*Journal of Food Protection, Vol. 74, No. 10, 2011, Pages 1708–1716*
doi:10.4315/0362-028X.JFP-10-417


# Burger Preparation: What Consumers Say and Do in the Home

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MS 10-417: Received 29 September 2010/Accepted 27 May 2011

## ABSTRACT

Ground beef has been linked to outbreaks of pathogenic bacteria like *Escherichia coli* O157:H7 and *Salmonella*. Consumers may be exposed to foodborne illness through unsafe preparation of ground beef. Video footage of 199 volunteers in Northern California preparing hamburgers and salad was analyzed for compliance with U.S. Department of Agriculture recommendations and for violations of the U.S. Food and Drug Administration's Food Code 2009. A questionnaire about consumer attitudes and knowledge about food safety was administered after each filming session. The majority of volunteers, 78%, cooked their ground beef patties to the Food Code 2009 recommended internal temperature of 155°F (ca. 68°C) or above, and 70% cooked to the U.S. Department of Agriculture consumer end-point guideline of 160°F (ca. 71°C), with 22% declaring the burger done when the temperature was below 155°F. Volunteers checked burger doneness with a meat thermometer in 4% of households. Only 13% knew the recommended internal temperature for ground beef. The average hand washing time observed was 8 s; only 7% of the hand washing events met the recommended guideline of 20 s. Potential cross-contamination was common, with an average of 43 events noted per household. Hands were the most commonly observed vehicle of potential cross-contamination. Analysis of food handling behaviors indicates that consumers with and without food safety training exposed themselves to potential foodborne illness even while under video observation. Behaviors that should be targeted by food safety educators are identified.

Foodborne illness imposes a significant health and economic burden on the population of the United States. The Centers for Disease Control and Prevention estimates that 31 major pathogens cause 9.4 million episodes of foodborne illness, 55,961 hospitalizations, and 1,351 deaths each year *(36)*. In 2009, a total of 17,468 laboratory-confirmed cases of infection were identified in 10 U.S. states through FoodNet, the Center for Disease Control and Prevention's Foodborne Disease Active Surveillance Network *(29)*. Ground beef is associated with outbreaks of *Escherichia coli* O157:H7, including the first documented outbreak of *E. coli* O157:H7 linked to fast food hamburgers *(41)*. Among the 183 foodborne outbreaks of *E coli* O157:H7 between 1982 and 2002, ground beef was the food vehicle in 41% of the cases *(34)*. *Salmonella* is also a pathogen of concern. Ground beef has been linked to outbreaks of multidrug-resistant strains of *Salmonella (27)*. The financial impact of foodborne illness can reach billions of dollars every year *(37)*. The annual cost associated with *E. coli* O157:H7 in 2003 was estimated to be $450 million in the United States *(16)*. These outbreaks lead to illnesses, recalls of millions of pounds of beef, and financial damage including lost wages, layoffs, and medical costs *(3, 4, 8, 9)*.

Cooking is an effective way of eliminating *E. coli* O157:H7 and *Salmonella*. However, studies show that knowledge of and adherences to guidelines for meat preparation are not widespread. Videotaped observations reveal that consumers defrost meat at room temperature despite claiming otherwise *(20, 23)*. The most common method consumers use to determine meat doneness is cutting the meat open and checking the color, even though color is not a reliable way of assessing doneness *(18, 28, 42)*. Few use a thermometer to check doneness of meat, poultry, or seafood *(1, 22)*. A U.S. Food and Drug Administration (FDA) telephone survey of 4,539 adults revealed that 70% said they would never use a meat thermometer when cooking burgers even though 64% owned an instant-read thermometer *(25)*.

The low rate of thermometer use may be attributed to an emphasis on time or visual cues to determine doneness. Popular magazines include recipes with contradicting advice for hamburger cooking times. For example, consumers are advised to grill burgers for ''3–4 minutes'' in *Parade* magazine but are told to cook them for 12 minutes, ''flipping once,'' in *Saveur* magazine *(2, 13)*. Furthermore, analysis of heat transfer in frozen burgers indicates that following label recommendations on cooking time could lead to inadequate cooking *(30)*.

Twenty percent or more of consumers do not associate risk with home-cooked food *(38)* and blame outside food as the cause of foodborne illness *(17)*. Generally, consumers report that they keep food safe through personal and kitchen hygiene and washing vegetables *(15, 26)*. However, direct observation reveals that consumers do not adequately wash hands or clean surfaces after contacting raw meat and that cross-contamination is common *(1, 19)*. Laboratory simulations of food preparation confirm the possibility of

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significant bacterial transfer from contaminated foods to kitchen surfaces, hands, and ready-to-eat foods *(10, 35)*. While adequate chilling slows bacterial growth, consumers do not know the recommended refrigerator temperature, and some units are set to operate above 5°C (32 to 41°F) *(20, 23, 25)*.

