Food Safety Education: What Should We Be Teaching to Consumers?

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ABSTRACT Food safety education is most effective when messages are targeted toward changing behaviors most likely to result in foodborne illness. The five major control factors for pathogens are personal hygiene, adequate cooking, avoiding cross-contamination, keeping food at safe temperatures, and avoiding foods from unsafe sources. Pathogens associated with poor personal hygiene have the highest incidence and costs. Inadequate cooking and cross-contamination have lower incidence. Keeping food at safe temperatures and unsafe food sources have the lowest incidence, although costs per case are sometimes very high. We recommend that consumer food safety educators primarily focus on hand washing, adequate cooking, and avoiding cross-contamination. Secondary messages should focus on keeping food at safe temperatures and avoiding food from an unsafe source. Evaluation tools are needed to evaluate self-reported behavior changes. The evaluation questions must focus on salient behaviors that are most likely to result in foodborne illnesses and must withstand rigorous standards of reliability and validity.

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INTRODUCTION

The epidemiology of foodborne diseases is rapidly changing as newly recognized pathogens emerge and well-recognized pathogens increase in prevalence or become associated with new food vehicles.[1] Thus, there is a need to examine food safety education programs to ensure that messages are aimed at reducing the risk of the most prevalent and/or serious causes of foodborne illness. Research studies and reports were reviewed in order to establish the rationale for recommendations for subject matter content of food safety education programs. Topics that were considered pertinent for development of the recommendations were (a) estimates of the incidence and costs of illness from each common foodborne pathogen, (b) food-handling errors and common food sources associated with each pathogen, and (c) consumer behaviors regarding food handling in the home.

INCIDENCE OF FOODBORNE ILLNESSES

Sources of data on acute foodborne illnesses come from foodborne disease outbreak reports collected by the Centers for Disease Control and Prevention (CDC), laboratory databases or health surveys in which intestinal diseases are reported, risk models based on infectious doses and pathogens' prevalence in foods, and experts' extrapolations to estimate the number of foodborne cases.[2] Since it is impossible to determine the exact number of foodborne illnesses, various estimates exist.[1–4] The CDC estimates that foodborne illnesses cause approximately 76 million illnesses, 325,000 hospitalizations, and 5000 deaths in the United States each year.[4] Some foodborne pathogens have not yet been identified. The CDC estimates that unknown pathogens account for 81% (62 million) of the total cases of foodborne illnesses and 64% of the deaths.[4]

Foodborne disease outbreak reports. Outbreaks of foodborne illness are reported to the CDC by state and local health departments. The data are generated when two or more individuals experience a similar illness, which is investigated by a state or local health department, and it is determined that food is the common source. It is important to recognize that the number of outbreaks reported by this passive surveillance system probably represents only a small proportion of the outbreaks that occur. Large outbreaks, interstate outbreaks, restaurant-associated outbreaks, and outbreaks involving serious illness or death are more likely to be reported than are outbreaks occurring in a single family. In addition, foodborne diseases with short incubation periods (such as *Staphylococcus aureus* and *Clostridium perfringens*) and those that involve common pathogens (such as *Salmonella* species) are more likely to be reported, and pathogens that

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cause mild illness (such as *Campylobacter jejuni*) are less likely to be reported.[3]

Foodborne Diseases Active Surveillance Network (FoodNet). Recently, FoodNet, an active surveillance for foodborne diseases of populations, has been implemented in selected sites in the United States.[5] Components of FoodNet in the selected sites include foodborne outbreak reports, laboratory surveys, health surveys of the population, case-control studies, and surveys of physicians in the areas. FoodNet is an active surveillance system, a search for the true incidence of foodborne illnesses in the selected sites. The goals of FoodNet include an improvement in the estimate of the frequency and severity of foodborne diseases in the United States and identification of the sources of specific foodborne diseases.

Expert estimates of incidence of foodborne illnesses. Food scientists and epidemiologists extrapolate from the available data to estimate the incidence of various foodborne illnesses in the United States. An excellent review of the process is found in Mead et al.[4] Outbreak and laboratory data and estimates of incidence of foodborne illnesses are useful in helping to decide the food-handling behaviors that should be targeted in food safety education. Table 1 presents the experts' estimates of the incidence and costs associated with 13 common foodborne pathogens. Also presented is information on the severity, common food sources, food-handling errors, and primary control factors associated with each pathogen.

