This conclusion is based on 8 studies, including five randomized block trials (LeBlanc, 2005; Liu, 2009a; Liu, 2009b; McCurdy, 2004; McKee, 2005); two non-randomized trials (DeVere, 2007; Yucel Sengun, 2005); and one case-control study (Kounosu, 2007). These studies evaluated the accuracy and reliability of several types of home thermometers and the effectiveness of antibacterial products, including wipes, food contact surfaces, and sanitizers.

Thermometers

Four randomized block design studies evaluated the accuracy and reliability of several types of cooking thermometers available to the general consumer (LeBlanc, 2005; Liu, 2009a; Liu, 2009b; McCurdy, 2004).

In two randomized, block designed studies by Liu et al. (2009 a & b), the accuracy and reliability of commercially available instant-read consumer thermometers (forks, remotes, digital probes, and disposable color change indicators) were assessed in several grades of beef patties and cuts of chicken. Three models of each thermometer were evaluated under three different cooking methods. These studies indicated that all models of thermometers tested were poor indicators of accurate temperatures in that they did not match the calibrated controls over a broad range of acceptance standards (0% to 92% acceptance). The results suggest that using these thermometers could either undercook or overcook these foods, thereby compromising food safety and food quality, and that these thermometers required more than the recommended time to register products as cooked (Liu, 2009 a & b).

LeBlanc et al. (2005) assessed the attributes of six models of analog fork thermometers and six types of digital instant read-probe thermometers. These products were evaluated while cooking pre-formed beef patties and roasts. When applied to these foods, fork thermometers and digital read thermometers underestimated the temperature of the cooked foods by 1°C to 11°C (1.8-19.8°F). However, when the thermometers were correctly used according to manufacturers' instructions, such as proper placement in the food for a specified time (at least 30 seconds), the analog and digital thermometers provided reliable information on cook temperatures.

In a similar study McCurdy et al. (2004) evaluated 21 models of instant-read pocket food thermometers (8 dial models and 13 digital models available from local grocery, department, and hardware stores, by catalog/internet order, or free from the Idaho Beef Commission). Accuracy and response time were assessed using standardized protocols. Importantly, the accuracy of dial and digital thermometers was good (within 2°F) for 98 percent of those tested. On the other hand, response time in small meat items was quite variable (10-31 seconds).

Antibacterial Products for Cleaning Food Contact Surfaces

A single nonrandomized study (DeVere, 2007) investigated the effectiveness of domestic antibacterial wipes and sprays in decontaminating food contact surfaces. Four commercially available antibacterial products were evaluated under controlled laboratory conditions. Using *E. coli* and *S. aureus* as Gram negative and Gram positive indicators of food contact surface contaminants, the antibacterial wipes were applied and used as stipulated by the manufacturers. Food contact surfaces included plastic, glass, wood and antimicrobial treated materials. Microbial survival was the indicator of antimicrobial effectiveness. This small study indicated that the effectiveness of these products was dependent upon the type of surface (lower microbial reduction with plastic surfaces, countertops, utensil materials, etc.) and type of antimicrobial product (wipes were least effective) (DeVere, 2007). The active ingredients in wipes were butoxypropanol and ethanol or Microban® (a broad-spectrum antimicrobial containing triclosan). The sprays contained isopropanol and surfactants or Microban® as antimicrobial agents. The effectiveness of the wipes was dependent upon the applier who controlled the amount of surface and degree of pressure applied (DeVere, 2007).

Unless food contact surfaces, such as counter tops, cutting boards, and refrigerator shelves, are cleaned and sanitized on a regular basis, the risk of microbial contamination and subsequent foodborne illnesses increases. In addition to following recommended cleaning practices that include washing in hot water (sanitizing temperature ≥155°F) with appropriate detergents, consumers can use numerous antimicrobial products in the form of sprays, wipes, and sponges. These products are intended to reduce the presence of and contamination with food pathogens (DeVere, 2007). The effectiveness of these products varies with the kind and concentration of bacteria, the type of surface (e.g., glass, plastic, stone, wood), and the apparent active ingredient. The most common active ingredients are quaternary ammonium compounds, such as the sanitizing agents used in commercial environments and hospital settings. One important aspect for the effective application of products is residence time, namely the time the surface is exposed to the sanitizing agent. Thus, many manufacturers of these kinds of products recommend their application after cleaning the contact surface, and allowing the surface to air dry without any rinsing. This air dry approach is critical to ensure adequate surface cleaning. Consumers also must remember that another key concern is potential contamination if the rinse water or solution and applicator, if used, are not clean. For simplicity and to reduce costs, according to the CDC (2008), it may be easiest for most consumers to use approximately 3 tablespoons of ordinary, unscented bleach per 1 gallon of clean water. This solution may be easily applied as a spray, wipe or dip. The contact surfaces should not be dried or rinsed for at least 10 minutes. This is an excellent approach of decontamination for most microbes and food surfaces, as well as other common contact points found in the home kitchen.