Direct observation and video recordings can be used to analyze actual food handling behavior and the relationship between reported and observed behaviors. For example, Jay et al. *(19)* showed that over 40% of their volunteers who claimed to wash their hands with soap failed to do so in actual practice. Video camera footage provides compelling visual evidence that consumers are not following food safety guidelines while preparing food and are therefore exposing themselves to possible foodborne illness *(1, 19, 38)*.

The purpose of this study was to record practices that could put consumers at risk for foodborne illness while preparing hamburgers and salad in their homes. The focus was on how volunteers determined when burgers were done, but receptivity to measures to reduce risk by using a thermometer or purchasing labeled irradiated ground beef and practices of refrigeration, personal and kitchen sanitation, and potential cross-contamination were also recorded. This article presents data on burger preparation and cross-contamination, while washing of salad ingredients is reported elsewhere *(33)*.

## MATERIALS AND METHODS

An advertisement inviting people who eat burgers to ''show us how you cook them'' was placed in local newspapers, posted on community and library bulletin boards and the Internet, and shared by word-of-mouth. Additionally, the study was publicized through a segment on local television news. People volunteered by contacting the authors via telephone. Participants were required to be 18 years or older and not trained as a microbiologist, nurse, physician or dietician. They must eat beef burgers and speak English.

In appreciation for their participation, they were given ingredients for the burgers and salad and a gift card valued at $50. The volunteers were informed that they would be videotaped and would be briefed about informed consent prior to filming. After volunteers agreed to participate in the study, food delivery and meal preparation times convenient for the volunteer and researcher were designated. Frozen burger patties, buns, whole-head lettuce, celery, and tomatoes purchased in a local supermarket were delivered to the home of the volunteer at least 2 days before the food preparation. This timing allowed volunteers to defrost the patties if desired.

On the day of the filming, two research assistants reviewed informed consent and the Consumer Bill of Rights with the volunteer and obtained a signed consent form. A camera was deployed in the food preparation areas of the volunteer's home to capture food preparation footage. Cameras were positioned to capture footage of hand washing, vegetable preparation, and cooking. A second camera was deployed if necessary to ensure that all relevant food preparation actions were recorded or if the cooking took place in an area separate from the kitchen, like a backyard. A live video feed was enabled through the use of a Pinnacle video capture device linked to a laptop, so that the research assistants could remotely view the actions of the volunteer from another room where possible. This was done to reduce observational bias while footage was being captured.

The volunteer was asked to prepare the salad and the burgers following his or her normal food preparation methods and to inform the research assistants when the cooking was deemed to be complete. A Fisher brand refrigerator/freezer thermometer (model 15-105-5, Fisher Scientific, Pittsburgh, PA) was placed in the refrigerator near or at the location where ground beef was defrosted. If burgers were not defrosted, the thermometer was placed on a shelf in the refrigerator. After the burgers were declared done, a research assistant took the internal temperature of the cooked patty using a Fisher Scientific traceable instant-read thermometer (model 14-648-45). If the internal temperature of the cooked patty was less than 160°F (ca. 71°C), the volunteer was informed and allowed to either continue cooking the patty to 160°F or to serve it if he or she felt it was appropriate to do so.

After preparation of the meal was complete, the volunteer ate the meal while survey personnel packed the video equipment. When the volunteer finished eating, a 23-question survey was verbally administered to the volunteer. Questions asked included the frequency of ground beef preparation, methods for testing burger doneness, knowledge about current food safety issues, thermometer use, and attitudes toward food irradiation. The temperature of the refrigerator was recorded. For participating in the study, the volunteer was given the gift card, a food thermometer, and a refrigerator thermometer. Informational flyers containing food safety recommendations on cooking ground beef (''Now You're Cooking . . . Using A Food Thermometer!'' *(39)*), on washing produce (''Safe Handling of Fruit and Vegetables'' *(7)*), and on food irradiation (''Frequently Asked Questions About Food Irradiation'' *(6)*), were also distributed. The protocol for this study was approved by the Institutional Review Board of the University of California, Davis.

The video footage was scored for behaviors relevant to food safety. The scoring criteria included events deemed to be ''critical violations'' according to the FDA Food Code 2009 *(44)*. Consumer behaviors that constitute critical violations or critical items in the Food Code 2009 include noncompliance with recommended hand washing procedures (washing for at least 20 s with a cleaning compound like soap), food contact surface cleaning procedures, and utensil cleaning procedures. Kitchen counters, utensils, and cutting boards were considered clean when first used. Towels hanging in the kitchen were considered used. Towels removed from a drawer or cupboard were considered clean. Other behaviors analyzed included salad preparation and burger cooking methods. Potential contamination and cross-contamination events were noted. Potential cross-contamination events are defined as any event that may lead to a transfer of foodborne pathogens from a contaminated item to a ready-to-eat food via the preparer or a fomite. Statistical differences were determined using Student's *t* test calculated through Microsoft Excel.