COSTS ASSOCIATED WITH FOODBORNE ILLNESSES

The calculated costs of foodborne illness include medical costs and productivity losses because the person was not at work. The estimated annual costs from illnesses associated with each foodborne pathogen are related to both the incidence and the severity of the illness. Estimates of annual costs for each pathogen were calculated using values for cost per case that were published in 1994[2]; thus, the estimated annual costs are likely conservative. The pathogen with the lowest cost per case is *Clostridium perfringens* ($184/case). Estimated costs per case of *Shigella*, *Bacillus cereus*, and *S. aureus* range from $375 to $460. *Salmonella*, *Yersinia enterocolitica*, *Campylobacter jejuni*, and Norwalk-like virus are estimated to cost about $900 per case.[2]

Some pathogens can cause very severe illness, and the cost per case reflects this severity. These pathogens include *Escherichia coli* O157:H7 (>$3000/case), *Listeria monocytogenes* (>$12,000/case), *Clostridium botulinum* (>$18,000/case), and *Toxoplasma gondii* (>$110,000/case of congenital toxoplasmosis). Hepatitis A costs about $5000 per case, with only about 5% of cases attributed to contaminated food.[2]

FOOD-HANDLING ERRORS ASSOCIATED WITH COMMON PATHOGENS

To be most effective, food safety education needs to target changing those behaviors most likely to result in illness. The pathogens listed in Table 1 are grouped according to four control factors: personal hygiene, adequate cooking/avoid cross-contamination, keep food at safe temperatures, and avoid foods from unsafe sources. Although adequate cooking and avoid cross-contamination are actually separate control factors, they are combined in Table 1 because they are appropriate for the same pathogens. Estimated incidence from pathogens associated with the personal hygiene control factor is about 9.3 million cases at a cost of $8.2 billion. The incidence and cost associated with the adequate cooking/avoid cross-contamination control factors is 3.5 million cases at a cost of $4.3 billion. Estimated incidence of illness from pathogens associated with keeping food at safe temperatures is less than 0.5 million cases, with a cost of $142 million. Estimated incidence of illness associated with consumption of foods from an unsafe source is only 10,000 cases; however, since the pathogens can cause severe illness, the costs associated with the 10,000 cases are $30 million.

MESSAGES FOR FOOD SAFETY EDUCATION

In 1997, the Partnership for Food Safety Education launched the Fight BAC!™ campaign to teach consumers about safe food handling.[6] The campaign focuses on four messages, which are *clean:* wash hands and surfaces often, *separate:* don't cross-contaminate, *cook:* cook to proper temperature, and *chill:* refrigerate promptly. These categories are similar in focus to the control factors listed in Table 1 except that avoid foods from unsafe sources is not included as a specific message in the Fight BAC! campaign and cleaning surfaces is included with hand washing rather than in the avoid cross-contamination control factor as in Table 1.

Personal hygiene. Pathogens for which personal hygiene is a primary control factor are those for which transmission is primarily via human feces. Some other foodborne pathogens such as *E. coli* O157:H7 are also secondarily transmitted by infected food workers.

There is growing awareness that Norwalk and Norwalk-like viruses are responsible for a large number of foodborne illnesses. In 1994, a group of experts estimated that there were less than 200,000 cases of the Norwalk "agent" per year.[2] The most recent estimate is more than 9 million cases per year (66% of all cases from known foodborne pathogens).[4] Norwalk and Norwalk-like viruses usually cause a mild illness, with onset marked by sudden vomiting and diarrhea. Because the viruses multiply in the gut, a very large number of virus particles are excreted during the illness. The viruses

Table 1. Common foodborne pathogens: estimates of annual incidence and cost, disease severity, common food sources, food-handling error(s) associated with the pathogen, and primary control factor.

