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Review

Consumer Food Handling in the Home: A Review of Food Safety Studies

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ABSTRACT

Epidemiological data from Europe, North America, Australia, and New Zealand indicate that a substantial proportion of foodborne disease is attributable to improper food preparation practices in consumers' homes. International concern about consumer food safety has prompted considerable research to evaluate domestic food-handling practices. The majority of consumer food safety studies in the last decade have been conducted in the United Kingdom and Northern Ireland (48%) and in the United States (42%). Surveys (questionnaires and interviews), the most frequent means of data collection, were used in 75% of the reviewed studies. Focus groups and observational studies have also been used. One consumer food safety study examined the relationship between pathogenic microbial contamination from raw chicken and observed food-handling behaviors, and the results of this study indicated extensive *Campylobacter* cross-contamination during food preparation sessions. Limited information about consumers' attitudes and intentions with regard to safe food-handling behaviors has been obtained, although a substantial amount of information about consumer knowledge and self-reported practices is available. Observation studies suggest that substantial numbers of consumers frequently implement unsafe food-handling practices. Knowledge, attitudes, intentions, and self-reported practices did not correspond to observed behaviors, suggesting that observational studies provide a more realistic indication of the food hygiene actions actually used in domestic food preparation. An improvement in consumer food-handling behavior is likely to reduce the risk and incidence of foodborne disease. The need for the development and implementation of food safety education strategies to improve specific food safety behaviors is reviewed in this paper.

Illness resulting from foodborne disease (defined as ''a disease of an infectious or toxic nature caused by or thought to be caused by the consumption of food or water'' *(156)*) has become one of the most widespread public health problems in the world today *(89, 119)*. Internationally, foodborne diseases associated with microbial pathogens, biotoxins, and chemical contaminants in food present a serious threat to the health of millions of individuals *(173, 174)*.

Extensive surveillance has also been carried out by epidemiologists to estimate the extent of foodborne disease and food related illness in industrialized countries *(50)*. It has been estimated that 130 million Europeans *(172)*, 2.1 million to 3.5 million Great Britons from England and Wales, 76 million Americans *(112)*, and 4.7 million Australians *(18)* are affected by episodes of foodborne disease and food-related illnesses annually. Direct comparisons of incidence data are not possible because of differences in national surveillance systems; however, it has been suggested that Australia, the United Kingdom, and the United States appear to have similar incidences of foodborne disease *(39)*. It has also been suggested that individuals from England, Wales, the United States, and Australia may suffer from foodborne disease at least once every 4 to 5½ years *(131)*.

The true incidence of foodborne disease is difficult to ascertain because cases of illness are underreported *(103)*. Although foodborne illnesses can be severe and fatal, milder cases are not often detected through routine surveillance *(112)*. The majority (>95%) of cases of foodborne disease are believed to be sporadic *(63, 104)*. These cases, as well as small outbreaks that originate in the home, typically involve individuals or a small number of people and thus are less likely to be identified by public health authorities *(98, 176)*. Therefore, the actual proportion of foodborne outbreaks and individual cases originating in the home is likely to be much larger than it has been reported to be *(179)*.

Restaurants, cafeterias, and bars are the most frequently cited locations where foods implicated in reported foodborne disease outbreaks are consumed. However, it has been reported that illness from foodborne disease arising from foods consumed in private homes is three times more frequent than that arising from foods consumed in cafeterias *(26)*. Over the past decade, up to 87% of reported foodborne disease outbreaks in the United Kingdom, Europe, Australia, New Zealand, the United States, and Canada have been associated with food prepared or consumed in the home (see Table 1 and Fig. 1). Historically, the largest proportions of reported foodborne disease outbreaks associated with private homes have been caused by *Salmonella (156)*. Epidemiological studies have indicated that sporadic

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TABLE 1. *International and national incidences of foodborne disease originating in consumers' homes*

Country	Year(s) of data collection	Incidence
Australia	1999	20–40% of foodborne illness suggested to arise from private homes *(18)*
Canada	1982	14% of incidents (outbreaks and cases) caused by mishandling of foods in homes *(157)*
England and Wales	1992–1993	17% of general foodborne outbreaks of infectious intestinal disease associated with food prepared in private homes and served elsewhere *(41)*
	1993–1998	12% of general outbreaks of foodborne disease attributed to food consumed in private homes *(156)*
	1970–1979	20% of general and family outbreaks of food poisoning associated with family homes as the place of consumption or origin of food incriminated *(140)*
France	1993–1997	40% of foodborne disease outbreaks (microbiologically confirmed and suspected) associated with private homes (where food was eaten) *(156)*
Germany	1993–1998	36% of foodborne disease outbreaks associated with private homes (where food was eaten) *(156)*
Ireland	1997–1998	10% of foodborne disease outbreaks associated with private homes (where food was eaten) *(156)*
New Zealand	1997	~50% of cases of foodborne illness reported to be caused by poor food-handling techniques in domestic kitchens *(24)*
Scotland	1996–1998	9% of foodborne disease outbreaks occurring in private homes *(156)*
Spain	1993–1998	49% of foodborne disease outbreaks associated with private homes (where food was eaten or acquired) *(156)*
Sweden	1992–1997	19–22% of outbreaks and single cases attributed to food consumed in private homes *(106)*
Switzerland	1993–1998	11% of foodborne disease outbreaks associated with private homes (where food was eaten) *(156)*
United States	1993–1997	20% of reported bacterial foodborne disease outbreaks originating from place where food was eaten *(125)*

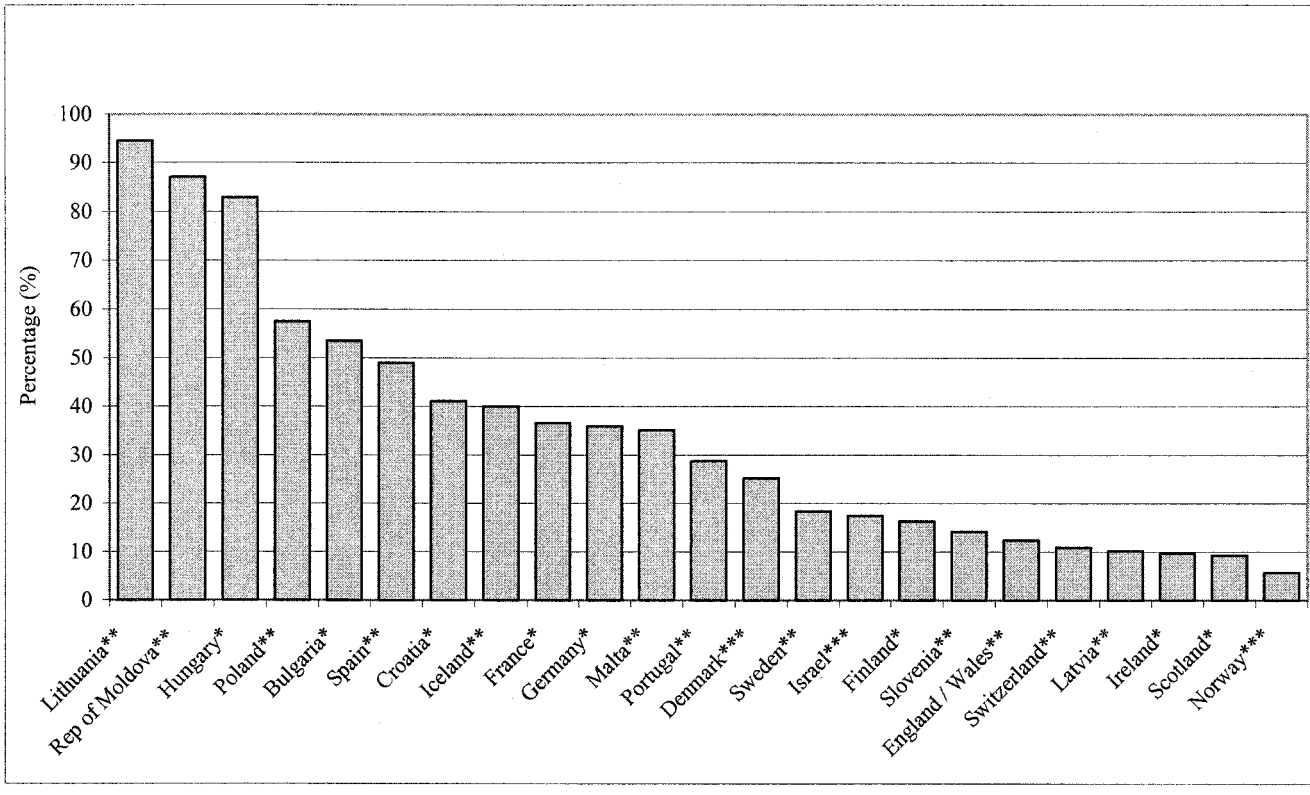

FIGURE 1. *Incidence of reported foodborne disease outbreaks associated with private homes in Europe (156). * Outbreaks of foodborne disease caused by food eaten or contaminated in private homes. ** Outbreaks of foodborne disease for which food was eaten or acquired in private homes. *** Outbreaks of foodborne disease for which food was prepared or contaminated in private homes.*

cases or small outbreaks in homes account for the majority of food poisoning incidents *(176).* Many cases of illnesses caused by *Campylobacter* are thought to be sporadic, and *Campylobacter* is known to cause more cases of foodborne disease than *Salmonella.* It has been estimated that private homes in the United Kingdom have accounted for more outbreaks of foodborne illness than have all other reported locations combined *(85).*

The importance of the home as a point of origin for foodborne disease has prompted surveys to evaluate aspects of bacterial contamination in the domestic environment. The persistence of microorganisms, presence and density of pathogens, and the potential spread of microbial contaminants from contaminated foods in the home have been reported *(72).* Rusin et al. *(142)* found the kitchen environment to be more heavily contaminated with fecal and total coliforms than the bathroom, suggesting that the risk of spreading infection in the home is highest in the kitchen environment. Microbial surveys of domestic kitchens have found significant contamination with a variety of bacterial contaminants, including fecal coliforms, *Escherichia coli, Campylobacter,* and *Salmonella (93).* Pathogens such as *Campylobacter* and *Salmonella* have also been detected in commercial and domestic kitchens after food preparation *(37, 45, 80, 138).* Pathogenic and nonpathogenic organisms are continually introduced into the home by people, food, water, pets, and insects and sometimes through the air *(25).* Indeed, the domestic kitchen is not a dedicated food production environment and may serve as a laundry, a workroom, and even living quarters for family pets *(78).* Nevertheless, it has been suggested that the implementation of appropriate hygiene practices can virtually eliminate the risk of transmission of foodborne pathogens *(96).* The safety measures taken by consumers play a critical role in the prevention of foodborne illnesses because they constitute the final step in the food preparation process *(178),* and safe food handling by the consumer in the domestic kitchen is considered to be "the final line of defense" *(70).*

The prevention of foodborne disease involves cooperation of all stages in the food chain *(72, 84, 171)*; no one stage carries the sole blame or responsibility *(2).* Effective food safety strategies require a dual approach integrating education and regulation *(94)* for the minimization of the risks of pathogenic contamination *(70, 73, 158).* Internationally, government agencies have prioritized the implementation of regulatory efforts for all sectors of the various food industries and the development of educational initiatives for consumers. In the United Kingdom, the Food Standards Agency's primary aims include the protection of public health and the interests of consumers with regard to food *(62).* The Food Standards Agency is considered to be independent and is responsible for the formulation and implementation of policies on all aspects of food safety and standards *(20),* and the protection of the consumer through effective enforcement is of primary importance *(61).* Similarly, in the United States, the food safety system is based on interactions between federal organizations such as the U.S. Department of Agriculture, the Food and Drug Administration, the Food Safety and Inspection Service, the Department of Health and Human Services, the Environmental Protection Agency, and the Animal and Plant Health Inspection Service. In Australia and New Zealand, an independent organization known as ANZFA (Australia and New Zealand Food Authority) collaborates with other authorities to "protect the health and safety of people through maintenance of a safe food supply" *(19).* ANZFA is a partnership between Australia's commonwealth state and territory governments and the New Zealand government.

Reflecting the recognition of their responsibility for food safety, governments have set up national food safety initiatives accounting for all stages of the food chain with the overall aim of reducing foodborne disease. In the United Kingdom, the "Farm to Fork" approach has been introduced to examine food safety and standards *(61)* and enable the identification of the need for the implementation of preventative measures at key stages of the food production process from the agricultural supply sector to the consumer *(20).* In the United States, the "From Farm to Table" initiative was set up in 1997 with the overall goal of reducing the incidence of foodborne illness to the greatest extent feasible *(162).* Similarly, in Australia, a "Paddock to Plate" approach has been launched to coordinate activities across the full spectrum of the food production process *(39).*

Multiple food safety responsibilities are required by consumers, because consumers not only purchase and receive products but also process and provide foods for themselves and for others *(39).* The implementation of proper food-handling practices can prevent cases of foodborne disease *(162),* and the way in which consumers handle food in the kitchen affects the risk of pathogen multiplication, cross-contamination to other products, and the destruction of pathogens by thorough cooking procedures. Foodborne pathogens such as *Salmonella* spp., *Campylobacter* spp., *Listeria* spp., and *E. coli* O157:H7 are associated with a range of raw foods that are regularly prepared in the domestic environment, and transmission of these pathogens within the household is therefore seen as inevitable *(92).* Raw food sold to the public may or may not be contaminated with pathogens; however, some foods, such as poultry and poultry products, are more likely to be contaminated than others *(78).* Numerous studies assessing *Campylobacter* and *Salmonella* contamination rates for poultry have determined that 7 to 48% of poultry is contaminated with *Salmonella* and 28 to 80% is contaminated with *Campylobacter (81, 131).* These figures illustrate the potential risk associated with the preparation of raw chicken in the domestic environment.

Studies detailing the food preparation and consumption patterns of U.K. consumers have found that at least 85% of the population prepare food in their homes at least once every day *(131).* Considering that 90 to 95% of the population have been reported to eat and purchase fresh meat *(64, 88),* the potential for contamination and subsequent infection is significant. Therefore, during the daily preparation of potentially contaminated foods in domestic kitchens, it is imperative that consumers apply hygiene procedures to achieve the reduction in the number of viable or-

ganisms to a level that no longer constitutes a threat to health *(85)*.

The importance of adequate consumer food-handling practices is widely acknowledged *(62, 71, 127, 148)*. A great deal of research has been carried out on manufacturing, processing, and distribution processes in the food industry. However, the consumer remains the least studied link in the food chain, and information available about the consumer has been considered to be largely anecdotal *(43)*. A considerable amount of food preparation and handling occurs in the domestic environment, so research and consumer education regarding the risk of unsafe food-handling practices is an essential element of the prevention of foodborne disease *(94)*.

