Consumer Food Safety Behavior: A Case Study in Hamburger Cooking and Ordering. By Katherine Ralston, C. Philip Brent, YoLanda Starke, Toija Riggins, and C.-T. Jordan Lin. Food and Rural Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 804.

Abstract

More Americans are eating hamburgers more well-done than in the past, according to national surveys. This change reduced the risk of *E. coli* O157:H7 infection by an estimated 4.6 percent and reduced associated medical costs and productivity losses by an estimated $7.4 million annually. In a 1996 survey, respondents who were more concerned about the risk of foodborne illness cooked and ordered hamburgers more well-done than those who were less concerned. However, respondents who strongly preferred hamburgers less well-done cooked and ordered them that way, even after accounting for their concern about the risk of illness.

Keywords: hamburger doneness, ground beef, food safety, food safety education, *E. coli* O157:H7, consumer behavior, survey, risk, foodborne illness, risk perceptions, palatability, information, microbial pathogens.

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Contents

Summary

Promoting the benefits to consumers of following food safety recommendations—through food safety education as well as through media coverage of foodborne illness outbreaks—appears to be influencing cooking and eating behavior.

For example, more Americans are eating their hamburgers more thoroughly cooked than before, according to several national surveys. Cooking and ordering hamburgers well-done reduces the risk of infection by *E. coli* O157:H7 and other pathogens. For example, the change in behavior reported in the 1996 Hamburger Preparation Quiz (HPQ), a national survey of hamburger cooking and ordering preferences, translates to an estimated 4.6-percent lower risk of *E. coli* O157:H7 infection and an estimated $7.4-million annual reduction in medical costs and productivity losses as well as reductions in other foodborne illnesses associated with rare and medium-rare hamburger. Food safety messages about cooking and ordering hamburgers may encourage consumers to handle other foods more safely as well. While *E. coli* O157:H7 in hamburger is a small part of the burden of foodborne illness—estimated at 5,000 deaths and more than $6.9 billion in medical costs and reduced productivity annually—these findings illustrate the potential benefits from encouraging consumers to follow food safety recommendations as part of an overall strategy to reduce the toll of foodborne illness.

Consumers make their decisions on how to cook and order foods based on several factors, including taste, palatability, and perceived food safety risk. Consumer behavior has changed over time, due in part to increased awareness of the risk of foodborne illness and the importance of thorough cooking in reducing that risk. Of respondents to the 1996 HPQ, 70 percent of those who had switched to more well-done hamburgers in the past 5 years reported they had done so out of fear of foodborne illness. Respondents with higher motivation to avoid foodborne illness were significantly less likely to cook or order hamburgers rare or medium-rare than those with less motivation, holding other factors constant.

Taste preferences, however, proved even more important than motivation to avoid foodborne illness. Thus, food safety education not only must convey the risk of lightly cooked hamburgers, but also should include information on how to retain juiciness and flavor in a thoroughly cooked hamburger.

Consumers in the South, Northeast, and in large cities were more likely to order hamburgers rare, medium-rare, or medium-pink, even after accounting for risk perceptions, tastes, and other factors. However, consumers in different regions and areas of different sizes reported similar doneness choices when cooking hamburgers for themselves. Only household size was significantly associated with how respondents say they cooked their own hamburgers, after accounting for risk perceptions and tastes. This suggests consumer education to encourage thorough cooking of hamburgers at home should be broadly dispersed rather than focused in certain regions.

White respondents, those with higher income, those with larger families, and those who had experienced foodborne illness had higher motivation to avoid foodborne illness, as did those whose main sources of food safety information were magazines, cookbooks, television, and government sources (such as hotlines). Conveying the consequences of foodborne illness may help motivate consumers to follow food safety recommendations.