Antibacterial Cutting Boards

Antimicrobial cutting boards, often color-coded to minimize cross-contamination, are readily available. The antimicrobial property of these cutting boards is based on the natural characteristics of silver-ions to fight off an array of bacteria, fungi, mold and some viruses commonly found in the home kitchen (Kounosu, 2007).

A single case-control study (Kounosu, 2007) evaluated the antibacterial properties of cutting boards treated with antimicrobial materials. This small (n=10 households) study, using *E. coli* and *S. aureus* as Gram negative and Gram positive indicators of antimicrobial effectiveness, also monitored other environmental microbes common in kitchens and food preparation areas. The effectiveness of cutting boards in reducing the microbial burden depended upon the antibacterial rating of the cutting boards (Kounosu, 2007). Another indicator for home food safety indicated that the use of these antimicrobial cutting boards tended to reduce the concentration of common organisms, such as *Pseudomonas, Flavobacerium, Microccus,* and *Bacillus* better than untreated cutting boards (Kounosu, 2007).

Consumable Sanitizers for Foods

One small randomized block designed study (McKee, 2005) and one non-randomized trial (Yucel Sengun, 2005) evaluated the effectiveness of consumable sanitizers intended to decontaminate foods. McKee et al. (2005) evaluated household juices, baking soda, sodium chloride (table salt solution), wine, soy sauce (low pH, high sodium) and vinegar (lower pH) on several cuts of raw chicken. The microbial load of cranberry juice and vinegar-rinsed chicken cuts was typically lower than the other solutions except for 10% sodium chloride and 10% sodium bicarbonate solutions (McKee, 2005). However, all of the tested in-home products that lowered the pH, particularly white vinegar and salt solution (10% brine), produced a lower microbial burden (McKee, 2005).

In a laboratory study, Yucel Sengun and Karapinar (2005) noted that a solution of equal volumes of vinegar (source of acetic acid) and lemon juice (source of citric acid) can be effective in reducing potential *Salmonella* burden on lettuce surfaces following a 15-minute no-rinse period. Chicken meat marinades often consist of this kind of mixture which, in turn, may reduce the risk of other kinds of microbial contaminants, such as *Campylobacter jejuni* (Birk, 2010). However, the impact of organic acids on food safety is generally considered not as effective or efficient as commercial agents.

Many foods, such as olives and some poultry and fish, are traditionally "preserved" in brines. Brining or salting is one of the oldest forms of food preservation for reducing food spoilage, and some US food regulations that set food standards require this approach in the production of commercial foods to ensure food safety (Title 21, US Code of Federal Regulations, Parts 130-169; Title 9, US Code of Federal Regulations, Parts 319 and 381).

SEAFOOD

Question 9. What are the Benefits in Relationship to the Risks for Seafood Consumption?

Conclusion

Moderate, consistent evidence shows that health benefits derived from the consumption of a variety of cooked seafood in the US in amounts recommended by the Committee outweigh the risks associated with methyl mercury (MeHg) and persistent organic pollutants (POPs) exposure, even among women who may become or who are pregnant, nursing mothers, and children ages 12 and younger. Overall, consumers can safely eat at least 12 oz. of a variety of cooked seafood per week provided they pay attention to local seafood advisories and limit their intake of large, predatory fish. Women who may become or who are pregnant, nursing mothers, and children ages 12 and younger can safely consume a variety of cooked seafood in amounts recommended by this Committee while following Federal and local advisories.

Implications

Seafood is a healthy food choice that can be safely promoted provided that the types and sources of seafood to be limited or avoided by some consumers are clearly communicated to consumers. Consumers may be able to eat safely more than 12 oz. per week of seafood if they chose to do so provided they choose the right mix of seafood that emphasizes the consumption of seafood species with relatively low concentrations of contaminants such as MeHg and POPs. Encouraging consumption of seafood in the US is justified, as consumption continues to be far below amounts recommended for health by the Institute of Medicine and by this Committee (see ***Part D. Section 3: Fatty Acids and Cholesterol***).

Current Federal advisories on consumption of seafood species with high MeHg levels that vulnerable groups need to avoid are well justified by the scientific evidence. Regarding women who may become or who are pregnant, nursing mothers, and young children, there is emerging evidence that consumption beyond 12 oz. per week may be safe. However, additional benefit/risk modeling is needed taking into account the simultaneous presence of multiple contaminants in a shifting seafood supply. State and local agencies should continue to reach out to vulnerable groups and the population at large with advisories about the presence of diverse environmental contaminants in different water bodies. This is particularly relevant for seafood caught by consumers. The public also needs to be advised that eating a variety of seafood, as opposed to just a few choices, is likely to reduce their exposure to 'single source' contaminants. Clear, consistent evidence indicates that consumers will need access to publicly available user-friendly benefit/risk information to make informed seafood choices that maximize their health taking into account their seafood preferences.