Information about domestic food-handling practices comes from two main sources: analyses of food poisoning outbreaks and consumer-based research studies *(78)*. Internationally, numerous consumer-based research studies have been conducted to evaluate the food safety practices of consumers. Different approaches have been adopted, including questionnaires and interview surveys, focus group discussions, and observational studies. Epidemiological studies provide quantitative data regarding contributory unsafe food-handling practices that have resulted in cases of food poisoning. However, a retrospective analysis of food poisoning provides limited information about consumer food safety behavior. The accuracy and availability of data are limited because it is often difficult for people to recall exact food consumption details and handling practices that may have taken place some time before the illness was reported.

The purpose of consumer food safety studies is to ascertain how consumers handle food in their homes and to determine what consumers know about food safety and why some safe food-handling practices are or are not implemented. General food safety and hygiene knowledge has been determined by several investigators *(113, 151, 153, 159),* and other workers have sought to obtain an understanding and an awareness of specific food safety issues *(21, 55, 76, 121, 131, 169)*. Many studies have assessed consumers' self-reported practices *(7, 30, 53, 91, 113, 168),* whereas others have assessed actual food-handling behaviors *(15–17, 74–76, 80, 87, 131, 135, 138, 175, 176)*. Some studies have investigated general attitudes about aspects of food safety *(60, 64, 65, 91, 131),* and a few investigations have used the constructs of psychological theories to attempt to understand the relationships between knowledge, attitudes, intentions, and behaviors with regard to food safety practices *(76, 120)*. The overall aim of the majority of the studies reviewed in this paper was to provide information for the development of effective communication strategies to promote safe food handling *(7, 55, 131, 144, 164, 168)*.

The measurement of consumer knowledge, attitudes, and behaviors can provide a basis for the formulation of health promotion programs *(166)*. Foster and Kaferstein *(67)* have stated that only when existing attitudes and practices regarding food safety are known is it possible to plan effective strategies to encourage and strengthen desirable behaviors and discourage unsuitable ones. The use of social cognition models for health-related issues has enabled the identification of the relationship between attitudes, beliefs, and behaviors and behavioral change *(47)*.

The aim of the present review paper is to critically analyze 88 consumer food safety studies. The review will provide information regarding similarities and disparities between knowledge, attitudes, intentions, self-reported practices, and actual behaviors from studies on domestic food preparation. Following a detailed discussion of the social cognitive determinants influencing food safety behaviors in the domestic environment, areas in which information is lacking will be identified. Findings will be discussed in the context of government targets and strategies for reducing foodborne disease and the development of future consumer food safety initiatives. In addition, studies will be evaluated in terms of the research method implemented for data collection, the study size, the country of origin, and the year of study completion.

MATERIALS AND METHODS

An extensive search of previous literature was conducted to locate published and unpublished consumer food safety studies. Electronic searches of computerized library databases and the screening of reference lists from relevant research papers and reports facilitated the identification of many published studies. Internet browsers were used to search the World Wide Web, and responses from the Foodsafe listserv were used to obtain many unpublished international studies. Attendance at international food safety–related conferences and personal communication with experts in the field resulted in the acquisition of additional studies.

Consumer food safety studies were examined according to social cognitive components, observed behaviors, and food safety findings. The grouping of food safety issues and concepts provided a more complete picture of what food safety behaviors consumers perform and why they may do so. Although objective comparisons have been made between findings of different studies, it is important to make allowances for the interpretation of responses to survey questions in the context of the question type, the research method used, and cultural effects.

Inclusion and exclusion criteria for reviewed consumer food safety studies. Studies included in the present review evaluated consumers' knowledge, attitudes, intentions, self-reported practices, and actual hygiene behaviors relating specifically to food preparation in the domestic kitchen. Only studies that assessed individual consumers and targeted consumer groups were included for review. Persons classed as consumers included anyone who prepared food on a regular basis and was not a professional food handler. All research methods for data collection, such as surveys, interviews, focus groups, and actual observations, were included and analyzed for review purposes. Research has indicated that actual observed food preparation behaviors of trained food handlers from food service environments are safer than those of consumers *(80),* and therefore results of studies involving trained food industry workers were excluded to alleviate any bias of common findings and conclusions within the review. Additional studies that were excluded were those predominantly based on risk perceptions of other aspects of food safety, such as pesticide residues or bovine spongiform encephalopathy, as well as those evaluating hygiene behaviors in less developed countries.

TABLE 2. *Years in which consumer food safety studies were completed*

Years	No. (%) of studies completed (n = 88)
1975–1979	1 (1)
1980–1984	1 (1)
1985–1989	2 (2)
1990–1994	11 (13)
1995–1999	46 (52)
2000–2002	27 (31)

RESULTS AND DISCUSSION

Breakdown of consumer food safety studies. Over the past 26 years, at least 88 consumer food safety studies have been carried out. The earliest study obtained for this review was undertaken in the late 1970s, and the most recent was undertaken in 2002 (see Table 2). Few surveys were carried out during the 1980s, when, although safe food production was a priority, the importance of the consumer's role in the food production process was not so widely recognized. During the 1980s and the early 1990s, the international incidence of foodborne disease increased considerably, and a variety of media "food scares" brought food safety issues to the attention of the consumer. As a consequence of these factors, it was recognized that there was significant potential for foodborne disease to be acquired from the domestic kitchen. This realization prompted more interest in the consumer's role in the production of safe food. Consequently, many different organizations, research institutions, and government agencies investigated aspects of safe food preparation in the domestic environment. In the early 1990s, several studies and reports emphasized that very little was known about the knowledge, attitudes, and actions of consumers with regard to safe food-handling practices and microbial contamination *(2, 78)* and that there was a need for further research. From 1990 to 1999, more than 55 studies were completed, the majority (81%) of which were undertaken between 1995 and 1999. Since 2000, there have been an additional 26 studies completed. Reflecting the trend of increasing incidence of illness resulting from foodborne disease, there has been an increase in the collection of data detailing consumers' food preparation practices from all over the world. In addition to the studies reviewed, it is probable that during the past 25 years many more unpublished studies on the food-handling practices of consumers have been conducted.

TABLE 3. *Countries of origin where reviewed consumer safety studies were completed*

Countries of origin	No. (%) of studies completed (n = 88)
United Kingdom and Northern Ireland	42 (48)
United States	37 (42)
Canada	1 (1)
Southern Ireland	1 (1)
Italy	1 (1)
Australia	2 (2)
New Zealand	4 (5)

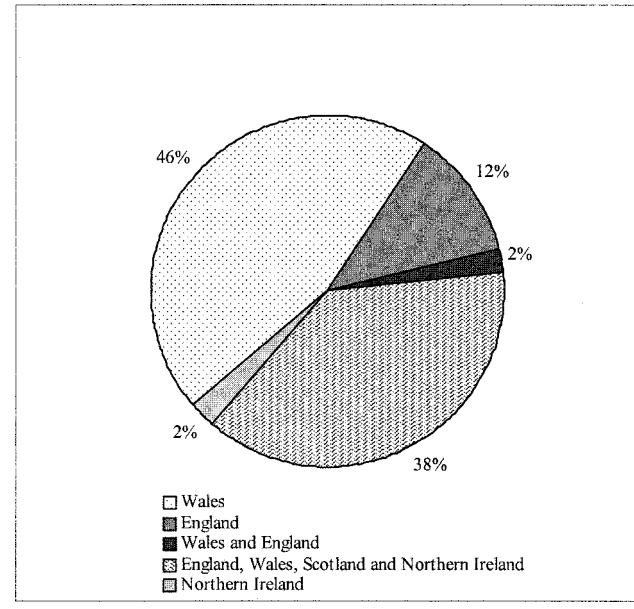

FIGURE 2. *Breakdown of consumer food safety studies completed in the United Kingdom and Northern Ireland* (n = *42).*

Origins of consumer food safety studies. Data presented in Table 3 show the origins of all of the reviewed consumer food safety studies. The majority of the studies collected for review were undertaken in the United Kingdom and Northern Ireland (48%). More than half of the studies reviewed were collected from the United States (42%), Australia and New Zealand (7%), Europe (2%), and Canada (1%). Of the studies completed in the United Kingdom and Northern Ireland, 19 (46%) involved Wales, 16 (38%) involved the whole United Kingdom and Northern Ireland, 1 (2%) involved Northern Ireland only, 1 (2%) involved England and Wales, and 5 (12%) involved England (see Fig. 2).

Research methods used for consumer food safety studies. Research methods used for data collection in the studies reviewed include self-completion questionnaires and interviews (collectively known as surveys), focus groups, and observational studies. Table 4 shows the pro-

TABLE 4. *Methods of data collection used in reviewed consumer food safety studies* (n = *88)*

Method of data collection	No. (%) of studies using method
Self-completion questionnaires	23 (26)
Postal	9 (11)
Self-administered	12 (14)
Online	2 (2)
Interviews	43 (49)
Telephone	19 (22)
Face-to-face	24 (27)
Focus group	7 (8)
Observation	15 (17)

portion of the studies in which each research method was used. Interviews were found to be the most common method for obtaining information on consumer food safety (used in 49% of the studies), followed by self-completion questionnaires (used in 26% of the studies). Focus groups were used in 8% of the studies, and the direct-observation technique was used in 17% of the studies.

Social surveys involve a quantitative method for collecting information from a population sample, usually by personal interviews or by self-completion questionnaires. Survey methods like interviews and questionnaires have been used for the assessment of participants' knowledge of food-handling practices, foods at risk for transmitting infection, and foodborne pathogens, for the determination of food safety perceptions, and for the measurement of psychological influences on food safety behaviors. Discrepancies between what is reported by participants and the actual behavior of these participants have previously been described *(42, 71, 87, 154).* Studies using questionnaires and interviews to assess hygiene behaviors have found evidence of a tendency for participants to overreport behaviors perceived to be "good" *(42, 109, 154).*

Focus groups, although more recently adopted, are relatively underused as a means for obtaining consumer food safety information. The focus group research method involves carefully planned group discussions designed to ascertain attitudes and perceptions regarding a defined area of interest *(101).* Focus groups are known to be particularly effective in providing information about why people think or feel the way they do, and group interaction provides more insight into why certain opinions are held *(100).*

Various methods, such as personal direct observation and observation through video recordings, have been used to collect information about consumers' actual food safety behaviors. Fifteen observational studies of consumer food safety practices were obtained for this review. Data were collected for 47% (7 of 15) of these studies by direct observation, whereby an observer openly watched participants prepare meals in home kitchens and concurrently recorded the steps used in the preparation of these meals. Forty three percent (3 of 7) of these direct-observation studies were conducted in South Wales *(120, 131, 176),* 43% (3 of 7) were conducted in the United States *(15–17),* and 14% (1 of 7) were conducted in England *(76).* Video camera recording has been used to observe consumers' food-handling practices in the United Kingdom, Australia, and the United States. The majority (67%) of widely reported observational studies have been undertaken by the Food Research and Consultancy Unit in Cardiff, South Wales, whereby closed-circuit TV has been used to observe consumers' food preparation practices in a model domestic kitchen. A number of studies have been carried out to determine the repeatability and reproducibility of consumers' food safety behaviors *(75, 135).* Quantification of food safety behaviors of a cross section of the population by using notational analysis and a risk-based assessment *(74, 75)* has been completed. Additional studies have evaluated food safety behaviors of targeted groups of individuals and have associated the actual microbiological isolation of *Campylobacter* and *Salmonella* with observed unsafe practices *(138).* Moreover, the relationship between actual observed behavior and psychological variables, such as knowledge, attitudes, beliefs, and intentions, has also been investigated in an attempt to understand why consumers implement some food safety behaviors and do not implement others. In a study undertaken in Australia *(87),* time lapse video was used to monitor food safety behaviors from single mounted cameras in home kitchens for periods of 1 or 2 weeks. In an American study *(14),* portable video cameras were used to record the practices involved in the preparation of one meal in participants' home kitchens.

Sample sizes used for consumer food safety studies ranged from 40 to more than 13 million respondents. Telephone interviews were used for the consumer food safety studies involving the largest numbers of consumers, with 100 to 13,221,007 respondents being reached. Face-to-face interviews were used to reach 84 to 10,172 respondents, postal questionnaires were used to reach 82 to 869 respondents, and self-administered questionnaires were used to reach 62 to 824 respondents. Focus group studies and observational studies involved far fewer participants than did survey studies, largely because the focus group and observation methods may be more time-consuming and expensive. Redmond and Griffith *(133)* have discussed the validity and reliability of research methods used for consumer food safety studies.

Content analysis of consumer food safety surveys. Different types of questions have been asked in interviews and questionnaires to obtain a better understanding of why individuals perform a variety of food safety behaviors. Questions to identify social cognitive factors (attitudes, intentions, and knowledge) affecting food safety behaviors have been included in a considerable proportion of surveys, as have questions about self-reported practices (Table 5). Cognitive factors determine whether or not an individual practices health behaviors, and these factors are relevant to aspects of health promotion, because they mediate the effects of other factors such as social and demographic variables in attempts to change health behaviors *(40).* In the majority of consumer food safety research studies, it is not possible to make direct observations of actual food preparation practices, so, as an alternative, questions are often asked of respondents to obtain self-reports of food-handling practices. Data from reviewed food safety surveys will be discussed in the context of food safety concerns, awareness, knowledge, attitudes, intentions, and self-reported practices.

A breakdown of the types of questions included in the surveys analyzed can be found in Table 5. A content analysis of the 66 food safety surveys (questionnaires and interviews) reviewed revealed that 13 (20%) surveys included only questions on self-reported practices. Only 1 (1%) survey was found to investigate only consumer attitudes, 2 (3%) surveys investigated only knowledge, and no surveys investigated only consumer intentions. Only 3 (5%) of the surveys reviewed assessed self-reported practices, attitudes, knowledge, and intentions. The majority of the surveys (41%) investigated self-reported practices along with atti-

TABLE 5. *Content of food safety surveys* (n = 66)[a]

Inclusion of cognitive component				No. (%) of survey studies including cognitive component combination
Self-reported practice	Attitude	Knowledge	Intention	
X	X	X	X	3 (5)
X	X	X		27 (41)
	X	X	X	1 (1)
X		X	X	3 (5)
X	X		X	0
X	X			2 (3)
		X	X	0
X			X	0
	X	X		1 (1)
X		X		13 (20)
	X		X	0
X				13 (20)
	X			1 (1)
		X		2 (3)
			X	0

[a] Self-reported practice questions were used in 61 survey studies (92%), attitude questions were used in 35 (53%), knowledge questions were used in 50 (76%), and intention questions were used in 7 (11%).

tudes and knowledge about food safety, 20% of the surveys examined self-reported practices along with knowledge, and 20% examined only self-reported practices. In the following discussion, food safety findings from consumer food safety survey studies are compared with those from focus group studies. Comparable and contrasting knowledge levels, attitudes, intentions, and self-reported practices are detailed.