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Introduction

Foodborne pathogens cause 76 million illnesses and 5,000 deaths in the United States each year (Mead et al., 1999). While the 1996 changes to Federal meat and poultry inspection regulations were intended to reduce the probability of pathogen contamination during processing, thorough cooking and safe handling are also required to kill any bacteria that may remain and to prevent cross-contamination. The 1997 Food Safety Initiative recognizes this with a specific component to expand consumer education to improve safe handling practices (U.S. Department of Health and Human Services, U.S. Department of Agriculture, and U.S. Environmental Protection Agency, 1997).

This report focuses on one important food safety recommendation: to cook hamburgers thoroughly and to order them thoroughly cooked in restaurants. The surveys discussed in the report asked consumers how they cook and ordered their hamburgers, using doneness descriptions such as rare, medium rare, medium, medium-well, and well-done, or colors such as red, pink, light brown, or dark brown. The Food Safety and Inspection Service, the Food and Drug Administration, and the Centers for Disease Control and Prevention now recommend that consumers use a thermometer to cook hamburgers to 160 degrees Fahrenheit (USDA, FSIS, 1998a) because research showed that color was not a reliable indicator of whether a hamburger was thoroughly cooked (Killenger, et al. 2000; USDA, FSIS, 1998b; Berry and Stanfield, 1993; Mendenhall, 1989). While the descriptions of hamburger doneness used in recent surveys do not correspond exactly to the safety of the hamburger, the descriptions do give an indication of how well consumers were following previous recommendations.

Consumption of undercooked hamburgers has been identified as a risk factor for infection from *E. coli* O157:H7 (Slutsker, 1998). This pathogen causes an estimated 62,458 illnesses, 1,843 hospitalizations, and 52 deaths per year (Mead et al., 1999). An estimated 21 percent of *E. coli* O157:H7 cases are attributed to ground beef (Powell et al., 1999). While this appears to be a small fraction of the total burden of foodborne illness, *E coli* O157:H7 has been targeted as a high priority for food safety measures because of the severity of the resulting illness and the high level of public concern over the danger to young children (Petersen et al., 1996). Further, cooking hamburgers thoroughly may prevent other illness as well, because ground beef can also be contaminated with other pathogens such as *Salmonella* and *Campylobacter*, although the number of illnesses resulting from these pathogens due to ground beef has not been established.

Consumers learn about food safety from meat labels, supermarket brochures, materials from Federal, State and local agencies, and private-public partnerships. The Food Safety Initiative has expanded consumer education by initiating a national media campaign called Fight BAC!™ to expand consumer compliance with food safety recommendations. Understanding how many consumers follow food safety recommendations, as well as which consumers and why, can help food safety educators reach more consumers in the future through targeting and designing food safety messages for specific subpopulations.

Education and information about food safety risks and the importance of safe handling can affect consumer behavior in ways that help prevent foodborne disease. Consumer awareness about food safety risks can be an important determinant of how safely they cook and order their foods. Consumer awareness is critical, because it is at the point of cooking and consumption that they can take direct action to protect themselves from health hazards such as *E. coli* O157:H7. Further, specific food safety messages about cooking and ordering hamburgers may encourage consumers to handle other foods more safely.

Consumers have control over the doneness of hamburgers only in their own homes and in restaurants where a choice of doneness is offered. According to USDA's 1994-96 Continuing Survey of Food Intakes by Individuals (CSFII), about 34 percent of hamburgers consumed in the United States are consumed at home, and another 7 percent are consumed in restaurants where consumers may be able to request a specific level of doneness (table 1). Most of the remainder are consumed in fast food establishments, cafeterias, residential dining facilities, and other locations where the preparation of the hamburger is regulated by various State and local authorities and the consumer may have little choice in the level of doneness. Thus, we focus on how consumers cook their hamburgers at home and how they order hamburgers in restaurants.