## RESULTS

Volunteers from Northern California (Santa Clara, Alameda, San Francisco, Sacramento, Stockton, and Yolo counties) participated in the study. While 201 households were video recorded and interviewed between August 2008 and December 2009, two questionnaires were lost, leaving a sample size of 199 for demographic analysis. Most participants, 58%, were Caucasian, with 14% each of volunteers identifying themselves as Asian and Hispanic and 13% as African American. Compared with the state's population, Hispanics were underrepresented in this study,

TABLE 1. *Methods volunteers say they use to prevent foodborne illness*

| Prevention method | % of volunteers who said they use method ($n$ = 199)[a] |
|---|---|
| Proper cooking | 60 |
| Hand washing | 33 |
| Clean surfaces | 26 |
| Proper refrigeration/storage | 16 |
| Prevent cross-contamination | 13 |
| Wash vegetables | 5 |
| Use bleach | 3 |
| Use gloves | 2 |
| Buy organic | 2 |
| Buy local | 2 |

[a] Responses may exceed 100% because multiple responses were accepted.

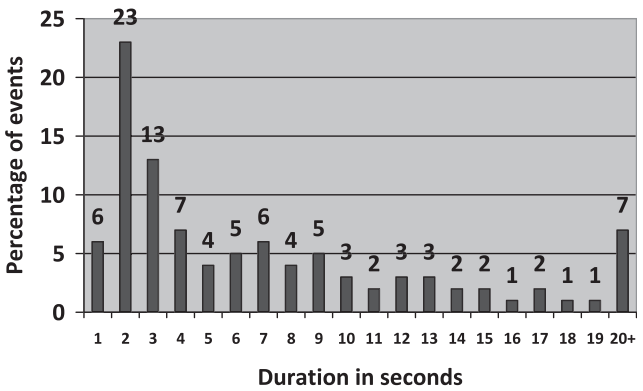


FIGURE 1. *Hand washing duration (*n = *650 washing events).*

while Caucasians and African Americans were overrepresented *(40)*. A little over half of the volunteers, 56%, indicated that they had at least a college degree, with an additional 35% having completed some college education without finishing their degree. Less than 10% of the respondents did not attend college. College degree holders were overrepresented in this study, since 56% held a degree as opposed to 27% in the state. The study consisted mostly of younger families, with 49% having children who were 12 years old or younger. Households with older adults were also represented, with 26% of families with adults in their 50s or older, including 9% of families with adults 60 years or older.

Although people with specialized medical or microbiology training were excluded from the study, about 50% of the volunteers reported some formal food safety training. Of these, 48% mentioned that they were trained in basic food safety protocols while working at a fast food restaurant or commercial kitchen, 19% attended food safety classes, including certification courses that led to ServSafe certification, 16% received food safety training in school or college, 15% received job training other than in a commercial kitchen, and 7% attended culinary school.

**Attitudes toward foodborne illness.** The majority of volunteers, 89%, had heard of people getting sick as a result of eating burgers. Awareness of *E. coli* among the volunteers was also high, with 95% of volunteers indicating that they had heard of it. Fast food restaurants were mentioned as a source of foodborne illness by about 16% of volunteers, with several specifically mentioning the 1994 outbreak of *E. coli* associated with Jack-In-The-Box restaurants. The possibility of contracting *Salmonella* or mad cow disease was mentioned by 14 and 10% of volunteers, respectively. When asked if they or their families could become ill from eating hamburgers, 84% thought it was possible; however, 18% thought they could only get sick if the burgers were prepared outside the home.

Nearly half of the volunteers, 45%, believed that meat packers were responsible for the safety of ground beef, followed by consumers themselves, mentioned by 37%, and government agencies like the FDA or the U.S. Department of Agriculture (USDA), specified by 30% of respondents. Three volunteers mentioned the role of celebrities like Oprah Winfrey in raising their awareness of foodborne illness and burgers.

**Preventing foodborne illness.** When asked about measures they took to prevent foodborne illness, 60% of volunteers mentioned proper cooking, followed by hand washing, cleaning, and refrigeration (Table 1).