Review of the Evidence

Background

Mercury in water is derived from human activities involving the combustion of fossil carbon fuels and from natural sources, including volcanic emissions. MeHg is formed through the normal biological processing of mercury by aquatic microorganisms, and it bioaccumulates up the trophic food chain in the muscle tissue of aquatic animals (IOM, 2007). As a result, large, predatory fish such as shark, swordfish, tilefish, and king mackerel have the highest MeHg concentrations.

On the one hand, seafood consumption has been associated with health risks for infants, children, and adults. MeHg exposure has been found to impair the neurological development of the fetus and young child (IOM, 2007). In addition, it has been proposed that MeHg is a risk factor for CVD perhaps as a result of pro-oxidant mechanisms involving the activation of free radical formation and the inhibition of cellular antioxidant systems (Guallar, 2002). However, the evidence for this risk is inconsistent (IOM, 2007; Stern, 2007) with a recent meta-analysis of five prospective and one retrospective studies suggesting no overall significant association between coronary heart disease (CHD) risk and high MeHg exposure (i.e., top quartile) in European and US populations (Mozaffarian, 2009). However, a Finnish prospective study (Rissanen, 2000) did identify an interaction between serum n-3 polyunsaturated fatty acids (PUFA) and hair MeHg on CHD risk. Consuming seafood was protective against CHD for those with higher (upper tertile) and lower (two lower tertiles) MeHg exposures but the benefit was greater for those in the lower MeHg exposure group.

On the other hand, seafood consumption also offers CVD and neurological development benefits associated with EPA and DHA consumption (see ***Part B. Section 2. The Total Diet: Combining Nutrients, Consuming Food***; ***Part D. Section 2. Nutrient Adequacy***; and ***Part D.***

Section 3: Fatty Acids and Cholesterol). In March 2004, the EPA and the FDA issued a seafood advisory based on seafood benefit/risk considerations, entitled, *What You Need to Know about Mercury in Fish and Shellfish* (EPA/FDA, 2004). It specifically targeted pregnant and nursing women, young children, and non-pregnant women of childbearing age because of their potential vulnerability to the effects of MeHg. The advisory recommended that, in order for women to receive the benefits of eating seafood and be confident that they have reduced their exposure to the harmful effects of mercury, they could safely consume up to 12 oz. (2 average meals) per week of a variety of cooked seafood, but to not exceed white (albacore) tuna consumption beyond 6 oz. per week. The same advice was given for young children except that they would be fed smaller portions. These target groups were advised to avoid consuming species high in MeHg, including shark, swordfish, king mackerel and tilefish. This Federal advisory, which is still in effect, also recognized the importance of state seafood advisories for informing consumers about the safety of consuming locally caught and harvested seafood. These recommendations are consistent with those issued by other national scientific groups (IOM, 2007) and other countries, including Canada (Health Canada, 2009).

The 2005 DGAC Report concluded that it is possible for vulnerable groups to obtain the benefits of seafood consumption without exceeding tolerable levels of MeHg intakes. Re-addressing this question is relevant because new evidence has become available and consumers are still receiving conflicting seafood consumption messages, some of which are inconsistent with Federal advice (Ginsberg, 2009).

Review of the Evidence

This conclusion is derived from nine studies, including three quantitative risk/benefit assessment studies (Ginsberg, 2009; Guevel, 2008; Sioen, 2008); four cross-sectional studies (Dewailly, 2007; Huang, 2006; Rawn, 2006; Verger, 2008) which also included a risk/benefit analysis; one meta-analysis (Gochfeld, 2005), and one systematic review (Mozaffarian, 2006). A report from the IOM, *Seafood Choices* (2007), was used as evidence before 2006 to develop the conclusion.

Since the publication of the 2005 DGAC Report, five quantitative (Ginsberg, 2009; Guevel, 2008; Gochfeld, 2005; Sioen, 2008; Verger, 2008) and two qualitative (IOM, 2007; Mozaffarian, 2006) risk/benefit assessments have been published. These studies targeted the US (Ginsberg, 2009; Gochfeld, 2005; Mozaffarian, 2006), French (Guevel, 2008; Verger, 2008), and Belgian (Sioen, 2008) populations. The two US quantitative benefit/risk analyses modeled neurodevelopmental and CVD benefits and risks associated with DHA and MeHg in seafood (mostly fish), respectively (Ginsberg, 2009; Gochfeld, 2005). The French study based on the Quality-Adjusted Life Year (QALY) approach modeled neurodevelopmental benefits and risks associated with DHA and MeHg but did not include the function describing the potential harm of MeHg on cardiovascular health (Guevel, 2008). The Belgian study examined different levels of seafood intake in relationship to the tolerable weekly intake levels of MeHg and dioxin-like compounds (Sioen, 2008). The other French study examined seafood intake thresholds based on omega-3 PUFA recommendation and the upper tolerable intake limits for dioxins and polychlorinated biphenyls (PCBs), a type of POP (Verger, 2008). The two qualitative analyses addressed benefit and risks on neurodevelopment and cardiovascular health attributed to DHA and MeHg. In addition, Mozaffarian and Rimm (2006) estimate the benefit/risk ratios based on omega-3 PUFA benefits and POPs exposure risks.