Consumer knowledge, awareness, and understanding of food safety issues. Assessment of consumer knowledge featured in 75% of the surveys reviewed. Determination of knowledge is relatively straightforward, and information obtained in a survey is likely to accurately represent respondents' knowledge on the issue in question. Before a food safety education initiative is implemented, it is sometimes necessary to use a survey to determine consumers' baseline level of knowledge regarding behaviors targeted by the initiative to ensure that a suitable level of education is provided. Furthermore, determination of consumer knowledge has been used to evaluate the effectiveness of health promotion initiatives after they have been implemented *(107)*.

Research on health-related behaviors has suggested that individuals make rational decisions about such behaviors when they are aware of and have some knowledge about the associated health problems *(111)*. However, the acquisition of knowledge alone does not automatically produce the corresponding behavior, nor will it necessarily lead to appropriate changes in behavior *(1)*. Nevertheless, knowledge allows consumers to make informed choices regarding their actions, so the accuracy and extent of a person's knowledge can be of major significance.

It has been found that consumers have a high level of concern about food safety issues *(13)*. A survey from the United States found that 89% of consumers considered issues regarding food safety more important than issues regarding safe drinking water, crime prevention, health and nutrition, and the environment *(35)*. Similarly, Bruhn and Schultz *(30)* reported that more U.S. consumers were concerned about bacterial contamination of food than pesticide residues; mercury, aluminum, or lead contamination; or irradiated food. Levels of consumer concern about food safety have been thought to be largely incident driven *(36)*. Recent food poisoning outbreaks and coverage of food safety issues in the media have been reported to have improved public awareness about the consequences of consuming unsafe food *(24)*. However, despite media attention and concern expressed by consumers, it has been reported that many consumers still lack sufficient levels of awareness *(90)* of the practices required for safe food preparation.

The majority (80%) of consumers think themselves to be adequately informed regarding food safety, and they have been found to be aware of some safe food-handling practices while lacking knowledge of others *(30)*. Levels of consumer knowledge determined in food safety surveys have differed, although the majority of the survey studies reviewed concluded that consumer knowledge of food safety is inadequate and requires improvement. Inadequate knowledge may lead to implementation of common unsafe food preparation practices that contribute to foodborne disease *(96)*. Responses to survey questions about consumers' failure to implement appropriate food preparation behaviors have shown that 40% of consumers did not know or were not consciously aware that they were using unsafe practices *(17)*. Generally, consumers' knowledge has been found to be insufficient to ensure that food preparation in the home is performed so that the risk of illness is minimized *(88)*. Many surveys have identified gaps in or a lack of such knowledge *(7, 10, 13, 21, 24, 83, 88, 144, 169, 170)*. In addition, Beddows *(21)* found that practices necessary to prevent food poisoning appear to be largely unknown or misunderstood. Similarly, a more recent survey carried out by Albrecht *(7)* indicated that consumers did not clearly understand or implement safe food-handling practices. It has been found that knowledge of food safety practices does not always result in the correct implementation of food safety behaviors. Redmond *(131)* found that 73% of consumers surveyed in the United Kingdom reported practicing all of the food hygiene precautions they knew during food preparation, suggesting that more than a quarter of consumers do not always implement food safety practices that they reportedly know. Knowledge concerning key food-handling concepts such as cross-contamination, temperature control, causative agents, and contributory factors for foodborne disease has been investigated. A summary of findings regarding such knowledge is presented in Table 6.

Understanding of terms of reference. Surveys have shown that many consumers appear to lack a clear understanding of basic food safety terms *(53)*. The survey results presented in Table 6 show that misunderstandings of key

terms and concepts used in health promotion initiatives are prevalent among consumers. Such misunderstandings could nullify the impact of attempts to educate consumers. Survey results have shown that up to 75% of consumers lack familiarity with the term *cross-contamination* and principles associated with cross-contamination. However, such a term is frequently used in food safety education intervention materials, e.g., as part of the "Fight-Bac" campaign in the United States *(128)* and Foodlink activities in the United Kingdom *(66).* It is therefore possible that substantial proportions of consumers may not fully comprehend food safety education messages. It is suggested that food safety initiatives include explanations of terms to ensure that messages are effectively communicated.

Knowledge of pathogens. Consumer knowledge of pathogens was assessed in 12% of the surveys reviewed. As expected, survey questions containing the names of pathogens generated more responses indicating knowledge of those pathogens than did questions that did not mention pathogen names. For example, 79% unprompted consumers could name *Salmonella (58)*; however, when prompted, 80 to 97% of consumers indicated that they had heard of *Salmonella (8, 88, 110, 164).* Survey results also indicated that only <5 to 21% of consumers had heard of *Campylobacter (8, 88, 110).* One reason for consumers being more aware of *Salmonella* and *Listeria* (see Table 6) than of *Campylobacter* may be the sensationalized media food scares of the mid-1980s. It is disconcerting to realize that large proportions of consumers from the United Kingdom, the United States, and Australia still lack knowledge of *Campylobacter. Campylobacter* has been found to be responsible for the majority of cases of foodborne disease in England and Wales, the United States *(141),* and Australia *(38)* in recent years, and its minimum infective dose is also known to be lower than those of other pathogens. Moreover, experimental investigations have suggested that *Campylobacter* may have more potential to spread during consumer food handling than other pathogens do *(139),* thus increasing the potential risk of cross-contamination. It has been suggested that knowledge of the microbiology of foodborne pathogens may motivate consumers to use safe food storage, preparation, and cooking procedures *(8).* However, research detailing risk perceptions and willingness to change unsafe behaviors has indicated that consumers with an awareness of specific pathogens and food safety procedures are not any more willing to change their behavior than those lacking awareness *(111).*

Focus groups of mothers with young children and 60- to 75-year-old women commonly referred to all bacteria as "germs" *(136, 138).* These groups also acknowledged the invisible nature and inherent presence of bacteria; for example, one respondent commented, "you can't see them, but they are there" *(136).* Most U.S. consumers demonstrated an understanding that bacteria and improper handling of food are causes of foodborne illness *(55).* However, misconceptions about the nature of foodborne pathogens appear to persist; for example, one respondent commented, "that is where the germs are, in the air" *(138).*

Knowledge of hand-washing and -drying practices. The determination of knowledge about hand-washing practices has largely concentrated on the importance of hand washing in decreasing foodborne disease or the timing of hand washing during food preparation. As expected, the majority (75 to 100%) of respondents recognized that hand washing is a necessary food safety practice *(8, 24, 31, 76, 87, 102, 110).* Although data have suggested that consumers know the correct procedure for adequate hand washing and drying *(76),* study results have also indicated that nearly a fifth of the sampled population from the United Kingdom and the United States are unfamiliar with desirable hand-washing and -drying procedures (see Table 7). None of the consumer food safety surveys reviewed evaluated consumer knowledge of the specific procedures required for effective hand washing and drying during domestic food preparation. Although the drying process is deemed to be of critical importance in maximizing the reduction of transient and resident bacteria *(23, 115, 118),* consumers' knowledge of specific hand-drying procedures was not specifically determined in any of the reviewed consumer food safety surveys.

Knowledge of separation of raw and cooked foods during food preparation. The microbiological risks associated with the contamination of ready-to-eat (RTE) foods prepared with unclean utensils previously used for the preparation of raw meat and poultry are considered high or very high *(138).* A lack of knowledge of appropriate food safety practices to circumvent such risks could result in the contamination of cooked foods and potentially give rise to illness. As was the case for hand washing, many international surveys assessed this aspect of safe food handling, and the results were comparable. While surveys have sometimes reported that high percentages of people have such knowledge, large numbers of consumers (albeit small percentages) lack the appropriate knowledge. Indeed, it has been suggested that up to 36% of UK consumers and up to 22% of U.S. consumers do not recognize the importance of using separate or adequately cleaned utensils for the preparation of RTE foods after these utensils have been used in the preparation of raw meat and poultry (Table 7). Comparable data have also been obtained in New Zealand (see Table 7).

Knowledge of temperature control. Numerous microbiological surveys have found the presence of pathogenic bacteria in many foods consumed and prepared in consumers' homes on a daily basis. Pathogenic contamination of such foods indicates the need for consumer knowledge of adequate temperature control, including knowledge of heating practices, cooling principles, and refrigeration and freezing temperatures, to minimize the proliferation of any organisms present. Knowledge of adequate heating practices has been investigated in the United Kingdom, New Zealand, and the United States, whereas assessments of consumer knowledge of refrigeration temperatures have come predominantly from the United Kingdom. Data denoting consumer knowledge of cooling practices has been lacking in all surveys. Data presented in Table 7 il-

TABLE 6. *Comparison of levels of positive knowledge about common food safety issues for some of the reviewed consumer food safety surveys*

Food safety issue	Respondents' knowledge about food safety issue as demonstrated in:		
	UK and European surveys	U.S. and Canadian surveys	Australian and New Zealand surveys
Adequate cooking	20% knew what the temperature should be inside a piece of meat when it was well cooked *(175)* (UK survey)[a] 89% thought undercooking was a risk factor associated with food poisoning *(110)* (UK survey) 15% knew the temperature at which a beef burger was safe to eat *(76)* (UK survey)[a]	67% thought that cooking meat well decreased the risk of food poisoning *(8)* (Canadian survey) 74–92% knew that eating undercooked meat or chicken could cause food poisoning *(10, 31)* (Canadian survey, U.S. survey) 7% did not know about cooking to a proper temperature *(16)* (U.S. survey)	93% did not think that the best way to see if a roast chicken is cooked is to see that it is dark brown all over *(83)* (New Zealand survey)[a] 96% answered that it is important to check the inside of the chicken to ensure that it is fully cooked *(24)* (New Zealand survey)
Cooling principles	69% knew that keeping food at room temperature or contamination of food after cooking causes food poisoning *(110)* (UK survey)[a]	49% agreed that cooked food should be cooled at room temperature before refrigeration or freezing *(30)* (U.S. survey)	79% knew that foods cool more quickly when cooled in a shallow dish *(83)* (New Zealand survey) 90% knew that a casserole should be cool before being placed into the refrigerator for storage *(83)* (New Zealand survey)
Storage temperatures of foods	13% knew the correct temperature at which chilled foods should be kept *(153)* (UK survey) 7–11% knew the correct recommended refrigerator temperature *(46, 59)* (UK surveys) 37% knew that correct refrigerator temperature was 0–5°C *(58)* (UK survey) 50% knew the correct temperature for a refrigerator *(76)* (UK survey)[a]	56% knew the refrigerator should be kept below 40°F (5°C) *(7)* (U.S. survey) 60% of adults knew the ideal temperature settings for a refrigerator and a freezer *(49)* (U.S. survey) 75% knew that bacteria responsible for causing foodborne illness grow at room temperature *(113)* (U.S. survey)	32% did not know correct refrigeration temperature *(88)* (Australian survey)[a]
Separation of raw and cooked foods during storage	75% were unaware of potential risks associated with storing raw meat and poultry on upper shelves of refrigerators *(144)* (European survey)	69% thought that failing to keep foods separate during preparation and storage could cause food poisoning or foodborne illness *(31)* (Canadian survey) 79% knew how to avoid cross-contamination of RTE foods with juices from raw meat *(113)* (U.S. survey)	18% agreed that it was better to store raw food above cooked food in the refrigerator (32% did not know) *(83)* (New Zealand survey) 10% agreed that it was better to store cooked food above raw food in the refrigerator *(96)* (New Zealand survey)
Understanding of food safety terms and concepts	44% lacked understanding of the term *disinfectant,* 26% lacked understanding of the term *detergent,* and 22% lacked understanding of the term *sterilization (144)* (European survey)	75% reported understanding the concept of cross-contamination *(7)* (U.S. survey)	Unprompted, 49% knew of the meaning of the term *cross-contamination (88)* (Australian survey) 38% had overall high awareness of cross-contamination *(83)* (Australian survey)
Hand washing and drying	37% of adults thought that insufficient hand washing was hazardous *(116)* (UK survey) 95% thought that washing hands before preparing food was very important *(102)* (UK survey) When prompted, 80% thought poor hand washing was a risk factor associated with food poisoning *(110)* (UK survey)	86% knew that washing hands before preparing food decreases the risk of food poisoning *(8)* (U.S. survey) 75% knew that the most important thing they could do to keep food safe from germs was to wash their hands *(31)* (Canadian survey)	87–99% knew that hand washing should occur after visiting the toilet, patting a cat or dog, or smoking a cigarette *(24)* (New Zealand survey) 82% thought that is was important to wash hands before and after preparing food *(88)* (Australian survey)