**Hand washing.** A total of 650 hand washing events were video recorded during meal preparation. Less than half (43%) of volunteers washed their hands before beginning food preparation. The average duration for all hand washing events was 8 s, with the greatest number of washes lasting 2 s (Fig. 1). Only 7% of all hand washing events lasted 20 s or longer, as recommended in the Fight BAC! safe food handling guidelines and the Food Code 2009 *(32, 44)*. There was no significant difference in hand washing time between those with and without food safety training. The mean hand washing time for those with food safety training was 7 s, while those without training washed for 8 s ($P$ = 0.36). Only 41% of hand washing events involved the use of soap, although liquid hand soap was available in 65% of households and dish soap was in 49% of households, based upon 180 households in which the sink was visible. Hand washing was not observed in 27% of households even though soap was available. Among these volunteers, 51% had food safety training and 49% did not. About one-third, 32%, of volunteers did not wash their hands directly after handling raw ground beef. Additionally, 42% failed to wash their hands before assembling hamburgers. Overall, 62% of volunteers committed at least one failure to wash hands before handling ready-to-eat food. Shaking hands to remove water was the drying method used in 47% of the events. Cloth towels were used in 31% of drying occasions, followed by clean paper towels used 17% of the time. People did not dry hands in 4% of the events, and 1% dried hands by wiping them on their clothes. Hand drying behavior did not differ significantly between those with and without food safety training.

**Cross-contamination.** A total of 6,576 potential cross-contamination events were noted in this study. Most

TABLE 2. *Reported and observed burger handling and preparation methods*

| Reported or observed method or knowledge | % of volunteers ($n = 199$) |
|---|---|
| Reported ground beef patty thawing methods | |
| Refrigerator | 56 |
| Counter | 16 |
| Microwave | 6 |
| Do not thaw | 22 |
| Observed cooking methods | |
| Stove | 49 |
| BBQ | 38 |
| Electric grill | 11 |
| Oven | 2 |
| Reported methods of determining when burgers are done[a] | |
| Patty color | 51 |
| Juice clarity | 38 |
| Patty firmness/texture | 16 |
| Experience | 10 |
| Patty size | 9 |
| Time | 9 |
| Temp | 6 |
| Reported knowledge of recommended internal end-point temp for ground beef | |
| Did not know the recommended temp for cooking ground beef | 65 |
| Responded that they knew the temp but responded incorrectly | 22 |
| Responded correctly, 155°F (1%) or 160°F (12%) | 13 |
| Reasons for not using thermometers ($n = 152$)[a] | |
| Not necessary | 51 |
| Did not have one | 23 |
| Experience | 18 |
| Awkward | 6 |

[a] Responses may exceed 100% because multiple responses were accepted.

volunteers, 76%, performed actions that may potentially cross-contaminate food, with an average of 43 potential cross-contamination events per household. Almost one-third, 32%, of these events involved touching lettuce, 32% tomatoes, and 16% celery after handling raw meat. The majority of potential cross-contamination events, 93%, involved the food preparer's hands. Almost two-thirds, 65%, of volunteers potentially contaminated a faucet handle during food preparation and then touched the faucet again after washing, thus potentially contaminating the ready-to-eat food they subsequently touched.

About half of the volunteers, 48%, washed their knives before reuse. Plain water was used in 88% of the 142 knife-washing events and water and soap were used in 11% of events, while 1% used sanitizer only without soap. Shaking off the water was the most common method for drying knives, observed in 88% of drying events, with 6% each drying with a paper towel or dish towel. Less than half of the volunteers, 40%, were observed washing their cutting boards when switching from one preparation to another. Cutting boards were washed with water alone in 81% of washing events, while soap was used in 17% of washing events, and 2% used sanitizer solution without soap. Water was shaken off cutting boards by 89% of participants, while 6% dried with a dish towel and 5% used a paper towel.

**Burger preparation.** Burgers were frequently prepared by the volunteers. Frozen patties were used at least monthly by 26% of volunteers, while 51% prepared burgers using fresh ground beef. The majority of volunteers, 56%, reported thawing ground beef patties in their refrigerators, and 16% acknowledged that they thawed burgers on the counter (Table 2). However on camera, a higher percentage, 69%, used defrosted patties. Most cooked the patties as is; however, 5% thawed the patties, added their own ingredients, and formed patties by hand. Half of the volunteers cooked their burger patties indoors on a stove, while 38% cooked the meat on a barbeque grill and 11% used a double-sided electric grill. Typically, consumers removed the patties from their package and placed them directly on the cooking surface, so a platter was not used to carry the raw meat to the cooking area. Volunteers flipped burgers an average 2.5 times during the course of cooking. Five volunteers did not flip their burgers at all. Cooked burgers were placed on a clean plate and carried to the kitchen counter where burger assembly took place.

About 75% of consumers reported preferring their cooked ground beef to look brown throughout after cooking, 23% preferred pink interiors, and 2% preferred their cooked ground beef to be red inside. Visual appearance was the most commonly reported method for determining doneness of burgers, with checking for brown interior reported by half of the volunteers, followed by juice clarity or color and patty size or shrinkage (Table 2). Additionally, 9% of volunteers reported cooking for a certain amount of time to make sure that burgers were done.