A comprehensive assessment of the evidence by the DGAC indicates that neurodevelopmental and/or cardiovascular benefits of seafood consumption outweigh the MeHg risks associated with the same outcomes provided that consumers stay within amounts recommended for safety, according to the MeHg and POPs content of the mix of seafood species being consumed. Furthermore, the benefit threshold for neurodevelopmental and CVD outcomes appears to be at seafood intakes below the harm threshold associated with MeHg consumption (Gochfeld, 2005).

With regard to the risk of POPs exposure, evidence suggests that POPs levels at current and recommended (EPA/FDA, 2004) levels of seafood consumption in North America from commercially caught or farmed seafood are safe (Dewailly, 2007; Mozaffarian, 2006; Rawn, 2006; Santerre, 2004; Tittlemier, 2004). However, concerns continue to be raised about the higher levels of POPs found in farmed versus wild seafood, including salmon (Huang, 2006). Regarding this concern, Mozaffarian and Rimm (2006) documented strong benefit/risk ratios (range: 100 to 1000-fold) associated with the consumption of wild or farmed salmon taking into account cardiovascular benefits associated with DHA consumption and excessive cancer rates attributed to potential exposure to POPs. Consistent with this finding, Verger et al. (2008) found that recommended intakes of omega-3 PUFA can be met and even exceeded through eating seafood without going beyond POP's upper tolerable intake limits.

In summary, benefit/risk modeling studies indicate that if appropriate seafood choices are made, namely emphasizing consumption of seafood low in MeHg and POPs, consumers may be able to eat 12 oz. or more of a variety of seafood per week safely, although additional CVD benefits may not be obtained beyond 12 oz. (Mozaffarian, 2006). Indeed, this is the only quantitative study that conducted benefit/risk assessments by seafood species consumed in the US (based on MeHg risk only). Ginsberg & Toal (2009) concluded that individuals can consume safely one 6-oz. meal per day for seven out of the 16 seafood species modeled taking into account infant neurodevelopment, and for nine of these species when modeling cardiovascular health.

Related Contextual Issues

Implications of Dietary Selenium and the Potential Health Risks of Methyl Mercury Exposure from Seafood

In reviewing the literature on the benefits and risks related to seafood consumption, the Committee was interested in the role selenium may play in mitigating harmful effects of MeHg and POPs. However, no studies were identified that met the inclusion criteria for this question for the topic of selenium. Therefore, a summation of current evidence is provided here for context.

Several investigators have hypothesized that dietary selenium from seafood may play a possible role in protecting against environmental exposure to MeHg and PCBs (Berry, 2008; Kaneko, 2007; Ralston, 2008; Ravoori, 2009). On the other hand, high exposure levels to MeHg can inhibit vital functions of selenium. The mercury-selenium ratio in seafood may, in part, explain some of the health benefits and adverse effects of some species of seafood consumed as observed in several prospective studies, such as those in the Seychelles Islands versus Northern Europe (Kaneko, 2007; Myers, 2009; Rice, 2008). However, a recent study of flatfish harvested from the New Jersey coast did not indicate a strong correlation of mercury-selenium ratio, regardless of season or geographic location (Burger, 2009). Thus, although the review of several recent studies on the potential benefit-risk relationship of seafood consumption and selenium show an interesting possible protective effect of selenium, the data are insufficient to affect the immediate and consistent public health recommendation regarding the consumption of seafood previously reported in this chapter.

Implications of Aquacultural Practices for a Safe, Nutritious Food Supply

The recommendations of the Committee related to seafood consumption led to discussions of the role of aquaculture in providing a safe and nutritious food supply. Aquaculture refers to the breeding, rearing, and harvesting of plants and animals in all types of water environments, including ponds, rivers, lakes, and the ocean (NOAA, 2010). Similar to agriculture, aquaculture can take place in the natural environment or in a manmade environment. Using aquaculture techniques and technologies, researchers and the aquaculture industry are "growing," "producing," "culturing," and "farming" all types of marine and freshwater species. About 20 percent of US aquaculture production is marine species; the rest is freshwater species. Aquaculture techniques also can be applied to some plants, including vegetables (Cahu, 2004). Aquaculture is the most rapidly growing form of food production on a global basis. Globally, nearly 50 percent of the fish consumed comes from aquaculture farms (Naylor, 2009; FAO, 2010). In response to the rapid growth of and need for aquaculture, the Committee has included research recommendations on this topic.