Table 1—Hamburger consumption by meal location

Location	1989-91	1994-96
	Percent	
Hamburgers eaten at home	54	34
Hamburgers eaten in restaurants	5	7
Hamburgers eaten in fast food establishments or cafeterias/residential dining	29	51
Hamburgers eaten in other locations	12	8
Total hamburgers reported (unweighted)	5,803	4,954

Source: USDA Continuing Survey of Food Intakes by Individuals, 1989-91; 1994-96. Estimated using sample weights.

We estimated the proportion of hamburgers consumed with red or pink in the center based on the 1996 Hamburger and Egg Consumption Diary (HECD). We compared these results to estimates based on usual consumption practices as reported by the same households in another survey module, the Hamburger Preparation Quiz (HPQ).

We used the HPQ to examine the role of consumers' attitudes toward risk and hamburger characteristics in their choices of hamburger doneness. We also used the HPQ to examine the relationship between information sources and risk attitudes and the relationship between demographics and attitudes toward palatability characteristics (taste, texture, and juiciness) of hamburgers. Finally, we used HPQ data on usual behavior in 1996 and respondents' recollections of their choices 5 years earlier to examine how hamburger cooking and ordering behaviors have changed over time and how these changes have altered the risk of becoming ill from a hamburger contaminated with *E. coli* O157:H7.

Measuring Hamburger Cooking and Ordering Behavior

We compared two different measures of consumer cooking and ordering behavior. The first is the proportion of hamburgers cooked to red or pink in the center, based on descriptions of hamburgers recorded in food diaries in the HECD. The second is the proportion of adult respondents to the HPQ who usually cook or order their hamburgers rare, medium-rare, or medium-pink. Because the HPQ was a separate survey module completed by the same households as the HECD, we had the opportunity to compare two different measures from the same households. The comparison provides a test of the validity of the HPQ questions on usual cooking and ordering, which are similar to a question asked in the Food Safety Survey (FSS) conducted by the Food and Drug Administration (FDA) and USDA's Food Safety and Inspection Service (FSIS) in 1988, 1993, and 1998. These measures differ, as we discuss further below.

The 1996 Hamburger and Egg Consumption Diary and Hamburger Preparation Quiz

The Market Research Corporation of America conducted the HECD and HPQ by including supplemental modules in its ongoing Menu Census Survey (MCS) during March 1996 - February 1997. The MCS is a nationally representative mail survey in which respondents complete a 2-week diary of all food consumption for themselves and their families followed by a questionnaire on attitudes related to food purchases. The survey annually covers about 2,000 households selected from a 12,000-household purchase diary survey.

The HECD supplement accompanied the MCS food diary form sent to survey participants. It requested additional information when someone in the family ate a hamburger: where the hamburger was eaten, and, if at home, how it was prepared (freezing, thawing, cooking method) and the appearance of the cooked hamburger in the center (red, pink, light brown, or dark brown). The Menu Census Survey covered 1,833 households during the period that the supplement was added, with a total of about 5,041 individuals. A total of 2,588 individuals recorded eating hamburgers at least once during the 2-week diary period, of which 2,306 (89 percent) provided sufficient demographic information for weighting purposes. A total of 6,454 hamburgers were eaten during the diary period, of which 5,822 (90 percent) could be linked to demographic weights.

The HPQ module supplemented the attitude questionnaire each household received after completing the Menu Census Survey food diary. To identify consumers who usually cook hamburgers lightly cooked or order hamburgers lightly cooked in restaurants, the HPQ asked respondents how they usually cook hamburgers for themselves (rare, medium-rare, etc.). Consumers who usually cook or order hamburgers medium were asked what color indicates a medium hamburger, so that medium-red and medium-pink hamburgers could be included in estimates of risky behavior. The supplement also included questions on how respondents cooked and ordered hamburgers 5 years previously (in 1991), and respondents' attitudes about foodborne illness and the palatability attributes of hamburgers.

In order to ensure equal probability of selecting male and female heads of households, the household adult with the most recent birthday completed the questionnaire. The survey supplement was completed by 1,132 individuals. Response rates to questions used in this study vary as noted in later discussion.