The majority of volunteers, 78%, cooked their ground beef patties to the Food Code 2009 recommended temperature of 155°F (ca. 68°C) or higher (Fig. 2), while 70% cooked their burger to the USDA consumer recommended temperature of 160°F. The remainder undercooked their ground beef patties, including four volunteers who pronounced their burgers done at internal temperatures of less than 120°F (ca. 49°C). Of those who declared their burgers done when the temperature was 154°F (ca. 68°C) or less, half had food safety training. There was no statistical difference between the mean internal patty temperatures ($P = 0.38$) or cooking times ($P = 0.89$) for patties cooked from the frozen state versus those that were defrosted prior to cooking. Covering burgers cooked from the frozen or thawed state had no effect on the temperature of the burgers when declared done by the volunteers.

Although 53% of volunteers indicated that they owned meat thermometers and 33% said that they knew how to use a thermometer to test the doneness of burgers, actual use of a thermometer to check doneness occurred in only 4% of the households. Most volunteers, 65%, reported not knowing the recommended temperature for cooking ground beef

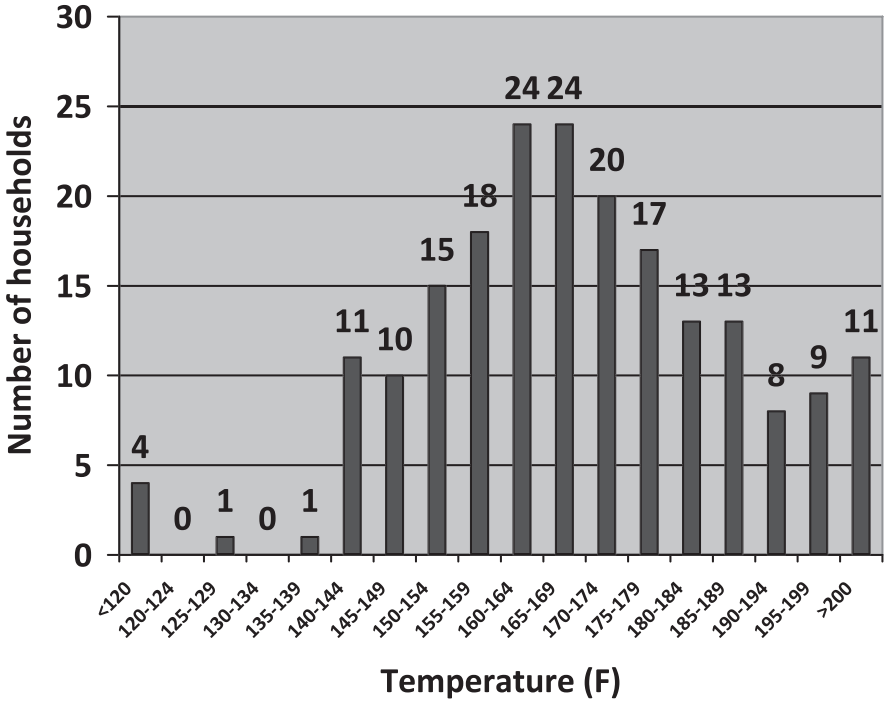


FIGURE 2. *Internal temperature distribution for cooked ground beef (*n = *199).*

(Table 2). Of those who thought they knew, only 12% responded correctly with the USDA guideline of 160°F, and an additional 1% cited the Food Code 2009 recommendation of 155°F. Erroneous answers ranged from 125°F (ca. 52°C) to 200°F (ca. 93°C).

A majority, 76%, of volunteers said that they would not use a thermometer to check the doneness of burgers. Of this group, 51% felt that using a thermometer in cooking ground beef patties was not necessary (Table 2). One volunteer cited the lack of thermometer use on television cooking programs as showing that people do not need to use them. Some were dismissive of using thermometers in burgers, describing the practice as ''cheesy,'' or stating that ''thermometers are for the house and not for food.'' Willingness to use a thermometer in the future, expressed by 24% of the volunteers, was not related to the burger endpoint temperature, the presence of children in the household, or the presence of family members older than 50 years.

When asked about possible improvements for the cooking directions on ground beef patty packages, 22% specifically wanted thermometer advice printed on raw ground beef package labels, and two suggested that the recommended temperature of 160°F be printed in bold type. About one-fifth, 19%, of volunteers mentioned that they would like to see the safe handling directions printed in a bigger text size, while 12% cited the need for pictures or diagrams to clarify directions. Volunteers wanted instructions that were ''simple'' and ''straight to the point,'' with ''layman's language,'' and important text highlighted with colors like red or yellow. Three volunteers were confused about the phrase ''cook thoroughly'' and suggested that ''thoroughly'' be better defined. In contrast, 11% admitted that they had not read the directions. One described reading directions as ''useless.'' Another said that nothing should be changed about packaging directions, and added, ''Surely everyone in the country already knows how to cook burgers.'' One volunteer admitted not knowing that cooking directions were printed on the package of frozen burgers that she received.