TABLE 6. *Continued*

Food safety issue	Respondents' knowledge about food safety issue as demonstrated in: UK and European surveys	U.S. and Canadian surveys	Australian and New Zealand surveys
Hand washing and drying (cont)	When prompted, 100% knew when and how it was necessary to wash hands *(76)* (UK survey)	45% knew that improper hand washing could result in food poisoning *(10)* (U.S. survey) 79% could identify each of five instances in which hand washing was necessary *(16)* (U.S. survey)	82% recognized that washing hands before handling or preparing food was a vitally important food hygiene activity *(88)* (Australian survey)[a]
Separation of raw and cooked foods during food preparation	82% knew that allowing raw food to contaminate cooked foods was hazardous *(11)* (UK survey) 64% thought that it was very important to use separate chopping boards for raw meat and other foods *(164)* (UK survey) 77% thought that it was important to use a separate chopping board for raw meat *(102)* (UK survey) When prompted, 100% answered questions correctly about use of different utensils for raw and RTE foods *(76)* (UK survey)	80% knew that putting steak on a plate that held raw meat increased the risk of food poisoning *(8)* (U.S. survey) 84% knew that keeping different foods separated from each other to avoid cross-contamination was important to prevent food poisoning *(31)* (U.S. survey) 55% correctly answered questions about cross-contamination *(16)* (U.S. survey) 78% recognized that washing cutting boards after handling raw meats and then cutting raw vegetables could result in food poisoning *(10)* (U.S. survey)	38% were unaware of the need to use separate or clean utensils for the preparation of raw and cooked foods together *(83)* (New Zealand survey) 28% agreed that one knife is all that is needed to cut up raw and cooked ingredients, as long as it is wiped with a clean damp cloth *(96)* (New Zealand survey) 97% respondents indicated that it is unsafe to use the same unwashed knife or chopping board to cut uncooked chicken and prepare a salad *(24)* (New Zealand survey)
Pathogens	When prompted, 95% knew of *Salmonella,* 92% knew of *Listeria,* and 21% knew of *Campylobacter* as causes of food poisoning *(110)* (UK survey) Unprompted, 79–97% could name *Salmonella*; <3–10% could name *Campylobacter (51, 58)* (UK surveys)	75% knew *Salmonella* was associated with raw poultry and eggs *(168)* (U.S. survey) 78% had heard of *Salmonella,* 9% had heard of *Campylobacter,* 30% had heard of *E. coli,* and 21% had heard of *Listeria (111)* (U.S. survey) 80% claimed to have heard of *Salmonella,* and <5% claimed to have heard of *C. jejuni* or *E. coli (8)* (U.S. survey)	96% had heard of *Salmonella,* 32% had heard of *Listeria,* 52% had heard of *E. coli,* and 8% had heard of *Campylobacter (88)* (Australian survey)
Foods likely to be contaminated with pathogenic bacteria	73% thought poultry was a food that might constitute a food poisoning risk *(51)* (UK survey) 60% recognized that soft or raw eggs were a possible danger to public health *(164)* (UK survey) 91% recognized poultry, 21% recognized beef, and 70% recognized meat pies and pasties as common sources of food poisoning *(110)* (UK survey)	88% thought that a rare hamburger was a high-risk food *(130)* (U.S. survey) 88% recognized that raw eggs could be a potential health risk *(7)* (U.S. survey) 56% considered poultry a high-risk food *(170)* (U.S. survey) 65% thought that meat and poultry had the greatest potential to cause food poisoning illness *(12)* (U.S. survey)	No data available

[a] Published study reported lack of knowledge.

lustrate that large proportions of consumers lack knowledge about adequate refrigeration temperatures. Surveys have indicated that up to 93% of consumers do not know that the correct refrigeration temperature is 0 to 5°C. Such knowledge is more widespread in the United States, with survey results indicating that 46 to 60% of consumers do not know the ideal refrigeration temperature. Survey findings detailing consumers' refrigerator temperatures correspond with the lack of knowledge described above. Results have shown that large proportions (up to 70%) of consumers' refrigerators exceed the recommended temperatures *(44, 90, 163),* giving rise to conditions that encourage the proliferation of

TABLE 7. *Estimated proportions of UK and U.S. populations lacking knowledge of key food safety practices*

Food safety issue	Country	% of population lacking knowledge of food safety issue	Projected no. of people in population who do not know safe food safety practices[a]
Hand-washing and drying	United Kingdom	15–20	8,963,355–11,951,140
	United States	14–21	40,115,685–60,173,528
Separation of raw and cooked meats during food preparation	United Kingdom	0–36	0–21,512,052
	United States	20–22	57,308,122–63,038,934
Refrigeration temperatures	United Kingdom	50–93	29,877,850–55,572,801
	United States	40–56	114,616,244–160,462,742
Correct heating temperature	United Kingdom	80–85	47,804,345–50,792,345
	United States	80–93	229,232,489–266,482,769

[a] Based on calculations involving population figures for the United Kingdom *(122)* and the United States *(160)* and data from Table 6.

bacterial cells to potentially dangerous levels and increasing the risk of illness.

Undercooking has been acknowledged by 89% of UK consumers to be a risk factor associated with foodborne disease *(110),* and data from the United States have shown that 67 to 74% of consumers think that the thorough cooking of meat decreases the risk of food poisoning. However, it has also been reported that 15 to 20% of consumers do not know what the temperature should be inside a piece of meat for the meat to be considered safe to eat. Consumer knowledge of how to determine heating adequacy has been evaluated by several studies. It has been found that 93 to 96% of consumers recognize that it is important to check the inside of a chicken to ensure that it is fully cooked. However, 88% of consumers think that a subjective measurement is acceptable to determine the end of the cooking process *(21).*

Consumer knowledge of cooling principles has not been widely studied. However, the few results obtained have indicated that many consumers are unaware of the food hazards associated with inadequate cooling practices. Study findings have shown that 31% of consumers do not know that storage of food at room temperature may cause food poisoning *(110)*; nevertheless, it has been reported that 79% of consumers know that foods cool more quickly in a shallow dish *(83).*

Attitudes. The determination of consumer attitudes contributes to understanding actual behaviors. Attitudes are thought (both commonly and in the field of social psychology) to be causally related to behavior *(149).* A number of definitions of *attitude* exist, and each has been discussed and challenged by social psychologists. One definition put forward is as follows: "an attitude is a learned predisposition to think, feel and act in a particular way towards a given object or class of objects" *(47).* Components of an attitude include a belief about an object, behavior, or behavioral outcome and an evaluative element that involves an appraisal of that belief in terms of its value to an individual *(22).* Attitude determination has been used in psychological models to attempt to predict behavior. The association between attitudes and behavior has been discussed by numerous social psychologists *(5).* Although some researchers have found that attitudes can influence behavior directly *(143),* other workers have found no positive correlations between attitudes and behavior *(167).* Attitudes are viewed as being central to health promotion *(47),* as they affect responses and thus the potential effectiveness of initiatives.

It has been proposed that attitudes are affected by beliefs and values *(47)*; for the purposes of this review, these psychological constructs are grouped together and referred to collectively as *attitudes.* Attitudinal questions were included in just over half (53%) of the food safety surveys reviewed. However, a large proportion of these surveys (>44%) included only one or two questions relating to attitudes. Such questions usually concerned beliefs about causes of food poisoning, beliefs about favorable providers of information, perceptions of risky foods, beliefs about responsibility, and levels of concern about various aspects of food safety. Very few survey studies actually involved detailed investigations of the role of cognitive elements that may influence important food safety behaviors and specific practices.

Perception of the home as an important point of origin of food poisoning. Consumers' failure to associate home food-handling practices with foodborne illnesses is considered a serious impediment to convincing consumers to change inappropriate food-handling behaviors *(53).* Overall, most consumers surveyed in reviewed investigations perceived their homes and the homes of friends and family to be locations at which the acquisition of food poisoning was improbable; for example, only 9 to 23% of British, U.S., and Canadian consumers were found to perceive their homes as likely places in which to acquire food poisoning (see Table 8). Such data do not concur with the perceptions of Australian consumers, as Jay et al. *(88)* found that 77% of Australian respondents thought the home was a likely place to acquire food poisoning. Nevertheless, more Australian consumers, like U.S. and UK consumers, perceived takeaway vans, bars, and restaurants as locations at which one would be more likely to get food poisoning *(110, 131).* U.S. consumers also perceive a greater likelihood of food safety problems occurring in manufacturing facilities or in restaurants. Results concerning such attitudes

TABLE 8. *Perception of the home as an important location for food poisoning*

Country	Consumer food safety survey findings
Quantitative findings	
Australia	77% of respondents thought the home was a likely place to acquire food poisoning *(88)*
Canada	16% of consumers believed that food safety problems were most likely to occur in the home *(31)*
United Kingdom	11% of consumers regarded the home as a likely source of food poisoning *(116)* 9% of respondents regarded the home as a likely source of food poisoning; 61% perceived the home environment as having the potential to bring about food poisoning; 20% thought that food poisoning rarely, if ever, occurred in the home *(110)* 35% of consumers ranked the home as a likely location to get food poisoning *(131)*
United States	16% of consumers thought the home was the most likely place for the mishandling of food *(168)* 17% of consumers attributed foodborne illness to food prepared at home *(53)* 23% of consumers considered foods eaten at home to pose a lower risk of foodborne illness than those eaten away from home *(170)* No consumers thought that the home was where food safety problems were most likely to occur; 57% believed food poisoning to be common or very common from foods prepared at home *(14)*
Qualitative findings	
United Kingdom	"You'd like to think you wouldn't get it [foodborne disease] in your own home" *(138)* "I would not think of my kitchen as being unsafe" *(136)* "I think that it [the risk of foodborne disease] is higher away from home" *(136)* "I think [foodborne disease is more prevalent] in establishments not necessarily in our own homes" *(138)*

appear to be consistent across all international surveys reviewed, and despite increased media and educational attention, the perception of the home as a location at which one is unlikely to get food poisoning appears to have changed little over the past 15 years.

Findings concerning consumers' perceptions of food poisoning risk from focus group studies (qualitative data) are comparable to findings from consumer food safety surveys (quantitative data). More concern was expressed about acquiring foodborne illness from locations away from the home, because the members of the focus groups perceived themselves to have more control at home *(55, 136, 138).*

Perceptions of risk, control, and responsibility. Bruhn *(29)* has suggested that the incidence of food poisoning and the frequency of serious consequences are underestimated by consumers. This underestimation of personal risk posed by food poisoning may prevent consumers from taking appropriate steps to reduce their exposure to food-related hazards *(68, 144).* A large proportion (90%) of UK consumers perceive that there is a very low risk of getting food poisoning from food they have prepared themselves *(131),* and this finding supports results obtained by Frewer et al. *(68)* indicating that consumers associate the lowest personal risk of food poisoning with home-produced food. Consumers have also been reported to perceive a higher risk of food poisoning when food is prepared by others, as opposed to themselves (see Table 9). Such findings have been discussed within the framework of "optimistic bias" *(68, 131).*

Consumer perceptions of control were studied in only two of the attitudinal surveys reviewed *(110, 131).* Results presented in Table 9 indicate that 66 to 88% of consumers perceive themselves to have control over their own food safety. Perceptions of personal control have been evaluated, and results have indicated that consumers perceive themselves to have more control over their own food safety than others do, thus indicating judgments of optimistic bias *(132).*

Consumers are considered to be responsible for proper food-handling practices when preparing food in the home *(7).* However, it has been reported that consumers are frequently unaware of their role in the prevention of foodborne disease *(146).* The majority of consumers fail to recognize the significant risks and mechanisms of bacterial growth and contamination associated with foodborne disease *(94, 146).* Numerous studies in the United Kingdom, the United States, Canada, Australia, and New Zealand have investigated consumer perceptions of responsibility for safe food preparation. In the late 1970s, Jones and Weimer *(91)* found that most consumers underrated their individual responsibility for hygienic food preparation and relied on government inspection for the prevention of bacterial contamination of raw meat and poultry. Nearly 3 decades later, data suggest that many consumers remain unaware that food safety problems are likely to occur in their homes, believing that the responsibility for food safety lies instead with food manufacturers or restaurants *(176).* Even though recent surveys have indicated that large proportions of consumers believe that food manufacturers are ultimately responsible for food safety, other studies have suggested that consumers are beginning to recognize their own responsibility for providing safe food (see Table 9). Elderly women and mothers with young children in the United Kingdom expressed an acceptance of personal responsibility for hygienic food

TABLE 9. *Consumer perceptions of risk, control, and responsibility*

Personal risk	Risk of others	Personal control	Control of others	Personal responsibility	Responsibility of others
90% of consumers perceived the risk of illness from food they prepared themselves to be very low *(131)*	42% of consumers perceived other people's risk of experiencing food poisoning from food they prepared themselves to be very low *(131)*	66% of consumers thought that they had full or nearly full control of their food safety when they prepared food themselves *(131)*	58% of consumers thought that other people had total or nearly total control of their food safety when they prepared food themselves *(131)*	84% of consumers stated that they had total or nearly total responsibility for their own food safety *(131)*	68% of consumers agreed that food manufacturers were ultimately responsible for the safety of their foods *(131)*
Personal perception of risk related to food safety issues was low *(144)*		88% of consumers felt that they had control over food hygiene *(110)*		23% of consumers thought that they had the greatest responsibility to ensure that the food eaten at home was safe *(31)*	40% of consumers thought food suppliers, retailers, and the government had the greatest responsibility to ensure that the food eaten at home was safe *(31)*

preparation in their homes. For example, a respondent commented, "when it [food] is in the house, it's all down to you" *(136)*. Nevertheless, Canadian data have revealed that people are divided in their views regarding who is responsible for food safety in the home *(31)*. Similarly, UK consumers have indicated a common expectation that the government, retailers, and farmers should all share in the responsibility for safe food production *(138)*.

Attitudes toward hand washing and drying. Data reviewed denoting attitudes toward hand washing during domestic food preparation have been collected mainly in the United Kingdom. Attitudes toward the importance of hand decontamination can be found in Table 10.

Overall, attitudes toward hand washing and drying after handling raw meat and poultry were found to be predominantly positive. For example, 95 to 100% of consumers believed hand washing and drying after handling raw meat and poultry to be important and that there was a strong likelihood that the implementation of this procedure would prevent incidents of food poisoning. However, attitudes toward hand washing and drying before handling RTE foods were less positive. It was found that 55 to 80% of consumers considered hand washing and drying before handling RTE foods to be important, and just over half of a sampled population thought that there was a strong likelihood that the implementation of this procedure would prevent incidents of food poisoning. Such findings suggest that substantial numbers of consumers misperceive the extent of the need for the implementation of hand-washing and -drying procedures when handling RTE foods. Relatively small

TABLE 10. *Attitudes toward hand washing and drying*

	Attitudes toward hand washing and drying:	
Food safety issue	After handling raw meat or poultry	Before handling RTE foods
Prevention of food poisoning	95% of consumers believed that washing and drying hands after handling raw foods was very likely to prevent food poisoning *(76)*	55% of consumers believed that washing and drying hands before handling RTE foods was very likely to prevent food poisoning *(76)*
Importance of hand washing and drying	100% of consumers thought that washing and drying hands after handling raw food was very important *(76)* 95% of consumers thought that hand washing was important after handling raw chicken *(131)*	55% of consumers thought that washing and drying hands before handling RTE foods was very important *(76)* 80% of consumers thought that hand washing was important before handling cooked foods *(131)*
Component actions of hand washing and drying	95% of consumers agreed that the use of hot soapy water was necessary for hand washing *(110)*	
Hand washing as it relates to food poisoning	37% of consumers believed that insufficient hand washing resulted in cases of food poisoning *(116)* 29–43% of consumers believed that poor personal hygiene practices such as the failure to wash and dry hands adequately were a main cause of food poisoning in the home *(46, 56, 57, 59)*	

proportions of consumers believed that the failure of food preparers to wash and dry their hands adequately is a major cause of food poisoning. Such findings reiterate the need for consumer food safety education regarding the microbiological risks associated with handling RTE foods with unwashed or undried hands. Improved consumer perceptions regarding the need and timing of adequate hand washing and drying may increase the implementation of the procedure and ultimately help to decrease the risk of foodborne disease.