Chapter Summary

Consumers need to take more responsibility regarding food safety. In doing so, along with sound government policies and responsible food industry practices, consumers can help prevent foodborne illness. Consumers should better understand their role in ensuring that the foods they prepare at home or order at food service outlets are handled safely and contain ingredients known to them. Americans could benefit from improved food safety education on hand sanitation, use of food/appliance thermometers, prevention of cross-contamination, and consumption of certain risky foods in the home (e.g., cookie dough containing raw eggs), as well as outside the home (e.g., raw fish and shellfish). Even with current and future introductions of food safety technologies, food safety fundamentals in the home remain foundational. Seafood is a healthy food choice that can be safely promoted provided that the types and sources of seafood to be avoided are clearly communicated to consumers. Consumption of at least 12 oz. per week of seafood can be safe for the general population provided consumers choose the right mix of seafood, emphasizing species low in contaminants (e.g., MeHg and POPs). The Committee supports the recommendations of the 2004 FDA/EPA seafood advisory that states women who may become or who are pregnant, nursing mothers, and young children can safely eat up to 12 ounces of seafood, should limit white (albacore) tuna to 6 oz. per week, and should not eat large, predatory fish. Among these vulnerable groups, there is emerging evidence that consumption beyond 12 oz. per week may be safe; however, additional benefit/risk modeling is needed taking into account the simultaneous presence of multiple contaminants in a shifting seafood supply. Consumers need improved access to publicly available user-friendly benefit/risk information to make informed seafood choices.

Research Recommendations

Food Safety in the Home

1. Improve the validity of self-reported food safety behaviors.

   Rationale: The great majority of the published descriptive epidemiology on US food safety consumer behaviors is based on self-report. Food safety self-reported behaviors are subject to "social desirability" biases. This is particularly evident among hygiene/cleaning behaviors.

2. Understand how to improve consumers' food safety knowledge, attitudes, self-efficacy, internal locus of control and ultimately behaviors.

   Rationale: Studies have consistently documented the need to develop cost–effective consumer food safety behavior change interventions. This research needs to take into account the socio-ecological framework that acknowledges the constant interaction between environmental forces and individuals' choices on health behaviors (Levy, 2008; Mary Story, 2008). Whenever possible, these studies should include objective microbiological food safety indicators to assess the effectiveness of the interventions.

3. Understand whether and how home kitchen microbial cross-contamination during food preparation translates into actual risk for foodborne illness.

   Rationale: There is indisputable laboratory evidence demonstrating that potentially harmful bacteria (mostly *Campylobacter*) present in raw poultry can be transferred to ready-to-eat foods through cross-contamination in the home kitchen. Cross-contamination risk studies have heavily concentrated on the transmission of *Campylobacter* through poultry, and the great majority have been conducted in Europe, leaving a knowledge gap for the US. Studies are also needed in the US that concentrate on pathogens and food vehicles other than *Campylobacter* and poultry.

4. Improve monitoring and surveillance to better understand the epidemiology of home-based foodborne illness outbreaks.

   Rationale: The proportion of foodborne outbreaks that can be attributed to improper food safety practices in the home kitchen remains largely undetermined. Translating unsafe food safety behaviors into actual food safety risk will require prospective studies that collect microbial as well as associated morbidity data, in addition to observed food safety behaviors.

Technologies Related to Food Safety

5. Validate and apply food safety sensors for home appliances and cooking utensils.

   Rationale: The development of sensors that monitor commercial food processing standards has improved the quality assurance and safety of those food products. Applications of this technology should be incorporated into and validated in home refrigerators, stoves, ovens, and cooking utensils.

6. Develop, test, and apply environmentally friendly food safety packaging technologies to improve nutritional quality and safety of foods.

   Rationale: Future packaging materials and in-home containers, in addition to being biodegradable and environmentally friendly, will function beyond protecting the product from contamination and maintaining physical properties to nutritional qualities of foods. Some common food ingredients, such as several kinds of dietary fiber and food flavors, when incorporated into food packing materials, can inhibit the growth of potential pathogens. In addition, some foods, like meats, poultry, and seafood, may be packaged in an environment with different kinds of gases, such as nitrogen and carbon dioxide. Applications of these gases at the levels necessary to inhibit microbial growth in the food supply are considered safe by the FDA. (Title 21, US Code of Federal Regulations, Part 184). These kinds of environments, in conjunction with good sanitation practices, can effectively reduce the risk of microbial growth and subsequent contamination, and extend the quality and shelf life of frozen and refrigerated food products.