Pathogen	*Estimated Incidence*[a] *(Foodborne)*	*Estimated Cost*[b] *(Millions of Dollars)*	*Disease Severity*	*Common Food Sources*	*Food-Handling Error(s) Associated with Pathogen*	*Primary Control Factor*
Norwalk and Norwalk-like viruses	9,200,000	8160	Mild to moderate	Contaminated shellfish and prepared foods handled by infected food handlers	Poor personal hygiene of infected food handlers	Personal hygiene
Shigella spp	90,000	34	Moderate to severe	Prepared foods handled by infected food handlers	Poor personal hygiene of infected food handlers	Personal hygiene
Hepatitis A	4170	21	Moderate to severe	Contaminated shellfish and prepared foods handled by infected food handlers	Poor personal hygiene of infected food handlers	Personal hygiene
Clostridium perfringens	249,000	46	Mild, self-limiting	Meat, poultry products, and beans	Bacterial spores survive cooking; multiply when food is in danger zone	Keep food at safe temperatures
Staphylococcus aureus	185,000	85	Mild to severe (rarely)	High-protein foods handled frequently during preparation	Food handler contaminates cooked food, *S. aureus* produces toxin while food is in danger zone	Keep food at safe temperatures
Bacillus cereus	27,000	11	Mild, self-limiting	Cooked rice and pasta	Bacterial spores survive cooking; multiply when food is in danger zone	Keep food at safe temperatures
Campylobacter jejuni	1,960,000	1798	Mild to moderate	Raw milk, poultry, beef, pork, shellfish	Inadequate cooking, fecal/ environmental contamination	Adequate cooking/ cross-contamination
Salmonella spp	1,342,000	1190	Mild to severe	Meat, poultry, raw milk, eggs, fresh produce	Inadequate cooking, fecal/ environmental contamination	Adequate cooking/ cross-contamination
Toxoplasma gondii	112,500	1247	Mild to severe	Pork, ground beef, other meats	Inadequate cooking, fecal/ environmental contamination	Adequate cooking/ cross-contamination
Yersinia enterocolitica	86,731	77	Mild to moderate	Pork, milk or milk products	Inadequate cooking, fecal/ environmental contamination	Adequate cooking/ cross-contamination
Escherichia coli 0157:H7	62,500	205	Moderate to severe	Ground beef, raw milk, lettuce, unpasteurized apple cider	Inadequate cooking, fecal/ environmental contamination	Adequate cooking/ cross-contamination
Listeria monocytogenes	2493	29	Mild to severe	Raw milk, soft cheeses, raw vegetables, raw-meat sausages	Inadequate cooking, post-pasteurization contamination, lengthy refrigeration	Avoid food from unsafe source
Clostridium botulinum	58	1	Severe	Home-canned or fermented vegetables, meat, fish	Inadequate processing time for low-acid food; poor fermentation	Avoid food from unsafe source

[a]Estimated incidence from Mead et al.[4]; other information compiled from the Council for Agricultural Science and Technology.[2]

[b]Estimated cost calculated by multiplying incidence by cost per case from the Council for Agricultural Science and Technology.[2] Cost per case includes medical cost and productivity losses. Values for cost per case are likely conservative since they were published in 1994.

appear to be infective in very low doses; thus, the percentage of people who get ill after consuming a food contaminated with Norwalk-like viruses may be very high.[7] *Shigella* species and *E. coli* O157:H7 also have a low infectious dose and are transmitted by contaminated food.[8] If food safety educators are effective at convincing food handlers to wash their hands well after bowel movements, the incidence of foodborne illness will likely decrease substantially.

Adequate cooking. Pathogens that are transmitted from food animals to humans (zoonotic pathogens) can cause serious illness, and foods from animal sources are frequently contaminated with these pathogens.[8] At the current time, pasteurization/cooking is the primary control mechanism for zoonotic pathogens in meats, eggs, and dairy products. Adequate cooking messages need to include various time/temperature combinations that produce safe meat, eggs, and dairy products that are of acceptable quality.

Because of the high incidence and the gravity of illness caused by some of the zoonotic pathogens, adequate cooking needs to be strongly emphasized in food safety programming. Most people use visual cues to determine whether meat and eggs are adequately cooked. The Fight BAC! pamphlet gives endpoint cooking temperatures for meats,[6] and the U.S. Department of Agriculture has launched a campaign to encourage consumers to cook food to a safe internal temperature (for additional information, see www.fightbac.gov and www.fsis.usda.gov/thermy). Research is needed to determine effective ways to teach consumers how to evaluate when meat and eggs are adequately cooked. Effective ways to motivate consumers to use a thermometer when cooking are needed.

Avoid cross-contamination. There are few data regarding the frequency with which ready-to-eat foods are cross-contaminated with pathogenic bacteria in the home. However, the incidence of *Campylobacter* infections gives clues that cross-contamination may be a frequent cause of foodborne illness. *C. jejuni* is a common contaminant of poultry products[8] and is relatively easy to kill by heat.[8] Few people report the use of undercooked chicken.[9,10] Thus, the conclusion could be drawn that many of the campylobacteriosis cases are the result of cross-contamination of kitchen equipment that was used to prepare raw poultry and then was inadequately cleaned before preparation of ready-to-eat foods. Effective ways to "reveal" the invisible pathogens and teach how to avoid cross-contamination are needed.

Keep food at safe temperatures. Traditionally, food safety education has focused a great deal of attention on the need to cool and thaw foods properly. The pathogens primarily associated with inadequate control of refrigeration and hot holding (*S. aureus*, *C. perfringens*, and *B. cereus*) cause relatively mild illness, and it is estimated that there are less than 500,000 illnesses per year from these three pathogens (see Table 1). When a limited time is allocated for food safety education, we suggest that keeping food at safe temperatures be secondary messages rather than the focus of the lesson.