**Cooling.** The majority of respondents maintained their refrigerator at or below the recommended temperature of 40°F (ca. 4°C) (Fig. 3). Over 19% of the refrigerators tested registered temperatures of 43°F (ca. 6°C) or higher, with 3% of refrigerators over 50°F (10°C).

About 90% of volunteers indicated that they stored their leftovers in the refrigerator, while the rest indicated that they dispose of leftover food, either in the garbage or by feeding it to their pets or livestock. Of those who refrigerated leftovers, 91% said that they put them in the refrigerator within 1 h of finishing a meal, with 6% refrigerating them within 2 h and the rest waiting more than 2 h to put their leftovers away. One volunteer said that their family would put their food away ''before they go to bed,'' and another said that their family would put food away after ''three to four hours.''

**Food irradiation.** More than half of the study volunteers, 57%, had not heard of irradiation. Among those who had heard of the technology, the most common response was that irradiation kills germs and makes meat safer (Table 3). If volunteers were not familiar with irradiation, they were given a brief description. Following this, 49% indicated that they would buy irradiated burgers. Volunteers who had positive opinions about meat irradiation said things like, ''I think it's [a] wonderful, cheap, quick, easy way of getting rid of microbes'' [sic]. Those who did not want to buy irradiated burgers expressed concern about safety or flavor changes. One volunteer cited opposition to ''corporate meat packing practices'' as a reason not to choose irradiated burgers. Another did not like the idea of

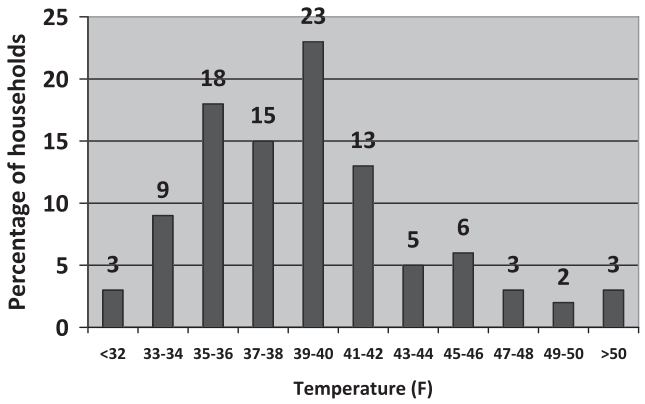


FIGURE 3. *Temperature distribution of volunteer's refrigerator (*n *= 190).*

''radiation going into the body.'' When asked if they wanted more information about irradiation, 21% of volunteers wanted to hear more about safety.

## DISCUSSION

This sample included households with children and older people who are at increased risk for foodborne illness due to age, yet almost all families made food handling errors, even those who reported food safety training. While people believed they should act responsibly, they also expected the meat industry to produce safe products. Almost one of five believed they could only get sick from burgers prepared in a restaurant. This result is consistent with other reports in which consumers ascribed foodborne illness to inappropriate handling by others *(14, 17, 38).* Educational materials need to emphasize the important role of the consumer in preventing foodborne illness and that foodborne illnesses can result from foods prepared in the home.

The findings indicate that consumer hand washing is likely to be inadequate both in technique and in duration according to guidelines from the Food Code 2009 and Fight BAC! Food preparers are advised to wash their hands for at least 20 s with a cleaning compound *(44),* yet the most common hand washing time in this study was 2 s. Furthermore, people did not wash their hands directly after handling meat, and hand washing frequently did not involve the use of soap. These findings are consistent with other reports in the literature, suggesting continued failure to comply with hand washing recommendations *(1, 19, 38).* Inadequate hand washing was the norm even though about a third of the volunteers specifically mentioned hand washing as a way to avoid foodborne illness. The gap between the awareness of the importance of hand washing and the actual practice of adequate hand washing should be addressed by food safety educators.

Consistent with USDA Food Safety and Inspection Service recommendations, the majority of volunteers thawed their frozen burgers in their refrigerators *(45).* However, 16% of volunteers reported thawing patties on their countertops, a practice that could allow bacteria to multiply if temperature is not closely monitored.

Almost one-quarter of volunteers, 22%, reported that they do not thaw frozen burgers. This is consistent with the directions on the package label. McCurdy et al. *(30)* noted that 23 of 37 different packages advised consumers to cook the patties in the frozen state. This reveals a conflict between the Fight BAC! recommendation to thaw burgers prior to cooking and product labels *(45).*

TABLE 3. *Volunteered knowledge of and interest in irradiated meat*

| Volunteer knowledge and concerns about food irradiation | % of volunteers ($n$ = 199)[a] |
|---|---|
| Knowledge | |
| Have not heard of irradiation | 57 |
| Irradiation kills germs | 23 |
| Irradiation is safer | 4 |
| Interest in buying irradiated burgers | |
| Yes | 49 |
| Uncertain | 22 |
| No | 29 |
| Concerns of those who would not buy | |
| Burgers may be dangerous | 12 |
| Concerned about changes appearance/ taste/smell | 11 |
| Makes food radioactive | 7 |
| Would not buy if too costly | 7 |
| Not natural | 7 |
| Carcinogens | 4 |
| Information desired | |
| No specific information requested | 63 |
| Safety of irradiated meat | 21 |
| Current use | 7 |
| Radioactivity | 4 |
| Read studies in the scientific literature | 3 |
| Cost/price | 2 |

[a] Responses may exceed 100% because multiple responses were accepted.