7. Further develop and promote contemporary educational resources for encouraging food safety behaviors in the home.

Rationale: The USDA has numerous food safety education sources in contemporary electronic game formats. It is expected that the further development and acceptance of these kinds of educational sources linked to in-home food safety practices and monitoring of in-home environments will reduce the risk of food-related illnesses in the home.

Seafood Safety

8. Conduct consumer risk communication research to determine how best to translate seafood benefit/risk findings to the public.

Rationale: An unfortunate outcome for the 2004 EPA/FDA Federal seafood consumption advisory was an unintended decrease in fish consumption among pregnant women (Oken, 2008). This may have been the result of a lack of proper coordination and formative evaluation in benefit/risk communications targeting diverse audiences. Since then, researchers have developed user-friendly computer-based educational systems (Domingo, 2007a; Santerre, 2009). However, much more research is needed in this area to effectively reach out to the socioeconomically and culturally diverse US population with the tools needed to maximize the health benefit of their individual seafood choices (Ginsberg, 2009; Verger, 2008).

9. Further refine seafood intake recommendations for US consumers (IOM 2007).

Rationale: Improving seafood intake recommendations will require a better understanding of benefit(s) and risk(s) response functions that take into account the simultaneous presence of multiple beneficial and detrimental bioactive substances in a variety of seafood (Domingo, 2007b; Ginsberg, 2009; Gochfeld, 2005; Mozaffarian, 2006; Sioen, 2008; Verger, 2008). Similar information also will be needed for other key protein sources (e.g. dairy, meat, plant-based), as consumption changes in one protein source lead to concomitant changes in consumption of other protein sources.

10. Improve and optimize current seafood contaminants surveillance and monitoring.

Rationale: Monitoring of POPs and other contaminants should be a priority, especially because of the increasing reliance in aquaculture and the multiple origins of seafood being consumed in the US. In particular, systems should become more proactive and less reactive in nature (IOM, 2006).

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Part D. Section 8: Food Safety—Tables

Table D8.1. Original and final research questions for food safety techniques and consumer behaviors in the home

Original Questions	Final Questions
To what extent do consumers follow proper techniques/behaviors and procedures for food storage and food preparation and handling?	Question 4. SEPARATE: What techniques for preventing cross-contamination are associated with favorable food safety outcomes? Question 5. COOK AND CHILL: To what extent do US consumers follow adequate temperature control during food preparation and storage at home?
What in-home techniques for food storage and food preparation and handling are associated with favorable food safety outcomes, such as reduced pathogen loads and subsequent risk of home-based foodborne illnesses?	See Questions 4 and 5.
To what extent do consumers follow proper techniques/behaviors and procedures for hand washing?	Question 1. CLEAN: What techniques for hand sanitation are associated with favorable food safety outcomes and to what extent do US consumers follow them?
What in-home techniques for hand washing are associated with favorable food safety outcomes, such as reduced pathogen loads and subsequent risk of home-based foodborne illnesses?	See Question 1.
To what extent do consumers follow proper techniques/behaviors and procedures for washing/cleaning utensils, equipment, and surfaces used in food preparation, serving, cooking, and eating?	Question 3. CLEAN: To what extent do US consumers clean their refrigerators? See Question 4.
What in-home techniques, for washing/cleaning utensils, equipment, and surfaces used in food preparation, serving, cooking, eating, are associated with favorable food safety outcomes, such as reduced pathogen loads and subsequent risk of home-based foodborne illnesses?	See Questions 3 and 4.
To what extent do consumers follow proper techniques/behaviors and procedures for washing/cleaning foods (such as fruits, vegetables, meat, poultry, seafood, eggs) at home? Which food washing/cleaning technique(s) are most commonly used by consumers?	Question 2. CLEAN: What techniques for washing fresh produce are associated with favorable food safety outcomes and to what extent do US consumers follow them? See Question 4.
What in-home techniques for washing/cleaning foods such as fruits, vegetables, meat, poultry, seafood, eggs are associated with favorable food safety outcomes, such as reduced pathogen loads (and reduced chemical contaminant load related to fruits and vegetables) and subsequent risk of home-based foodborne illnesses?	See Questions 2 and 4.
To what extent do consumers follow proper techniques/behaviors and procedures for consumption of undercooked or raw foods?	Question 6. AVOID RISKY FOODS: To what extent do US consumers eat raw or undercooked animal foods?
	Question 7. To what extent do specific subpopulations practice unsafe food safety behaviors? (Question 7 was within the criteria for all questions, and was made into a question of its own.)