Qualitative data obtained from focus groups have indicated a widespread unprompted understanding of the need for hand washing and drying during food preparation for "hygiene reasons" *(138),* yet it was notable that inaccurate perceptions of correct hand-washing and -drying procedures were common. The majority of the 60- to 75-year-old women and the mothers with young children were insistent that hand washing and drying was a vitally important procedure and that they implemented this procedure effectively before, during, and after food preparation. However, thorough descriptions of hand-washing and -drying procedures were perceived to be "too time consuming" *(136, 138).* Qualitative findings regarding the need for the use of soap for adequate hand washing did not correspond with the quantitative findings of Mathias *(110),* which indicated that the majority of consumers have a positive attitude about the use of soap for hand washing during food preparation. Additional research is required to investigate specific attitudes toward component actions of the hand-washing and -drying process during domestic food preparation.

Attitudes toward food safety practices for the preparation of raw and cooked foods. Generally, attitudes toward safe food-handling practices regarding the use of utensils for the preparation of RTE and cooked foods were positive. It was found that 81 to 90% of consumers agreed that it is better to use different chopping boards for the preparation of raw and cooked meats *(75, 110, 131).* Similarly, 90% of consumers believe that the use of different utensils or washed utensils for the preparation of raw and RTE foods will help to prevent food poisoning *(76).* In addition, 100% of consumers have stated that they think the use of different utensils and/or washed utensils for the preparation of raw and RTE foods is important *(76).* The safety of the use of wood chopping boards relative to that of the use of plastic chopping boards has previously been discussed *(6),* and research has shown that consumers have differing attitudes toward the use of different types of chopping boards; however, there appears to be a preference for the use of plastic boards *(138).*

Focus group study findings indicate that the unprompted understanding of the need for the use of separate and/or adequately cleaned utensils for the preparation of raw chicken and RTE foods was prevalent. For example, one respondent stated, "I've got a meat knife and a vegetable knife" *(136).* However, many respondents considered the rinsing of chopping boards and/or knives after they have been used for raw chicken and before they are used for RTE foods to be an acceptable food safety procedure. For example, respondents stated, "I always wipe over the board . . . between preparing things," and "I just swill everything" *(136),* and "I don't use soap, just under hot water" *(138).* As was the case for hand washing, respondents perceived themselves to be implementing adequate food safety procedures and appeared to realize the importance and the need for the implementation of such procedures; however, the same respondents also unknowingly reported unsafe practices that may present a potential risk of cross-contamination during domestic food preparation.

Attitudes toward temperature control. Attitude areas investigated regarding temperature control can be classified into three categories: heating, cooling, and storage of foods at room temperature. Consumer attitudes toward cooking practices in the domestic kitchen have been identified in few consumer food safety surveys. Recent findings have revealed that the majority of consumers have positive attitudes toward adequately cooked foods. Even though low proportions (12 to 14%) of consumers have been found to have negative attitudes, there is significant cause for concern, especially when such proportions of consumers may represent people making food-handling errors.

Several U.S. studies have presented results of group discussions regarding the use of thermometers for assessing heating adequacy *(32, 55, 99).* Findings have suggested that some groups of consumers are more likely than others to use thermometers to assess heating adequacy upon learning that color is not always a good indicator of heating efficacy *(55).* Qualitative findings for focus groups regarding attitudes about heating adequacy and perceptions of adequately cooked food can be found in Table 11. Consumers indicated positive attitudes toward determination of the end of the cooking process; indeed, several U.S. consumers perceived that meat was safe when it was overcooked *(99).* Such findings concur with those from surveys conducted in the United Kingdom, where consumer responses indicated an understanding of the purpose of and the need for adequate cooking. Most U.S. and UK consumers perceived that cooking kills the microorganisms in raw meat and poultry. Despite this perception, discussions about actual practices revealed that some respondents unknowingly follow improper handling practices when cooking at home *(55).* For example, respondents indicated inaccurate objective means for determining the end of the cooking process.

The evaluation of attitudes toward cooling practices and the storage of foods at room temperature were researched (with surveys) by only two workers from the United Kingdom (see Table 12). It was found that 14 to 28% of consumers had negative attitudes toward the storage of foods at room temperature, and up to 84% of consumers held negative attitudes toward adequate cooling practices, thus indicating that there is confusion among consumers as to what actually constitutes acceptable and safe cooling practices.

Behavioral intentions. Behavioral intentions can be regarded as being derived from two parallel cognitive processes: the first process involves consideration of the indi-

TABLE 11. *Consumer perceptions toward adequate cooking of food*

Type of findings	Consumer perceptions according to UK and U.S. study findings
Quantitative[a]	86% of consumers agreed that proper cooking of food prevents food poisoning *(110)* (UK study) 88% of consumers perceived a rare hamburger to pose a high risk of food poisoning *(130)* (U.S. study) 87% of consumers did not believe that it was all right to eat food if the outside looked well cooked *(131)* (UK study)
Qualitative	"I think all meat is safe if it is cooked properly" *(138)* (UK study) "When it's cooked all the way, it's done" *(99)* (U.S. study) "If I grill meat, I grill it well; I always cook it, overcook it" *(138)* (UK study) "I think you should overcook it . . . if you do overcook it, you do get rid of all the germs" *(138)* (UK study) "it's got to be cooked right through . . . you can't have any raw . . . make sure the meat is cooked right through to the inside" *(138)* (UK study) "the smell tells you it is close to being done" *(99)* (U.S. study) ". . . wiggling the leg, if it's loose, it's done" *(99)* (U.S. study)

[a] In quantitative studies, 12 to 14% of consumers were found to have negative attitudes (i.e., attitudes opposing acceptable or safe food preparation concepts).

vidual's own attitudes toward the behavior in question, and the second process involves consideration of social norms *(123)*. Intentions are an integral part of a variety of social cognition models such as the Theory of Reasoned Action (TRA) *(4),* the Theory of Planned Behavior (TPB) *(3),* and the Health Action Process Approach (HAPA) *(147)*. The TPB (a model derived from the TRA) postulates that behavior is planned and that planning is part of the function of an individual's intention *(129)*. Intention has been identified as the most immediate determinant of behavior *(54)*. For the HAPA, self-efficacy and outcome expectancies are the major predictors of intention *(123)* in what is known as the motivational phase of the approach, a phase which precedes an action phase. Research studies have determined that intention is not always directly translated into behavior *(150)*. A positive intention to wash one's hands adequately may not be translated into behavior because of a lack of soap, an overriding attitude that soap is not needed for hand washing, or external events that interrupt the behavior. In the United Kingdom, consumers were targeted on the basis of the motivational phase of the HAPA for an observational study; responses to questions on risk perceptions, outcome expectancies, and perceived self-efficacy were used as the basis for identifying the target consumers. Although such cognitive elements can lead to positive intentions to perform specific food safety procedures *(147),* the observed food-handling practices of the participants did not correspond to these positive intentions *(138)*.

Consumer intentions toward food-handling practices have been considerably understudied. Questions based on intentions to perform food safety procedures were included in only 11% of the surveys reviewed here. Only two studies reviewed here *(76, 120)* involved the use of social cognition models such as the TRA and the TPB to attempt to understand and explain the factors influencing food-handling behaviors. Both of these studies were undertaken in South Wales. In these studies, although the TPB was found not to significantly predict food-handling behaviors of adults, significant correlations between cognitive elements of the TPB and behavioral intentions were determined *(76)*. These results indicate that the TPB is useful for predicting food handlers' intentions to carry out food safety procedures from other cognitive components *(76)*. However, when Mullan *(120)* applied the TRA to food-handling behaviors and cognitive elements for children and young adults, a significant relationship between behavioral intention and actual observed food safety behaviors was determined.

Responses to consumer food safety surveys indicated that 100% of consumers intended to wash and dry their hands after the next time they handled raw food. Similarly, 90% of consumers indicated that they were "extremely likely" or "likely" to wash and dry their hands before han-

TABLE 12. *Consumer perceptions toward cooling and storage of foods at room temperature*

Food safety issue	Consumer perceptions according to UK study findings	% of consumers with negative attitudes[a]
Cooling	48–52% of consumers agreed that there is a need to cool hot food quickly after cooking *(110, 131)* 84% of consumers agreed that it is acceptable to cool foods at room temperature *(131)*	48–84
Storage at room temperature	84% of consumers agreed that it is unacceptable to store cooked meats at room temperature *(131)* 72% of consumers had the attitude that storing food at room temperature was not difficult to avoid *(110)*	14–28

[a] Negative attitudes are attitudes opposing acceptable or safe food preparation concepts.

TABLE 13. *Prevalences of self-reported unsafe food consumption practices according to U.S. consumer food safety surveys undertaken from 1977 to 2000*

Year(s)[a]	Prevalence(s) of consumption of ordering, preparation, and serving of undercooked hamburger patties	Prevalence(s) of consumption of raw, uncooked, or runny eggs or egg products
1977	15% *(91)*	No data available
1986	23% *(130)*	No data available
1994–1995	19% *(111)*, 23% *(97)*	50% *(97)*
1997–1998	4% *(159)*, 5% *(130)*, 6% *(124)*, 20% *(177)*	13% *(159)*, 50% *(177)*
1999–2000	9% *(178)*, 14% *(86)*, 17% *(113)*, 20% *(9)*, 30% *(151)*	18% *(151)*, 19% *(113)*, 48% *(86)*, 50% *(9)*, 56% *(178)*

[a] No data are available for 1987 to 1985, 1987 to 1993, or 1996.

dling RTE foods *(76)*. The same study found that most consumers intended to use separate or washed utensils the next time they prepared raw and cooked foods and were ''extremely likely'' or ''likely'' to clean all food preparation surfaces between the preparation of raw foods and the preparation of RTE foods *(76)*. Such data may indicate that consumers have knowledge of correct and important food preparation practices, but as is the case for self-reported practices, responses may be subject to social desirability bias (defined below).

Self-reported practices. The majority (96%) of interviews and questionnaires reviewed here included questions about self-reported practices. Self-reported practices are personal accounts of one's actions and may or may not reflect actual behaviors. Data from self-report questions may provide valid information on awareness or indirect knowledge about ''correct'' behaviors rather than precise information on actual behaviors and thus may not provide an accurate representation of what actually constitutes a respondent's true behavior. Social scientists have suggested that a respondent may claim to carry out the perceived ''correct'' behaviors as opposed to behaviors perceived to be undesirable in order to convey a positive image *(27)*. This concept is known as *social desirability bias* and is reported to occur more frequently with questionnaires and telephone interviews than with face-to-face interviews *(126)*. An evaluation of such data could result in misleading findings *(42)*. Several of the survey studies reviewed here acknowledged the limitations with regard to the interpretation of self-reported data *(9, 177)*. Self-reports of behavior are sometimes collected to aid in the evaluation of health promotion initiatives. A self-reported behavioral change may be a change that a respondent only perceives to have made or reports in order to convey a positive image *(95)*.

Responses to self-reported behavior questions in several survey studies have suggested that reported unsafe practices and misunderstandings about safe food-handling practices exist with respect to all factors that are known to contribute to food poisoning. An overall assessment of interview responses from a U.S. survey indicated that 98% of food preparers reported at least one unsafe practice *(169)*. In a more recent survey, carried out by Altekruse et al. *(8)*, unsafe food hygiene practices were reported by one third of the respondents. It was apparent that questions regarding hand washing and the use of separate or washed utensils for the preparation of raw and cooked foods during food preparation were the issues investigated most frequently. There were notable differences in reports of safe and unsafe practices for different food safety issues.

Reported consumption of foods with the potential to cause foodborne disease. At least 25% of the reviewed consumer food safety surveys determined the prevalence of food consumption practices that may cause foodborne disease. Indeed, several surveys have been devoted solely to this topic. The majority of the data regarding the prevalence of unsafe consumption of foods were obtained in the United States and pertain to undercooked hamburgers and raw and undercooked eggs. A substantial level of media attention has been devoted to the microbiological hazards of both of these foods because of outbreaks of foodborne disease due to *E. coli* O157:H7 and *Salmonella*. Cases of illness caused by *Salmonella* Enteritidis have frequently been attributed to the consumption of raw or lightly cooked eggs *(82)* and in the United States, outbreaks of disease caused by *E. coli* O157:H7 have been attributed to the consumption of undercooked hamburgers *(33, 34)*.

A summary of proportions of consumers who reported consuming various unsafe foods is presented in Table 13. Overall, large proportions of consumers reported eating raw foods of animal origin. Since 1977, the prevalence of the consumption of undercooked hamburgers has ranged from 4 to 30% of the sampled populations. However, some surveys undertaken since 1997 have indicated that <5% of consumers continue to report a preference for and the consumption of medium rare and rare hamburgers *(113, 159, 170)*, suggesting that a reduction in the consumption of undercooked hamburgers may have taken place. Since 1994, the prevalence of the consumption of undercooked or raw eggs has ranged from 5 to 56%. The levels of consumption of raw and undercooked eggs appear to have been consistent from the mid-1990s to the present, indicating that up to 50% of consumers may still consume raw and undercooked eggs. However, as with hamburgers, some survey studies have found as few as 5% *(113)* of consumers to report such consumption behavior. The results of a U.S. study *(145)* indicate that susceptible populations with an increased risk for foodborne disease continue to consume inadequately cooked runny eggs and pink beef burgers, which gives rise to concerns about foodborne disease.

As with other self-reported practices, it is possible that the prevalence of the consumption of unsafe foods may be higher than it has been reported to be because of the influ-

ence of social desirability bias on responses. Nevertheless, large proportions of respondents admitted to such practices, which, combined with the risk of the potential contamination of the raw foods, constitutes substantial cause for concern. Consumers may be fully informed and aware of the risks associated with eating raw or uncooked foods of animal origin but choose to continue with such behaviors. Consumers may continue to consume these foods because they believe that the risks are outweighed by their culinary experience or that they have sufficient knowledge to control the degree of risk *(97).* Alternatively, the continuation of such behaviors may be due to optimistic bias *(165),* whereby negative effects are relatively unlikely to happen to them *(69).*

Reported hand-washing and -drying practices. Self-reported hand-washing and -drying practices were investigated in 25% of the reviewed survey studies. Surveys indicated that "safe" hand-washing practices (a safe [adequate] hand-washing and -drying practice includes the use of hot water and soap or detergent for the lathering and rinsing process, followed by the use of a clean, unused hand towel or disposable paper towel for the drying process *(75)*) were reported more frequently than were "unsafe" practices. Data presenting safe practices indicate that 62 to 100% of consumers always or usually wash their hands after handling raw meat and poultry and that 87 to 92% of consumers always or usually wash their hands with soap and water before handling food (see Table 14). The purpose of most self-reported hand-washing survey questions appeared to be merely to ascertain whether or not respondents washed their hands. Study results show that perceptions of what constitutes safe hand-washing practices are inaccurate *(138),* so a consumer may think the correct hand-washing and -drying procedure is being carried out properly and therefore may honestly (yet inaccurately) report that that is the case. Specific actions, such as using soap, touching the tap before and after washing, and lathering the hands, and methods used for hand drying have not been widely studied in terms of consumer food safety. Reports of unsafe hand-washing practices show that 17 to 50% of consumers admit to failing to wash their hands after handling raw meat and chicken or before the preparation of a meal. Such findings do not correspond to reports of safe practices, with larger proportions of respondents reporting that they "always" or "usually" implement adequate hand-washing practices. This discrepancy highlights the limitations of self-reported findings of this nature.