Foods from unsafe sources. The term "foods from unsafe sources" can have a wide variety of meanings. For this article, we are referring to ready-to-eat foods that are produced or processed in a way that does not kill pathogens. Examples of such foods include raw (unpasteurized) milk and raw-milk cheeses, uncooked seafood from contaminated water, and home-canned, low-acid foods that were improperly processed. Raw sprouted seeds appear to be classified in this category by the Food and Drug Administration (FDA).[11] The CDC fact sheet on listeriosis suggests that deli foods may be considered as foods from an unsafe source for pregnant women and immunosuppressed persons.[12]

Many foods from unsafe sources are more frequently consumed by a particular gender or ethnic group,[9] or the recommendations apply to only a certain high-risk group, such as pregnant women.[12] In some regions, home canning is common. Food safety educators need some knowledge of the food habits of their audience in order to determine how much attention to focus on avoiding foods from unsafe sources.

Other messages. One additional food safety message not covered by the five constructs listed above is washing of fresh fruits and vegetables. Although washing is only partially effective at removing pathogens from fresh produce,[13] this topic should be included in food safety programs since it is the only method that consumers have to reduce pathogen load on fresh produce. Washing of poultry, eggs, or meat in the home is not recommended.[14]

Targeting messages to the audience. Food safety education is most likely to be effective if the messages are directed specifically toward the audience. For instance, unlike most other foodborne pathogens, the incidence of campylobacteriosis is high among young men.[1] Most *Campylobacter* infections are associated with cross-contamination from poultry preparation or consumption of undercooked poultry.[1] It has been postulated that the high incidence of *Campylobacter* infections in young men may be a reflection of their poor food preparation skills.[1] To reduce the risk of campylobacteriosis, food safety education for young men should include information about cooking poultry completely and how to avoid cross-contamination during preparation of poultry products.

Older people are more likely to consume raw or undercooked eggs than they are to partake of any other risky food-related behaviors.[9] Most of the *Salmonella enteritidis* outbreaks for which a food vehicle could be determined were attributed to eating undercooked eggs.[3] *S. enteritidis* infections are particularly severe for the elderly.[9] Thus, messages designed for the elderly should include emphasis on the need to cook eggs well done.

Children have a higher risk of serious complications from *E. coli* O157:H7 infections than do adults.[15] Thus, food safety education for parents of young children and child care providers should include specific information about ways to reduce the risk of acquiring an *E. coli* O157:H7 infection from food. Information should include cook ground beef and veni-

son thoroughly (minimum 160°F), drink only pasteurized milk and apple juice, wash fresh fruits and vegetables thoroughly before eating, and do not use fresh manure from ruminants to fertilize vegetable gardens.[15]

CONSUMER BEHAVIORS REGARDING FOOD HANDLING IN THE HOME

Although foodborne illnesses are common and may be of moderate to serious severity, the public has generally been quite complacent about the risk of foodborne illnesses, tending to think of the consequences as being mild and that the greatest risk is from foods that are prepared outside the home. For instance, results from a national survey conducted in 1993 indicated that consumers believe that foodborne illness is a minor sickness and that these illnesses usually result from eating a contaminated food at a restaurant.[10] Most respondents did not recognize the range and seriousness of symptoms likely to be caused by foodborne microbes and the long incubation periods associated with some pathogens. In addition, most respondents who reported a foodborne illness also believed that their illness was caused by food prepared somewhere other than in the home.[10] If consumers underestimate the frequency with which serious consequences are associated with foodborne illness, they are less motivated to make effective behavior changes.[10]

Large outbreaks of foodborne illnesses are the most likely to receive media coverage and to be reported to CDC. Thus, consumers are likely to think that foodborne illness is most likely to be caused by eating foods prepared outside the home. However, epidemiologic studies indicate that sporadic cases (those not associated with an outbreak) and small outbreaks in homes comprise most of the foodborne illness cases in the United States.[16] The failure to associate at-home food-handling practices with foodborne illnesses is a "serious impediment to convincing consumers to change inappropriate food-handling behavior."[10]

How effectively do consumers practice recommended food-handling guidelines? A study to observe the food-handling practices of consumers, specifically to determine how often proper food safety practices were employed as part of home food preparation, was conducted in 81 cities in the United States and Canada by Audits International. Meal preparation, service, post-meal clean-up, and leftover storage were observed in 106 households, using the same techniques that are used in standard audits of restaurants.[17]