Most volunteers continue to depend on visual cues like meat color, size, and juice color to tell when their burgers are done even though meat color is not a reliable indicator of doneness *(28, 42)* and the USDA recommends using a thermometer. Food safety educators should address the lack of reliability of visual cues during cooking.

The majority of volunteers, 70%, cooked their burgers to the USDA consumer recommended temperature of 160°F, while 78% met the Food Code 2009 recommended minimum temperature of 155°F. The remaining 22% undercooked their burgers either from preference for rarer meat or inability to determine meat temperature. The very low rate of thermometer use is consistent with that observed by others. Anderson et al. *(1)* found that thermometers were used in 5% of households, 16% of volunteers in the study of Kendall et al. *(22)* used thermometers even though thermometers were provided in the study, and only one volunteer in Scott and Herbold's study *(38)* used a thermometer to check the internal temperature of a cooked hamburger. Consistent with these findings, in an FDA telephone survey of over 4,000 respondents, 70% reported that they never use a meat thermometer when cooking burgers *(25).*

This study points to a further need to educate consumers about the importance of cooking meat to the recommended temperatures and using thermometers to verify those temperatures. Three of four volunteers indicated that they would not use thermometers in burgers, and half said that thermometers were not necessary. Efforts to educate consumers about thermometers are complicated by messages in popular food media that espouse the use of other methods, such as time or touch. There is an immense opportunity for food celebrities to greatly improve food safety by recommending and practicing the use of food thermometers. The focus could be on cooking burgers safely while maintaining quality.

The volunteers were concerned about potentially confusing text on ground beef labels and offered suggestions for improvement. More than one-tenth of the volunteers admitted that they did not read label directions or they did not know that the directions existed. To facilitate the transmission of important safe food handling directions, a prominent label could be placed on the front of the package directing a purchaser to find those directions at the back of the package.

Most volunteers understood the importance of storing leftovers in a refrigerator in a timely fashion. Consistent with the results of the FDA survey, almost three-quarters of the household refrigerators registered temperatures of 41°F (5°C) or below *(25)*. Those households with refrigerators above 41°F could be putting themselves at risk for growth of pathogenic bacteria in their food, especially the 3% with refrigerators above 50°F. These findings suggest that information about appropriate refrigerator temperatures should continue to be addressed by food safety educators. Furthermore, refrigerator manufacturers should be encouraged to design appliances with a built-in thermometer both to stress the importance of appropriate temperatures and to enable consumers to more easily comply with recommendations.

This study recorded relatively high numbers of potential cross-contamination events compared with other investigations *(1, 19, 35)*. Every discrete act that could transfer bacteria was counted as a potential cross-contamination event. Lettuce was the food most commonly involved in potential cross-contamination, probably because it was touched more frequently than other foods during meal preparation. Chen et al. *(10)* found that up to 100% of bacteria can be transferred from raw chicken to hands and from hands to lettuce. If there had been pathogenic bacteria on volunteers' hands, large numbers could have been transferred to ready-to-eat foods.

It was interesting to note that 2% of cross-contamination events involved gloves because people neglected to remove gloves after handling meat or failed to wash their hands after glove removal. Gloves may not be a reliable barrier against bacteria *(11, 31)*. Consumers may be unaware that gloves are not a foolproof solution to food contamination.

Knives, cutting boards, and faucets were involved in cross-contamination events. In one case, the volunteer used a knife to pry apart frozen ground beef patties and then used it for preparing vegetables without cleaning it. Many contaminated their faucets during food preparation by touching and not washing them after handling raw beef. Chen et al. *(10)* showed that bacteria can be transferred from raw chicken onto a sterile spigot and then from the spigot to raw lettuce. Therefore, the volunteers who contaminated their faucets and then touched them repeatedly may risk a significant amount of bacterial transfer to ready-to-eat food. Volunteers never mentioned faucet cleaning during the interviews and may be unaware of the role of the faucet in cross-contamination. Food safety educators should emphasize faucet cleaning with soap and water as a way of preventing cross-contamination. Alternatively, this vehicle of cross-contamination would be eliminated if home faucets were operated by motion sensors or foot pedals as in food service establishments. This is an opportunity for the plumbing industry to enhance food safety by offering more hygienic alternatives to traditional faucets.