In some surveys, the majority of respondents have reported that they use proper hand-washing techniques *(7),* but in other surveys, 50% of the respondents have reported that they do not consistently wash their hands when barbecuing *(11).* This finding suggests that for questions of a general nature, consumers may have a tendency to report favorable practices; however, when asked about food preparation in specific circumstances (e.g., at a barbecue), the results may be quite different and may offer a more accurate representation of the respondent's actual behavior.

Reported use of utensils and/or chopping boards during food preparation. Self-reported behaviors related to the cross-contamination of RTE foods by raw meat and poultry during food preparation have been reported in at least 46% of the survey studies reviewed. The majority of the data reviewed were collected in the United States and in the United Kingdom; however, valuable information has also been collected in Australia and New Zealand. Cross-contamination behaviors with regard to the use of kitchen utensils during the preparation of raw and cooked foods were determined on the basis of proportionate frequencies of reported "safe" and "unsafe" practices (see Table 14).

Although the majority of consumers reported implementing safe food-handling practices (see Table 14), substantial proportions of consumers also reported using unsafe practices. It was found that 30 to 71% of the respondents reported using the same utensil and/or chopping board or surface to prepare raw meats and other foods, and 10 to 41% of the respondents indicated that they are not likely to wash utensils between the preparation of raw foods and the preparation of cooked foods. Such data constitute cause for concern, because such practices allow numerous opportunities for cross-contamination to occur during domestic food preparation.

Data relating to safe and unsafe practices with regard to the use of utensils and/or chopping boards during food preparation illustrate further inaccuracies in self-reported behavior data. Although up to 85% of consumers stated that they use separate utensils and/or surfaces for the preparation of raw and cooked foods, up to 71% of consumers also stated that they use the same utensil for the preparation for raw and cooked foods. This finding shows that large proportions of sampled populations have reported favorable practices. However, reports to the contrary by up to 71% of a sampled population indicates that significant numbers of consumers may lack an awareness of correct practices and implement unsafe behaviors, increasing the potential risk of foodborne disease.

Reported temperature control. Self-reported heating practices were evaluated in at least 7% of the survey studies reviewed. The results of these studies indicate that most consumers fail to use a thermometer to determine end point temperatures to check the "doneness" of meat. In 1999, the American Dietetic Association and the Conagra Foundation *(10)* found that only 12% of consumers reported using a meat thermometer, and in 2000 only 24% of consumers reported regularly using a meat thermometer during the heating of meat and poultry *(11).* Beddows *(21)* found that the majority (83%) of consumers reported that they determine the end of the cooking process subjectively. Data from Ireland, England, and Wales also indicate that many consumers use subjective measures to ensure that meat and poultry are adequately heated. It was found that 85 to 92% of consumers reported that food that is cooked is "piping hot throughout" at the end of the heating period. Although the subjective assessment of doneness is not considered a good practice *(161),* another survey found that 81% of consumers tend to cook meat and poultry longer than recom-

mended *(121).* Nevertheless, research has shown that the assessment of meat color is not an effective method for accurately evaluating the doneness of meat and poultry products *(152).*

Self-reported cooling practices are one of the least studied aspects of consumer food safety in the surveys reviewed, featuring in at least 6% of these surveys. Most of the data regarding this subject appear to have been collected before 1995. However, the most recent findings, from 1999, indicate that 86% of Australian consumers cool leftover foods, e.g., casseroles or other foods containing meat, fish, or poultry, at room temperature *(88)*—a practice that is not considered safe *(52).* The ability of bacterial pathogens to multiply rapidly to dangerous levels in foods that are allowed to remain warm for an extended period is a frequently implicated cause of foodborne illness *(98).* Research conducted by Bradford et al. *(28)* demonstrates the ease with which transferred organisms can grow on RTE foodstuffs held at ambient temperatures, thus increasing the potential risk of foodborne illness.

Observed food safety behaviors. Observation is a method of data collection that is used to understand complex behavioral situations more accurately *(27, 108).* The direct observation of human and animal behavior is believed by social scientists to be superior to other methods of data collection. This belief stems from the assumption that data gathered through the direct observation of actions reflect those behaviors directly rather than through an intermediary means such as a questionnaire *(155).* It is difficult to directly compare observational results from different studies because data were collected and recorded by different methods, which may result in differences in findings. Nevertheless, an overall picture of consumers' actual food safety behaviors during food preparation in the domestic environment can be deduced, and areas in which unsafe handling actions require improvement can be identified.

Repeatability and reproducibility of consumer food preparation behaviors. To date, most of the information detailing actual consumer food safety behaviors has been based on the preparation of single meals. However, the consistency of consumer food safety practices has been determined in research carried out in South Wales *(75, 77, 131).* Consumer food safety behaviors were allocated risk scores according to the frequency and implementation of unsafe practices. The results of this research showed that there were no significant differences ($P < 0.05$) between mean risk scores for repeated food preparation sessions involving the same meal, indicating that consumer food safety behaviors can be habitual *(75, 131, 135).* Study results show that the food safety behaviors of some consumers are more consistent than those of others. Repeated meal preparation sessions presented as much overall food safety risk (from all observed food safety behaviors) as the initial food preparation sessions. The reproducibility of the generic behaviors observed in different meal preparation sessions showed that it was probable that procedures such as hand washing and drying would be implemented from one meal to the next. However, heating efficacy varied considerably between meals, possibly because of the use of different cooking methods *(75, 131).*

Observed hand-washing and -drying behaviors. The role of hands in the transmission of disease is well established *(48),* and the transmission of pathogens via contaminated hands is considered to be a major route of infection in cases of food poisoning. Hand washing (scrubbing and rinsing with soap and water) and hand drying have been shown to effectively remove contaminating microorganisms from hands and to reduce the spread of foodborne illness *(79, 114).* Hand-washing practices were observed in all of the reviewed observational studies carried out in the United Kingdom, the United States, and Australia, and all of the results of these studies suggest that hand-washing practices are in need of improvement. The hand-drying process is considered to be of critical importance in maximizing the reduction of transient and resident bacteria *(79, 115).* Research carried out in the United Kingdom has examined hand drying when determining consumer behavior with regard to the desirable decontamination of hands.

The results of observational studies (Table 15) show that consumers in Australia and the United States demonstrated better hand-washing practices than did consumers in the United Kingdom. This finding may be due to the fact that different aspects of hand washing and drying were recorded in different studies. In Australian and U.S. studies, the rinsing of hands and the use of soap were considered, whereas drying practices were included as part of the process for the adequate decontamination of hands in UK studies.

Griffith et al. *(74)* found that during 92 meal preparation sessions, adequate hand-washing and -drying procedures were required on 339 occasions. Attempts were made to decontaminate hands (or remove residue from hands) on 50% of these occasions, and 44% of these attempts consisted of rinses only. Adequate hand washing was only implemented on 6% of these occasions after handling raw meat or poultry *(74).*

The data presented in Table 15 show comparable results for hand-washing and -drying practices observed in consumers' homes and those observed in a model domestic environment. In the model domestic kitchen, consumers from different target groups (60- to 75-year-old people, mothers with young children, and single young men) all failed to implement adequate hand-washing and -drying practices *(138).* Another study showed that 100% of 60- to 75-year-old women failed to wash and dry their hands immediately and adequately on at least one occasion after handling raw chicken, and 28% failed to do so on more than six occasions *(134).*

It was found in a recent study that 34% of whole-chicken packaging is contaminated with *Campylobacter* and 11% is contaminated with *Salmonella (81).* Observations indicated that 66 to 83% of UK consumers failed to wash and dry their hands immediately and adequately after touching raw meat and poultry packaging, giving rise to a potential

TABLE 14. *Comparison of self-reported practices with regard to common food safety issues from some of the reviewed consumer food safety surveys undertaken in the United Kingdom, the United States, Australia, and New Zealand*

	Respondents' self-reported practices with regard to food safety issues in:		
Food safety issue	UK and European surveys	U.S. surveys	Australian and New Zealand surveys
Cooking	81% tended to cook meat or poultry longer than recommended *(121)* (UK survey) 88% assessed end of cooking subjectively *(21)* (UK survey) 85–92% always or usually ensured that food they cooked or heated up was piping hot throughout *(57, 59)* (UK survey, European survey)	28% considered a hamburger that is pink inside cooked *(124)* 12% always used a meat thermometer to check the doneness of meats *(10)* 76% did not regularly use a thermometer to measure the doneness of meat or poultry *(11)*	No data available
Cooling	35% reported leaving leftover cooked chicken at room temperature for 2–4 h *(21)* (UK survey) 29% who prepared meals in advance stored cooked meals on work surface and 22% stored food in saucepan *(110)* (UK survey)	Almost 50% incorrectly thought that cooked food should be cooled at room temperature before refrigerating or freezing *(30)* 45% inappropriately left foods at room temperature after heating *(7)* Leftover stew would be stored in a deep container by 54% of respondents; only 32% said they would store it in a shallow container *(168)* 65% said they would immediately refrigerate chicken after cooking; however, 29% would let the chicken sit on the counter until it reached room temperature and would then refrigerate it *(168)*	86% reported that they would cool leftover casserole or other food with meat, fish, or poultry at room temperature *(88)* (Australian survey)
Storage	48% stored raw meat or poultry on top or middle shelf; 12% stored raw foods or poultry wherever there was space in the refrigerator *(175)* (UK survey) 12% stated that they stored uncooked meat at the top of the refrigerator *(153)* (UK survey) 91% kept raw meat, fish, and poultry separate from other foods *(102)* (UK survey) 57–68% kept raw food below cooked food in the refrigerator *(46, 57, 59)* (two UK surveys, one European survey)	>20% reported placing meat, poultry, or fish on a refrigerator shelf above other foods *(105)*	41% said they stored meat on the top or middle shelves of the refrigerator *(88)* (Australian survey)
Hand washing			
Safe practices	87–92% always or usually washed their hands with soap and water before handling food *(46, 57, 59)* (two UK surveys, one European survey) 75% always washed and dried hands after handling raw foods *(76)* (UK survey)	66–76% said they washed their hands after handling raw meat or poultry *(8, 55)* 72–93% said they almost always washed their hands after handling raw meat or poultry *(124, 151)*	62% always washed their hands after handling raw meat or poultry *(117)* (New Zealand survey) 82% said they washed their hands with soap or detergent *(88)* (Australian survey)

TABLE 14. *Continued*

Food safety issue	Respondents' self-reported practices with regard to food safety issues in: UK and European surveys	U.S. surveys	Australian and New Zealand surveys
Hand washing (cont)			
Unsafe practices	26% of men and 17% of women said they did not always wash their hands before preparing food *(58)* (UK survey)	20% did not wash their hands with soap after handling raw meat or chicken *(177)* 19% reported not routinely washing their hands with soap after handling raw meat or chicken *(9)* 44% consistently forgot to wash their hands properly before meal preparation *(10)*	No data available
Cross-contamination			
Safe practices	59–76% always or usually used separate utensils and chopping boards for preparation of raw meat and cooked food *(46, 57, 59)* (two UK surveys, one European survey) 80% always used different utensils or wash utensils with raw and RTE foods *(75)* (UK survey)	67% stated that they washed or changed cutting boards after cutting up raw meat or poultry *(8)* 85–93% always washed the chopping board after cutting raw chicken *(124, 151)* 77–80% said they never used the same plate for raw and cooked meat *(11, 30)* 83% washed cutting boards used for cutting meat or poultry with soap and/or bleach before using the cutting board again *(55)*	No data available
Unsafe practices	30–56% used same chopping board for uncooked meat and for cooked meats *(21, 153, 175)* (UK surveys) 76% did not prepare raw and cooked foods in separate areas of the kitchen *(175)* (UK surveys) 41% were unlikely to wash utensils and chopping boards between preparation of raw food and cooked meat *(59)* (European survey)	51% said a surface used to cut uncooked meat and poultry would be also used to cut cooked meat *(7)* ~25% said they would use the cutting board after cutting raw meat or chicken without cleaning it *(97)* 19–20% reported not washing the cutting board with soap or bleach after using it to cut raw meat or chicken *(9, 177)* 10% always or sometimes used the same plate for raw and cooked meat or did not wash the plate before using it for cooked meat *(30)*	66–71% used the same chopping board or knife for raw meats and other foods *(117)* (New Zealand survey) 30% would perform an unsafe cross-contamination action when preparing raw meat and salad vegetables *(88)* (Australian survey)

risk of cross-contamination during domestic food preparation *(75, 131)*.