Table D8.2. Recommended procedures for hand sanitation

When washing hands with soap and water:
• Wet your hands with clean running water and apply soap. Use warm water if it is available.
• Rub hands together to make a lather and scrub all surfaces.
• Continue rubbing hands for 20 seconds. Need a timer?
• Rinse hands well under running water.
• Dry your hands using a paper towel or air dryer. If possible, use your paper towel to turn off the faucet.
If soap and water are not available, use alcohol-based gel to clean hands. When using an alcohol-based hand sanitizer:
• Apply product to the palm of one hand.
• Rub hands together.
• Rub the product over all surfaces of hands and fingers until hands are dry.

Source: Adapted from http://www.cdc.gov/cleanhands/. Accessed April 19, 2010.

Table D8.3. Recommended techniques for washing produce

When preparing any fresh produce, begin with clean hands. Wash your hands for 20 seconds with warm water and soap before and after preparation.
Cut away any damaged or bruised areas on fresh fruits and vegetables before preparing and/or eating. Produce that looks rotten should be discarded.
All produce should be **thoroughly washed before eating**. This includes produce grown conventionally or organically at home, or produce that is purchased from a grocery store or farmer's market. Wash fruits and vegetables under potable running water just before eating, cutting, or cooking.
Even if you plan to peel the produce before eating, it is still important to wash it first.
Washing fruits and vegetables with soap or detergent or using commercial produce washes is not recommended.
Scrub firm produce, such as melons and cucumbers, with a clean produce brush.
Drying produce with a clean cloth towel or paper towel may further reduce bacteria that may be present.
Many precut, bagged, or packaged produce items like lettuce are pre-washed and ready to eat. If the package indicates that the contents have been pre-washed and ready to eat, you can use the product without further washing
If you do choose to wash a product marked “pre-washed” and “ready-to-eat,” be sure to use safe handling practices to avoid any cross-contamination. Wash your hands for 20 seconds with warm water and soap before and after handling the product and wash the produce under running water just before preparing or eating.

Source: Adapted from http://www.fda.gov/downloads/Food/ResourcesForYou/Consumers/UCM174142.pdf. Accessed April 19, 2010.

Table D8.4. Recommended techniques for keeping the refrigerator clean

Wipe up spills immediately—clean surfaces thoroughly with hot, soapy water; then rinse.
Once a week, throw out perishable foods that should no longer be eaten. A general rule of thumb for refrigerator storage for cooked leftovers is 4 days; raw poultry and ground meats, 1 to 2 days.
The exterior of the refrigerator may be cleaned with a soft cloth and mild liquid dishwashing detergent as well as cleansers and polishes that are made for appliance use.

Source: Adapted from http://www.fsis.usda.gov/Fact_Sheets/Refrigeration_&_Food_Safety/index.asp#11. Accessed April 19, 2010.

Table D8.5. Recommended techniques for preventing cross-contamination

When Shopping:
Separate raw meat, poultry, and seafood from other foods in your grocery shopping cart. Place these foods in plastic bags to prevent their juices from dripping onto other foods. Raw juices often contain harmful bacteria. It is also best to separate these foods from other foods at checkout and in your grocery bags.
When Refrigerating Food:
Place raw meat, poultry, and seafood in containers or sealed plastic bags to prevent their juices from dripping onto other foods. When not possible, store raw animal foods below ready-to-eat foods and separate different types of raw animal foods, such as meat, poultry, and seafood from each other so that they do not cross-contaminate each other.
Store eggs in their original carton and refrigerate as soon as possible.
When Preparing Food:
Washing raw poultry, beef, pork, lamb, or veal before cooking it is not recommended. Bacteria in raw meat and poultry juices can be spread to other foods, utensils, and surfaces.
Wash hands and surfaces often. Harmful bacteria can spread throughout the kitchen and get onto cutting boards, utensils, and countertops. To prevent this:
• Wash hands with soap and warm water for 20 seconds before and after handling food, and after using the bathroom, changing diapers, handling pets, or anytime hands become contaminated.
• Use hot, soapy water and paper towels or clean cloths to wipe up kitchen surfaces or spills. Wash cloths often in the hot cycle of your washing machine.
• Wash cutting boards, dishes, and countertops with hot, soapy water after preparing each food item and before you go on to the next item.
• A solution of 1 tablespoon of unscented, liquid chlorine bleach per gallon of water may be used to sanitize surfaces and utensils.
Cutting Boards:
Always use a clean cutting board.
If possible, use one cutting board for fresh produce and a separate one for raw meat, poultry, and seafood.
Once cutting boards become excessively worn or develop hard-to-clean grooves, you should replace them.
Marinating Food:
Always marinate food in the refrigerator, not on the counter.
Sauce that is used to marinate raw meat, poultry, or seafood should not be used on cooked foods, unless it is boiled just before using.
When Serving Food:
Always use a clean plate.
Never place cooked food back on the same plate or cutting board that previously held raw food.