At least one critical violation (one that could by itself potentially lead to a foodborne illness) was observed in 96% of the households. The most frequent critical violations were for cross-contamination (76%) and neglect of hand washing (57%). Major violations (contributing factors to foodborne illness) were most frequently observed for misuse of common cloth/sponge/towel (92%) and insufficient thermometer use (92%). Fewer than 1% of the households met the minimum criteria for acceptable performance, which was zero critical violations and no more than four major violations.[17] A recent replication of this study with 121 households in 82 North American cities has been completed and is published by Audits International.[18] In this study, the incidence of critical violations was only 69%, in part because of differences in methodology. Still, that means that more than two of three households were performing behaviors that would be considered critical food safety violations in restaurant settings. In a British study, Worsfold and Griffith observed 108 consumers preparing meals in their own homes and also found high rates of failure to follow food-handling guidelines.[19]

The "failure rate" of households in these observational studies is much higher than in surveys when consumers are asked to self-report their own errors in food handling. A nationwide study conducted by the FDA examined self-reported consumer behaviors related to three food-handling principles: hand washing, preventing cross-contamination of food, and thorough cooking of meat and poultry. About two-thirds of the respondents reported use of safe practices for washing hands, preventing cross-contamination, and adequate cooking of meat.[20] In a multistate survey on consumer food-handling practices, more than 80% of respondents reported that they washed their hands and cutting boards after contact with raw meat or chicken.[9]

The findings from observational studies indicate that errors in food handling are common; however, examining data from consumers' self-reported behaviors would lead to the conclusion that they are relatively uncommon. It would be prudent to use caution in interpreting self-reported behavior changes to evaluate outcomes of food safety educational programming.

KNOWLEDGE GAPS AND RESEARCH NEEDS

To impact the incidence of foodborne illness, actual and not just self-reported food-handling behaviors must change. Relationships between self-reported and actual behavior are not well understood; however, self-reported behavior is often the only data available to food safety educators. There is a need to establish validity of self-reported evaluation instruments with observational studies like those conducted by Daniels[18] and Worsfold and Griffith.[19]

There is also a need to evaluate whether food safety educational programs are addressing the most salient food safety behaviors. This involves determining the most important constructs that affect food safety behavior and lead to foodborne illness when not practiced. Such evaluation should be ongoing as new pathogens may emerge with potentially different relevant food safety behaviors necessary to prevent illness. (For example, the emergence of *E. coli* O157:H7 has resulted in additional food safety guidelines for consumers such as to use a thermometer to ensure that ground beef is cooked to at least 160°F.) Once the critical food safety behaviors are established, educational programs must be designed to address them.

As specific foodborne illnesses decrease in incidence, some traditional themes of food safety education will need

to be evaluated for importance. For example, if food safety education is focused only on thawing and cooling errors, the food-handling errors that result in the most frequent and costly causes of foodborne illness (as evidenced in Table 1) would be ignored. Likewise, if a food safety questionnaire assesses whether participants thaw meat on the counter as the key food safety behavior indicator question, yet this behavior rarely causes foodborne illness, the instrument may be measuring what has been taught but may not be a measure of the effectiveness of the program in decreasing the risk of foodborne illness.

IMPLICATIONS FOR RESEARCH AND PRACTICE

We suggest that consumer food safety education be organized around five behavior constructs: personal hygiene, adequate cooking, avoid cross-contamination, cold storage/hot-holding, and avoid foods from unsafe sources. The Fight BAC! campaign messages (clean, separate, cook, and chill) are similar to our proposed behavior constructs except that cleaning surfaces is included with hand washing in the clean message (rather than in the avoid cross-contamination behavior construct). Avoiding foods from unsafe sources is not included as a specific message in the Fight BAC! campaign.

It is our opinion that incidence of foodborne illnesses should be a primary determinant in determining the focus of food safety education. Thus, personal hygiene (associated with 10 million cases of foodborne illness/year) and adequate cooking/avoid cross-contamination (associated with 3.4 million cases of foodborne illness/year) should receive the most attention in food safety education programs. Due to the relatively low incidence of illnesses associated with improper cold storage/hot holding (0.5 million cases/year) and food from an unsafe source (10,000 cases/year), we suggest that these constructs receive less emphasis in food safety education than personal hygiene, adequate cooking, and avoidance of cross-contamination. In some circumstances, such as education of pregnant women or immune-compromised persons, messages regarding avoiding food from unsafe sources need to be emphasized since diseases associated with this control factor can be particularly severe for these audiences.

Evaluation tools are needed to evaluate self-reported behavior changes. The evaluation questions must focus on salient behaviors that are most likely to result in foodborne illnesses and must withstand rigorous standards of reliability and validity.

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