Observed actions presenting a risk of cross-contamination during the preparation of raw and cooked foods. Direct and indirect cross-contamination behaviors were observed during meal preparation sessions in studies conducted in the United Kingdom, the United States, and Australia. These observations indicated a substantial potential risk of the transfer of pathogenic bacteria from raw meat and poultry to RTE foods and kitchen surfaces, which could result in foodborne illness. Indeed, observational studies have revealed that direct and indirect cross-contamination behaviors were exhibited in the majority of consumer meal preparation sessions (see Table 15). In a UK study, unsafe food-handling practices were compared with actual pathogenic contamination of food products and kitchen surfaces. It was found that 17% of homemade chicken salads prepared in a model domestic environment tested positive for *Campylobacter (138).* All such salads had become contaminated by observed indirect contamination

TABLE 15. *Inadequate food-handling practices observed during consumer meal preparation sessions in the United Kingdom, the United States, and Australia*

Food handling practice	Observations for participants in: UK model domestic kitchen[a]	UK consumer home kitchens	U.S. consumer home kitchen	Australian consumer home kitchens
Cooking	3% failed to fry chicken pieces adequately *(138)* 15% did not cook foods to an internal temperature of 75°C *(175)*	0–3% failed to fry chicken pieces adequately *(138)* 50 and 83% undercooked homemade burgers and roast chickens, respectively *(75, 131)*	18–24% used internal cooking temperatures that were too low *(15–17)* 46 and 82% undercooked meatloaf and chicken, respectively; 95% did not use a meat thermometer *(14)*	No data available
Cooling	14% implemented all adequate cooling principles for rice and chicken korma *(131)*	100% failed to implement necessary actions for adequate cooling *(138)*	24–47% implemented improper cooling procedures for leftovers *(15–17)*	No data available
Storage	100% stored chicken korma and rice at room temperature after heating *(131)* 14% left chocolate mousse at room temperature for storage *(131)*	57% left cooked chicken salad at room temperature for storage *(138)*	44% stored leftover meatloaf in the original cooking container with lid or plastic covering *(14)*	No data available
Inadequate hand washing and drying	93–100% failed to wash and dry their hands immediately and adequately on at least one occasion while handling raw meat or poultry *(74–77, 131, 135, 136, 138, 175)*		29–57% neglected hand washing *(15–17)* 45% attempted to wash their hands before food preparation; of those who did, 84% used soap *(14)*	~75% failed to wash their hands or used an inadequate procedure for doing so (47% failed to wash their hands after handling raw meats; the 44% who washed their hands failed to use soap) *(87)*
Actions that increased cross-contamination potential during the preparation of raw meat or poultry and RTE foods	91% inadequately cleaned cutting board after use with raw ingredients *(175)* 67% failed to use separate or adequately washed and dried knife and/or chopping board for preparation of raw poultry and RTE foods *(131)* 83–90% did not use separate areas of the kitchen for preparation of raw and cooked foods *(75, 175)*	52% failed to use separate or washed and dried utensils for raw and RTE foods *(76)* 60% failed to wash and dry chopping board and/or knife for preparation of raw chicken and salad ingredients *(138)* 66–75% failed to wash and dry or use separate chopping boards and 23–61% failed to wash and dry or use separate knives for the preparation of raw meat or poultry and RTE foods *(75, 131)*	25–71% used improper cross-contamination procedures *(15–17)* 84% of cross-contamination actions observed involved transmission from potentially contaminated raw meat or eggs to RTE foods *(14)* 80% did not use separate areas of the kitchen for raw and RTE foods *(14)*	~35% failed to wash utensils between preparation of raw foods and that of other foods *(87)* ~30% failed to clean the preparation surface before preparing RTE foods *(87)*

[a] The model domestic kitchen is a test kitchen representative of a standard domestic environment (at the Food Research and Consultancy Unit, University of Wales Institute, Cardiff, UK).

TABLE 16. *Intrastudy comparisons of knowledge and self-reported practices for U.S. studies*

Sample size	Food safety issue	Respondents' knowledge of food safety issue	Respondents' self-reported practices with regard to food safety issue	Reference
1,620 adults	Hand washing	86% knew that hand washing reduced the risk of food poisoning	66% reported washing their hands after handling raw meat and poultry	*8*
	Cross-contamination	80% knew that serving steak on a plate that had held raw steak increased the risk of food poisoning	67% reported cleaning a cutting board after contact with raw meat or poultry	
	Heating adequacy	67% knew that cooking meat well reduced the risk of food poisoning	71% reported serving adequately cooked hamburgers at home	
426 adults	Cross-contamination from raw to cooked foods	88% demonstrated knowledge of cross-contamination from raw to cooked foods	75% reported implementing practices to prevent cross-contamination	*7*
	Improper cooling, leaving cooked foods at room temperature	81% demonstrated knowledge of adequate cooling principles	46% reported implementing adequate cooling procedures	
	Cooking	61% demonstrated knowledge of adequate cooking	97% reported cooking foods adequately	

during the preparation of a *Campylobacter*-positive chicken piece and RTE salad vegetables *(138)*.

The preparation of raw and cooked food in the same work area of a kitchen could increase the risk of cross-contamination during food preparation. Observational study results have shown that 80 to 90% of consumers failed to use separate parts of the kitchen for the preparation of raw and cooked foods *(14, 75, 175)*.

Significant risk potential has been attributed to the failure to use separate utensils (namely, knives and chopping boards) for the preparation of raw chicken and RTE foods. Real-time microbiological analysis of food preparation practices has shown that 81% (a probability of 9 of 11) of salad vegetables prepared with an unwashed or inadequately washed and dried chopping board and/or knife previously used for raw chicken were contaminated with *Campylobacter* and/or *Salmonella* from the raw chicken *(139)*. Many of the observational studies reviewed here have reported consumer use of utensils during the preparation of raw meat and poultry and RTE foods (Table 15). Observational study results have indicated that 66 to 75% of consumers appear to wash and dry chopping boards or use separate chopping boards for raw chicken and RTE foods, whereas 23 to 61% appear to wash and dry knives or use different knives *(75, 131)*. Other observational studies have revealed that more than half of UK consumers fail to use separate or adequately washed and dried utensils between the preparation of raw foods and the preparation of RTE foods *(76, 131)*. Although substantial numbers of consumers fail to implement safe practices, some observational study results have indicated that attempts to use adequately cleaned or separate utensils to prepare raw chicken and RTE foods are made. Redmond et al. *(138)* found that although 64% consumers failed to wash and dry chopping boards or use separate chopping boards for at least one RTE food after the preparation of raw chicken, fewer consumers (36%) failed to do so during the preparation of four different RTE foods. Sixty-four percent of the consumers failed

TABLE 17. *Intrastudy comparisons of knowledge and observed behavior for U.S. studies*

Sample size	Food safety issue	Participants' knowledge of food safety issue	Participants' observed food safety behavior	Reference
121 households	Hand washing	79% correctly identified instances in which hand washing was necessary during food preparation	20% were observed to neglect hand washing practices	*16*
100 consumers	Cross-contamination	97% rated the consumption of lettuce moistened by raw poultry dripping as a "risky" food-handling behavior	98% cross-contaminated RTE foods with raw meat or raw egg during food preparation	*14*
121 households	Cooking	7% indicated knowledge regarding heating foods to an adequate temperature	81% were observed to cook their foods to proper temperatures	*16*

TABLE 18. *Intrastudy comparisons of attitudes toward food safety and corresponding observed behavior (adapted from Redmond and Griffith, (132)*[a]

Food safety issue	Participants' attitudes toward food safety behavior	Participants' observed food safety behavior
Hand washing	100% believed hand washing after handling raw chicken to be an important food safety behavior	100% failed to wash their hands immediately and adequately after touching raw chicken
Use of separate chopping boards for raw and cooked foods	100% agreed that it is better to use different chopping boards for the preparation of raw and cooked foods	43% were observed to actually use separate boards
Use of "clean" utensils for the preparation of RTE foods	90% agreed that the use of clean utensils and equipment is essential for the handling of RTE foods	51% used the same unwashed knife or chopping board for the preparation of raw chicken and salad vegetables
Adequate cooking	97% agreed that inadequate cooking increases the risk of illness	100% cooked a chicken dish adequately

[a] The study was conducted in the United Kingdom and involved 30 targeted consumers (older adults, mothers with young children, and single young men).

to wash and dry utensils or use separate utensils for the preparation of contaminated raw chicken and RTE foods, and 13% of the foods prepared by these consumers were found to test positive for *Campylobacter (138).*

Observed temperature control. In the majority of the food safety observational studies reviewed, heating efficacy levels for raw meats, poultry, and eggs have been evaluated (Table 15). In these studies the adequacy of heating was assessed mainly on the basis of heating time or the actual temperature of the food product being heated. Research in the United Kingdom validated the use of the Charm Heat Efficiency (CHEF) test (Charm Sciences Inc.) to detect levels of alkaline phosphatase as a retrospective means of determining heating efficacy for meat and poultry *(137).* Furthermore, in validation studies, recommended cooking temperatures have been correlated with heating time to achieve adequate heating efficacy *(74).*

Overall, results denoting the adequate heating of food products by consumers have differed widely depending on the cooking method employed. Only 0 to 3% of consumers failed to fry chicken pieces for the recommended time *(138)* and all consumers cooked a chicken curry to a sufficiently safe level *(74).* However, 46 to 50% of consumers undercooked meat loaves and hamburgers *(14, 74)* and 83% failed to cook a roast chicken for the recommended time *(74).* In U.S. studies, the internal cooking temperatures of foods were found to be too low *(15–17).* It has been noted that the majority (93%) of consumers have been observed to rely on visual indicators to determine the doneness of meat products, as opposed to using a meat thermometer *(14).*

During the observation of individual meal preparation sessions, it is difficult to obtain detailed information about actual cooling procedures and storage methods. However, study results show that 24 to 47% of U.S. consumers used improper cooling procedures for leftovers *(15–17).* In a UK study, no participants were observed to implement all of the correct cooling practices prior to the storage of leftover cooked chicken and pasta salad *(138).* Indications of consumers' actual procedures for the storage of leftover foods were obtained from UK research. Substantial numbers of consumers have been found to leave meals such as chicken korma and rice, chicken salad, and roast chicken at room temperature for storage *(74, 131, 138),* thus encouraging the proliferation of any microorganisms present and increasing the risk of foodborne illness.

Correspondence between knowledge, attitudes, behavioral intentions, self-reported practices, and observed food safety behaviors. All of the described variables pertaining to the implementation and perceptions of consumer food safety behaviors have been evaluated in only one consumer food safety study *(76),* which was conducted in South Wales. However, the correspondence between knowledge and self-reported practice has been evaluated in several works *(7, 8, 168),* and other researchers have ascertained the relationship between knowledge and

TABLE 19. *Intrastudy comparisons of self-reported practice and observed behavior (adapted from Anderson et al. (14))*[a]

Food safety issue	Participants' self-reported practices with regard to food safety issue	Participants' observed food safety behavior
Hand washing	87% reported washing their hands all or most of the time before food preparation	45% attempted to wash their hands before beginning to prepare food
Cooking	30% reported owning a food thermometer	5% used a food thermometer to determine the doneness of their meat entrée

[a] The study was carried out in the United States and involved 100 consumers.

TABLE 20. *Results of a UK study (76) on knowledge, attitudes, intentions, self-reported practices, and actual food safety behaviors with regard to generic food handling practices*[a]

Food safety issue	Knowledge (%)[b]	Attitude (%)[c]	Intention (%)[d]	Self-reported practice (%)[e]	Actual behavior (%)[f]
Hand washing after handling of raw foods	100	100	85	75	0
Hand washing before handling of RTE foods	100	55	55	45	0
Use of different or washed utensils for raw and RTE foods	100	80	80	80	48

[a] The study involved 40 consumers.
[b] Percentage of questions answered correctly by participants.
[c] Percentage of participants considering behavior "extremely important."
[d] Percentage of participants indicating that implementation of appropriate procedure is "very likely" the next time food is prepared.
[e] Percentage of participants reporting "always" implementing procedure.
[f] Percentage of participants performing procedure adequately at all times during observed food preparation.

actual behavior *(15–17, 87).* In addition, the correspondence between attitudes about specific actions and actual observed behaviors has also been evaluated *(74, 131).* The following discussion presents comparable findings determined within consumer food safety studies (intrastudy comparisons) and between different studies (interstudy comparisons).

Intrastudy comparison of knowledge and self-reported practices. Analysis of results indicate that consumer food safety knowledge fail to correlate with self-reported safe home food preparation practices *(7, 8, 168).* The principal findings are presented in Table 16. Albrecht *(7)* found that a number of respondents knew about the concepts of proper food handling but did not report putting those concepts into practice. In Altekruse et al.'s *(8)* study, 20 to 27% of consumers demonstrated that they knew of safe food-handling behaviors to reduce the risk of food poisoning but did not report the implementation of the corresponding safe practices. Such disparities were not observed for the adequate cooking of meat and poultry. More consumers reported to serve adequately cooked meat than knew that adequate cooking of meat reduces the risk of food poisoning *(8).* Overall, surveys examining knowledge and self-reported practice have found that a respondent who knows a term or concept will not always use the corresponding safe home food preparation procedure *(168).*

Intrastudy comparison of knowledge and observed behaviors. Assessments of knowledge and actual behavior have featured in several U.S. studies *(14, 17)* and in an Australian study *(87)* (Table 17). On the basis of research conducted in the United States, it was concluded that knowledge does not correlate with actual food-handling practices *(17).* For example, although nearly all U.S. consumers rated the consumption of lettuce moistened with raw poultry drippings as a "risky" food-handling behavior, observations of food preparation practices showed that 98% of the same consumers cross-contaminate RTE foods with raw meat and raw egg *(14).* Nevertheless, a lack of knowledge does not mean that the use of an unsafe practice is imminent. For example, although only 7% of consumers knew the temperatures required for the adequate cooking of foods, >80% of consumers were observed to cook their foods to proper temperatures *(17).* Australian data also reveals significant variance between stated answers (given on a questionnaire) and observed (via video monitoring) food-handling and hygiene practices *(87).* Nineteen percent of households claimed to have soap available in the kitchen but did not, and contrary to participant statements, almost half of the surveyed households did not use a detergent or cleaner for cleaning kitchen surfaces *(87).* Because of such discrepancies between knowledge and actual behavior, researchers have concluded that knowledge is a poor indicator of actual behavior, and when it comes to food safety, it is difficult to measure what the general population does by what they know *(17).*

Intrastudy comparison of attitudes and observed behaviors. Very few studies have investigated the correspondence between consumer attitudes about food-handling practices and observed behaviors (Table 18). In a study conducted in South Wales, it was found that 79% of consumers perceive that are unlikely to get food poisoning in their homes. However, observations of the same consumers' food preparation practices indicated that no participant implemented all of the high-risk food safety behaviors necessary to prevent the cross-contamination of pathogens from raw chicken during the food preparation process *(132).* Results like these suggest that positive attitudes toward food safety concepts do not correspond with safe food-handling practices.

Intrastudy comparison of self-reported practice and observed behavior. The correspondence between self-reported practices and actual observed behavior was researched by Anderson et al. *(14).* The results of their study show that the proportions of consumers reporting the implementation of safe food-handling procedures was substantially larger than the proportions of consumers who actually performed these procedures (Table 19). For example, although nearly all respondents reported that they washed their hands before they prepared food, less than half actually did so, indicating that self-reports of food safety practices are not always a reliable indicator of actual behavior.