Source: Adapted from http://origin-www.fsis.usda.gov/Fact_Sheets/Does_Washing_Food_Promote_Food_Safety/index.asp and http://origin-www.fsis.usda.gov/Fact_Sheets/Be_Smart_Keep_Foods_Apart/index.asp. Accessed April 19, 2010.

Table D8.6. Recommended safe minimal internal temperatures

Food	Degrees Fahrenheit
Ground Meat and Meat Mixtures[a]	
Beef, Pork, Veal, Lamb	160
Turkey, Chicken	165
Fresh Beef, Veal, Lamb[a]	
Steaks, roasts, chops[a]	145
Poultry[a]	
Chicken and Turkey, whole	165
Poultry breasts, roasts	165
Poultry thighs, wings	165
Duck and Goose	165
Stuffing (cooked alone or in bird)	165
Fresh Pork[a]	160
Ham[a]	
Fresh (raw)	160
Pre-cooked (to reheat)	140
Eggs and Egg Dishes[a]	
Eggs	Cook until yolk and white are firm.
Egg dishes	160
Fresh Seafood [b]	
Finfish	145
	Cook fish until it's opaque (milky white) and flakes with a fork.
Shellfish	Cook shrimp, lobster, and scallops until they reach their appropriate color. The flesh of shrimp and lobster should be an opaque (milky white) color. Scallops should be opaque (milky white) and firm.
	Cook clams, mussels, and oysters until their shells open. This means that they are done. Throw away any that were already open before cooking as well as ones that didn't open after cooking.
Leftovers and Casseroles[a]	165

Source: [a]http://origin-www.fsis.usda.gov/PDF/Kitchen_Companion.pdf. Accessed May 6, 2010.
[b] http://www.fda.gov/Food/ResourcesForYou/HealthEducators/ucm082294.htm. Accessed April 26, 2010.

Table D8.7. Recommended techniques for food thermometers

To be safe, meat, poultry, and egg[a] and seafood[b] products must be cooked to a safe minimum internal temperature to destroy any harmful microorganisms that may be in the food.
A food thermometer should also be used to ensure that cooked food is held at safe temperatures until served. Cold foods should be held at 40°F or below. Hot foods should be kept hot at 140°F or above.[a]
Most available food thermometers will give an accurate reading within 2 to 4°F. The reading will only be correct, however, if the thermometer is placed in the proper location in the food.[a]
In general, the food thermometer should be placed in the thickest part of the food, away from bone, fat, or gristle.[a]
When the food being cooked is irregularly shaped, such as with a beef roast, check the temperature in several places. Egg dishes and dishes containing ground meat and poultry should be checked in several places.[a]
When measuring the temperature of a thin food, such as a hamburger patty, pork chop, or chicken breast, a thermistor or thermocouple food thermometer should be used, if possible.[a]
However, if using an "instant-read" dial bimetallic-coil food thermometer, the probe must be inserted in the side of the food so the entire sensing area (usually 2 to 3 inches) is positioned through the center of the food.[a]
To avoid burning fingers, it may be helpful to remove the food from the heat source (if cooking on a grill or in a frying pan) and insert the food thermometer sideways after placing the item on a clean spatula or plate.[a]
Food thermometers should be washed with hot soapy water. Most thermometers should not be immersed in water.[a]

Adapted from [a] http://origin-www.fsis.usda.gov/Fact_Sheets/Kitchen_Thermometers/index.asp. Accessed April 19, 2010.
[b] http://www.fda.gov/Food/ResourcesForYou/HealthEducators/ucm082294.htm. Accessed April 26, 2010.

Table D8.8. Recommended techniques for using refrigerator/freezer thermometers

For safety, it is important to verify the temperature of refrigerators and freezers.
Refrigerators should maintain a temperature no higher than 40°F.
Frozen food will hold its top quality for the longest possible time when the freezer maintains 0°F.
To measure the temperature in the refrigerator:
Put the thermometer in a glass of water and place in the middle of the refrigerator. Wait 5 to 8 hours. If the temperature is not 38 to 40°F, adjust the refrigerator temperature control. Check again after 5 to 8 hours.
To measure the temperature in the freezer:
Place the thermometer between frozen food packages. Wait 5 to 8 hours. If the temperature is not 0 to 2°F, adjust the freezer temperature control. Check again after 5 to 8 hours. An appliance thermometer can be kept in the refrigerator and freezer to monitor the ambient temperature at all times. This can be critical in the event of a power outage. When the power goes back on, if the refrigerator is still 40°F and the freezer is 0°F or below, the food is safe.

Adapted from http://origin-www.fsis.usda.gov/PDF/Appliance_Thermometers.pdf. Accessed April 19, 2010.