Cleanliness of kitchen utensils seems to be a less important issue for volunteers. Even though all used knives and cutting boards, less than half of the volunteers washed their knives and cutting boards before reuse. Furthermore, volunteers did not routinely use soap when washing. Only 26% of volunteers specifically mentioned that they would clean surfaces and utensils as a way of preventing foodborne illness. Fight BAC! guidelines recommend that different cutting boards be used for meat and ready-to-eat foods and that utensils be cleaned with hot soapy water before using for other foods to prevent cross-contamination *(32)*.

Fight BAC! guidelines also recommend that kitchen surfaces be dried with paper towels *(32)*. Consistent with the literature, few volunteers used paper towels and most shook their knives and cutting boards to remove water *(26)*. This clearly shows that consumers are not drying their utensils in an adequate fashion. The volunteers' drying methods may have been driven by financial or environmental reasons or the belief that drying wasn't important.

Knowledge about food irradiation is not widespread, with only about half having heard of irradiation and few having specific knowledge. Similar findings were reported by Bhumiratana et al. *(5)*, suggesting that lack of availability in the supermarket has kept the awareness of potential benefits static. Nevertheless, 49% of volunteers said they were willing to buy irradiated meat. While this is lower than the 76% reported by Johnson et al. *(21)* after consumers participated in an educational program, some responses were quite positive. Persistent misconceptions and ignorance about food irradiation point to a further need for education. Previous studies have shown that consumers are receptive to food irradiation when presented with accurate and positive information about it *(5, 21)*.

**Limitations.** While this study was an in-depth, comprehensive examination of actual consumer food handling practices in the home, there are limitations. This was not a random sample, but rather a self-selection of individuals who consume burgers.

Food handling practices were recorded in the presence of video cameras and two technicians not known personally

by the volunteers, and people knew that the temperature of the meat would be recorded. Volunteers were encouraged to prepare the food as they normally would, and the technicians were careful not to sensitize the volunteers to the food safety aspects of the study, but the volunteers may have been more careful than usual during food preparation. Deviations from recommended food safety practices occurred frequently despite any extra care the volunteer may have taken. Food safety violations may occur even more frequently in routine food preparation situations. Observational studies with nurses suggest that bias caused by the presence of cameras is limited *(12, 24)*. Therefore the behavior observed in this study may be considered typical.

Contamination, cleaning, or hand washing performed off camera was not recorded. If a volunteer washed his or her hands in a bathroom on the way back into the house after putting the patties on an outdoor grill, the washing would not have been counted. Kitchen surfaces were not swabbed, and contamination levels were not measured. Therefore, conclusions can only be made about potential risk of contamination rather than actual numbers of bacteria transferred.

**Implications.** Consumers frequently commit food safety violations during routine preparation of food in their homes. The food-handling practices of those who received food safety training are not significantly different from those without extra training. People are aware of the benefits of hand washing but do not follow recommended practices. This suggests that food safety education has not been sufficiently effective to generate behavior change.

Most people have not suffered serious harm by failing to follow safe food handling guidelines. People may discount recommendations when failing to follow them brings no ill consequences. We suggest that hand washing guidelines be validated by microbiological testing. The effectiveness of a 20-s wash compared with that of a 5-s or 10-s wash is unclear. If previously washed hands are contaminated by touching ground beef, and the fingers are rubbed under running water for 2, 5, or 10 s, how great is the potential for cross-contamination? The generation and pictorial representation of this data might increase the effectiveness of food safety education. If appropriate, food safety guidelines should be modified to reflect these assessments.

This study identified areas where consumers appear unaware that cross-contamination has taken place. Food safety educators should advise washing the faucet, as well as knives and cutting boards. That gloves do not prevent cross-contamination should be acknowledged. Furthermore, the importance of drying hands and utensils rather than using them wet should also be addressed.

The program to promote the use of thermometers when cooking burgers, initiated by the introduction of Thermy in 2000, has not been successful *(43)*. Despite repeated efforts by food safety educators and recommendations of Fight BAC!, consumers rely on visual indicators to determine doneness. People do not think thermometers are necessary, they don't see role models using thermometers, and they don't use them themselves. Furthermore, some people prefer their burgers less thoroughly cooked. To reduce the likelihood of foodborne illness associated with ground beef, the meat industry should utilize methods that further reduce pathogenic microorganisms. While safe handling by the consumer is always important, food irradiation could enhance ground beef safety. Half the consumers in this project indicated an interest in purchasing irradiated meat. While some consumers were opposed to this process, others had misconceptions that are easily addressed. Food safety educators and the meat industry should work together to expand the use of this safety-enhancing technology. High-pressure processing should also be explored as a method to reduce pathogens.

## ACKNOWLEDGMENTS

We gratefully acknowledge Outbreaks, Inc., for support of this study. We thank the volunteers for allowing us to observe and record their food preparation and the undergraduate and graduate students who assisted in filming and summarizing the data.

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