TABLE 21. *Comparisons of data from international consumer food safety studies on knowledge, attitudes, intentions, self-reported practices, and actual observed behaviors with regard to selected generic food-handling practices*

Food safety issue	Participants' knowledge	Participants' attitudes	Participants' intentions	Participants' self-reported practices	Participants' actual observed behaviors
Heating efficacy	96% knew that it was important to check the inside of the chicken to ensure that it was fully cooked *(24)* 85% did not know the temperature at which a beef burger was safe to eat *(76)*	40–64% believed that improper heating or cooking of food was a major cause of food poisoning in the home *(46, 56, 58, 59)* 86% agreed that cooking food properly prevents food poisoning *(110)*	No data available	85–92% always ensured that cooked or heated food was piping hot throughout *(57, 59)*	46–83% undercooked homemade burgers or meatloaf and chicken *(14, 75, 131)* 0% used a meat thermometer to determine heating adequacy for roast chicken or beef burgers *(131)*
Cooling	31% did not know that keeping food at room temperature or contamination of food after cooking caused food poisoning *(110)*	53% agreed that it was essential for hot food to be cooled down quickly for storage *(131)*	No data available	86% reported that they would cool leftover casserole or other food with meat or fish or poultry at room temperature *(88)*	100% failed to implement all procedures required for adequate cooling *(138)*
Storage of foods	75% thought that food should be refrigerated within 1 h of completion of cooking *(11)* 73% answered all knowledge questions regarding storage correctly *(76)*	83% agreed that it was unacceptable to store cooked meats at room temperature *(131)* 84% agreed that cooked foods, once cooled, should be refrigerated or frozen immediately *(131)*	No data available	45% reported leaving foods at room temperature after heating *(7)*	57% left chicken salad at room temperature for storage *(138)*
Hand washing and drying	82–100% knew that it was necessary to wash hands before and after preparing food *(76, 88, 102)* 86% knew that washing hands before preparing food decreases the risk of food poisoning *(8)*	100% believed that washing and drying of hands after the handling of raw food was very important *(76)* 95% believed that the washing and drying of hands after the handling of raw foods was very likely to prevent food poisoning *(76)*	85% intended to wash and dry their hands after handling raw food the next time they prepared food *(76)* 55% intended to wash their hands before handling RTE foods the next time they prepared food *(76)*	87–92% always washed their hands with soap and water before handling food *(46, 57, 59)* 62–78% always washed and dried their hands after handling raw foods *(8, 76, 117, 124)*	~75–100% failed to wash and dry their hands immediately and adequately after handling raw chicken *(74–76, 87, 138, 175)*

TABLE 21. *Continued*

Food safety issue	Participants' knowledge	Participants' attitudes	Participants' intentions	Participants' self-reported practices	Participants' actual observed behaviors
Cross-contamination	78% knew that failure to wash a cutting board after the preparation of raw meats and then cutting raw vegetables could result in food poisoning *(10)* 64–77% knew that it was very important to use separate chopping boards for raw meat and other foods *(102, 164)* 97% knew that it was unsafe to use the same unwashed knife or chopping board to cut uncooked chicken and prepare a salad *(25)*	90% believed that the use of different utensils or washed utensils for the preparation of raw and RTE foods was very likely to prevent food poisoning *(76)* 90% agreed that it was better to use different chopping boards for the preparation of raw and cooked meats *(131)* 91% agreed that contact between raw and cooked food could cause food poisoning *(110)*	80% indicated that they were extremely likely to use separate utensils or washed utensils for raw and RTE foods the next time they prepared food *(76)* 60% would wash a work surface between the handling of a raw turkey and the handling of a cooked turkey *(169)*	59–76% always or usually used separate utensils and chopping boards for the preparation of raw meat and cooked food *(46, 57, 59)* 65–85% indicated that they washed or changed cutting boards or plates for cutting up raw meat or poultry and RTE foods *(8, 76, 124)*	52–75% failed to wash and dry chopping boards and knives for the preparation of raw chicken and ingredients *(75, 76, 138)* 83–90% did not use separate areas of the kitchen for raw and RTE foods *(14, 75, 175)*

Intrastudy comparison of knowledge, attitudes, intentions, self-reported practices, and actual behaviors. Findings obtained in South Wales concur with U.S. and Australian data on discrepancies between knowledge, self-reported practices, and actual behaviors (Table 20). Griffith et al. *(76)* investigated knowledge, attitudes, intentions, self-reported practices, and actual behaviors with regard to hand-washing and cross-contamination actions. Observations of hand washing after handling raw food and before handling RTE foods showed that despite having the knowledge of, a positive attitude toward, and the intention to perform adequate hand-washing procedures, no participants were observed to wash their hands adequately at any time before RTE food was handled or after handling raw food. Actual hand-washing behavior did not appear to be influenced by attitudes toward each food safety action, as 100% of consumers thought hand washing after handling raw foods was "extremely important" and 55% thought hand washing before handling RTE foods was "extremely important"; however, neither practice was implemented adequately during the food preparation process.

A noticeable discrepancy between cognitive components and actual behavior like that observed with regard to hand washing was also observed with regard to use of different or washed utensils for the preparation of raw and RTE foods. As with hand washing, knowledge of measures for the prevention of cross-contamination during the preparation of raw and RTE foods was demonstrated by consumers, and positive attitudes toward the relevant behaviors were held. Consumers indicated an intention to carry out the required behaviors the next time they prepared food and just over half of the study participants reported that they always cleaned surfaces between the preparation of raw foods and the preparation of RTE foods. A larger proportion of the study participants reported that they always used different or washed utensils for the preparation of raw and RTE foods. However, smaller proportions of consumers were observed to actually implement appropriate practices such as using different or washed utensils for the preparation of raw and RTE foods and adequately cleaning surfaces between the preparation of raw foods and the preparation of RTE foods.

Interstudy comparison of knowledge, attitudes, intentions, self-reported practices, and actual behaviors. A comparison of knowledge, attitudes, behavioral intentions, self-reported practices, and observed food safety behaviors with regard to some generic food-handling practices from international studies is presented in Table 21. A comparison of data from all of the reviewed consumer food safety studies reveals that large proportions (82 to 100%) of consumers reported knowing that hand washing is an important action before and after handling food and that implementation of hand washing decreases the risk of food poisoning. Results from these studies also suggest that consumers know when and how to wash their hands properly. The majority of consumers also believed that the implementation of an adequate hand-washing procedure would help to prevent food poisoning, although smaller propor-

tions of consumers (55 to 85%) indicated an intention to wash their hands adequately the next time they prepared food. The proportions of consumers (62 to 78%) who reported that they always implemented adequate hand-washing practices were smaller than the proportions of consumers who demonstrated knowledge, expressed the intention to implement appropriate hand-washing procedures, and held a positive attitude toward hand washing, suggesting distinct discrepancies between self-reported practices and cognitive influences. Inconsistencies appeared to exist between knowledge, attitudes, intentions, and self-reported practices with regard to hand-washing behaviors, because observations showed that 75 to 100% of consumers failed to wash and/or dry their hands during observed meal preparation sessions.

Information presented in Table 21 shows that the majority of sampled populations demonstrated knowledge that failure to wash a cutting board after the preparation of raw meats and before the preparation of raw vegetables could result in food poisoning and that it is important to use separate utensils for raw meat and other foods. The majority of consumers (90 to 91%) demonstrated a positive attitude in agreeing that contact between raw and cooked foods can cause food poisoning and that it is therefore better to use different utensils for the preparation of raw and cooked foods. Most of a sampled population assessed in 2001 indicated a positive intention to use separate and/or washed utensils between the preparation of raw foods and the preparation of RTE foods. Earlier findings (from 1985) suggested that only 60% of consumers had positive attitudes toward the use of cleaned or different utensils for the preparation of raw and RTE foods, suggesting that over the past 16 years attitudes toward this particular food safety practice have improved. As with hand washing, an overall smaller proportion (59 to 85%) of consumers reported that they always implemented correct, safe food preparation procedures when preparing raw and cooked foods; however, such reports were not synonymous to observed associated behaviors. It was observed that 52 to 75% of consumers failed to actually use separate or adequately washed and dried utensils for the preparation of raw chicken and RTE salad, and up to 90% of consumers failed to use separate areas of the kitchen for the preparation of raw and RTE foods.

Study results regarding consumer knowledge of heating efficacy show that nearly all consumers know that it is important to check the inside of a chicken to ensure that the chicken is fully cooked. However, other findings indicate that consumers' knowledge of the internal temperature at which cooked meat is safe to eat is lacking. Nevertheless, substantial proportions of consumers have positive attitudes about the idea that cooking food properly prevents food poisoning. Corresponding with this attitude, 85 to 92% of consumers stated that they always ensured that cooked food was piping hot throughout. However, observations of actual behaviors showed that no participants used a meat thermometer to ensure heating adequacy, and substantial numbers of meat products and chicken were found to be undercooked, again indicating that disparities exist between cognitive influences and actual behaviors.

Cooling practices were not widely studied in the consumer food safety studies reviewed, and results obtained in these studies indicate that consumer knowledge of correct principles is inadequate. Only half of the study participants agreed that it is essential for hot food to be cooled down quickly for storage. In addition, large proportions of consumers stated that they leave foods, e.g., leftover casseroles, at room temperature after heating. Corresponding with this lack of knowledge, negative attitudes, and self-reported practices, observation results indicated that 90% of consumers failed to implement all of the procedures required for the adequate cooling of meat and poultry products.

Three quarters of consumers appeared to know about temperature control of foods for storage after heating, and most consumers expressed the attitude that it is unacceptable to store cooked foods (such as cooked meat) at room temperature. Although less than half of the study participants reported leaving foods at room temperature for storage, observation showed that more than half of the participants left meals requiring no further heating at room temperature.

CONCLUSIONS

Over the past 26 years, a substantial amount of valuable information about consumer food safety has been collected. The key findings from this review are as follows:

1. Epidemiological data from Europe, North America, Australia, and New Zealand indicate that substantial proportions of foodborne-disease can be attributed to food preparation practices used in the domestic environment.
2. Interest in domestic food-handling practices has prompted consumer food safety studies internationally. The majority of these studies have been conducted in the United Kingdom and Northern Ireland (48% of the studies reviewed) and the United States (42% of the studies reviewed).
3. Eighty-three percent of the consumer food safety studies reviewed have been carried out since 1995.
4. Data on consumer food safety were collected through surveys (questionnaires and interviews) in 75% of the reviewed studies.
5. Only one of the reviewed consumer food safety studies linked actual pathogenic contamination with observed food-handling behaviors; the study's results demonstrated extensive cross-contamination.
6. Few surveys have evaluated consumer attitudes and intentions regarding domestic food-handling behaviors with a view to determining why some food safety practices are implemented and others are not.
7. Observational study results suggest that substantial numbers of consumers still implement unsafe food-handling practices. For example, up to 100% of study participants failed to wash and dry their hands adequately after handling raw chicken, and more than half of the participants failed to use separate or adequately washed and dried utensils for the preparation of raw meat and poultry and the preparation of RTE foods.

8. Knowledge of food safety concepts does not generally correspond to self-reported practices for most food safety behaviors. For example, although 86% of consumers indicated that they knew that the implementation of adequate hand-washing procedures can reduce the risk of food poisoning, only 66% of consumers reported actually implementing such procedures.
9. A consumer's intention to perform a food safety procedure does not always result in the implementation of that procedure. For example, although 85% of consumers indicated that they intended to wash their hands after handling raw foods, no consumers were observed to do so.
10. Consumers demonstrated judgments of optimistic bias, perceiving themselves to be less at risk from foodborne disease than others and continuing to consume unsafe foods despite knowing the potential consequences of this behavior.
11. Positive attitudes about reducing the risk of foodborne disease associated with specific food-handling practices did not necessarily result in the implementation of the corresponding food safety practices.
12. Self-reported practices did not correspond to observed food safety behaviors, indicating that when food safety concepts are known, survey data may be subject to social desirability bias. Moreover, inaccurate perceptions of what constitutes "adequate practices" are widespread. For example, consumers may consider rinsing under running water "adequate hand-washing/drying" *(75)*; thus, survey responses may reflect inaccurate information about self-reported practices.
13. Comparisons of self-reported practices, knowledge, attitudes, intentions, and actual observed behaviors indicate that actual consumer food-handling behaviors may be represented more accurately by data obtained through observation than by data obtained through intermediary means.

One of the most notable conclusions extrapolated in this review is that consumer knowledge, attitudes, intentions, and self-reported practices determined by intermediary means such as interviews and questionnaires do not correspond well with actual observed behaviors. Nevertheless, the determination of consumer knowledge, attitudes, intentions, and self-reported practices with regard to food safety has provided information that can be used to facilitate the understanding of why consumers implement some food safety behaviors and not others. Although the measurement of such variables may aid in the evaluation of food safety education initiatives and provide health professionals with baseline data for use in the development of food safety interventions, direct observation of actual behaviors is thought to provide more accurate data on consumer implementation of safe food-handling practices. In UK research, direct observation was used to evaluate a community food safety education initiative that had been developed on the basis of the social marketing approach. Research results show that the observation of consumers' food preparation practices provides a reliable measure of the effectiveness of intervention material through the assessment of actual behavioral change *(134)*.

Food safety concepts that were not extensively represented in the reviewed studies include the component actions of hand washing and drying, cooling principles, and the correct storage procedures for cooked foods prepared in advance of consumption. Observational study results suggest that the procedures associated with these concepts are inadequately performed, and research is required to determine why this is so and to determine the extent of the use of unsafe practices. Such information may aid in the development of effective targeted food safety education programs to improve consumer understanding and implementation of specific food safety practices.

Content analysis of the reviewed consumer food safety surveys indicated that the psychological determinants of safe food-handling behaviors, such as attitudes and intentions, have not been studied extensively. A more complete understanding of why certain food safety practices are implemented and others are not may aid in the development of future food safety education initiatives.

Although many surveys have presented data indicating that large proportions of consumers possess adequate food safety knowledge, this review has determined that substantial proportions of populations in Europe, North America, Australia, and New Zealand appear to lack knowledge of key safe food-handling behaviors. Therefore, consumers may not even be aware that they are implementing unsafe practices. Although perceptions of the risk of foodborne disease appear to be generally accurate, a considerable number of consumers have demonstrated optimistic bias, which may impede attempts to improve food-handling practices through education. Even though majorities of consumers report practicing safe food-handling behaviors, substantial numbers of consumers report practicing unsafe behaviors. Such responses may indicate a lack of awareness of the risks arising from the use of unsafe food preparation practices, which constitutes substantial cause for concern. Observational study results have shown that despite nationwide food safety education attempts, unsafe food-handling practices are still frequently used during the preparation of food in the domestic environment. An increase in the frequency of the failure to implement safe food-handling procedures results in an increase in the potential risk of illness from food poisoning. The majority of unsafe food hygiene practices observed in the studies reviewed here were associated with cross-contamination; therefore, there is a need to minimize behaviors conducive to cross-contamination during the preparation of food. Educational efforts are required in order to reduce the risk of foodborne disease and improve consumers' food-handling behaviors in the domestic environment.

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