Weights were applied to each observation to match the 1990 Census proportions for categories based on sex, ethnicity, and education. These variables were chosen so that weights would be comparable to the weights used in the 1993 FSS. Weights were derived as the ratio of the Census cell proportion to the HECD/HPQ respondent's cell proportion. Unfortunately, three cells were completely missing in the HECD/HPQ responses: Black males with less than 12 years of education, Black females with less than 12 years of education, and other males with less than 12 years of education. Thus, the sample provides no representation for these groups.

Measuring Hamburger Doneness

To measure hamburger doneness, the HECD used the respondent's description of the color of the patty in the center (red, pink, light brown, and dark brown) and the HPQ used the respondent's judgment of the doneness of the hamburger (rare, medium-rare, medium, etc). These descriptions were based on the advice by FSIS prior to 1997 instructing consumers to cook hamburgers until neither the juices nor the meat showed any red or pink color. In 1997, FSIS began recommending that consumers cook hamburgers to 160 degrees

Fahrenheit (°F) using a thermometer to accurately measure temperature. In 1998, FDA and the Centers for Disease Control and Prevention (CDC) joined in promoting this recommendation (USDA, FSIS, 1998a). FSIS made the change because research at Kansas State University in 1997, confirmed by the Agricultural Research Service in 1998, showed that some meat appeared brown in the center before reaching a safe temperature (160°F), depending on the meat's age and freezing history, as well as what portion of the ground beef package was used to make the patty (Killenger et al, 2000, Berry and Stanfield, 1993). Other meat still appeared pink in the center even at temperatures above 160°F (USDA, FSIS, 1998b). The new thermometer recommendation was designed to prevent consumers from perceiving a brown, but unsafe, hamburger as thoroughly cooked, and to prevent overcooking of pink, but safe, hamburger or wastage of hamburgers discarded because they were pink and perceived to be unsafe.

While the descriptions of hamburger doneness do not correspond exactly to the safety of the hamburger, the descriptions do give an indication of how well consumers were following previous recommendations.

Results

Based on the HECD, 2.7 percent of hamburgers cooked at home and 9.2 percent in restaurants were reported as red or pink in the center (table 2). When an adult respondent from the same household completed the HPQ question on usual hamburger cooking and ordering practices, 20 percent said they usually cooked rare, medium-rare, medium-red, or medium-pink (medium with red or pink in the center) at home. Fifteen percent said they usually ordered that way in restaurants (table 3). The results of the HPQ were similar to results of the 1998 FSS, which asked, "How are hamburgers usually served in your home?" Sixteen percent of respondents to that survey said they served hamburgers rare, medium-rare, or medium-pink in their homes (table 4).

Table 2—Hamburger color reported for hamburgers recorded in a food diary survey, 1996 (N=5,822 hamburgers)

Color[1]	At home	In restaurants	All locations[2]
	Percent		
Red	0.6	0.5	0.4
Pink	2.1	8.7	3.5
Light brown	33.6	20.8	30.3
Dark brown	61.8	69.8	64.2
Other	2.0	0.2	1.6
Total red or pink	2.7	9.2	3.9

1) Mail survey supplement requested description of appearance of hamburger in the center for hamburgers (red, pink, light brown, dark brown, or other) eaten by all members of the household, including children.

2) "All locations" includes hamburgers in fast food establishments, cafeterias, and other locations, including other homes.

Source: 1996 Hamburger and Egg Consumption Diary. Responses weighted by gender, ethnicity, and education of household head.

We also compared the percent of hamburgers eaten at different levels of doneness in all locations combined. Among all hamburgers reported in the HECD, 3.9 percent were red or pink in the center (table 2). To estimate a comparable percentage for the HPQ, we used data from the 1994-96 CSFII (table 1) on the percentage of hamburgers eaten at home (34 percent), in restaurants (7 percent), in fast food establishments (51 percent), and in other locations (8 percent). If the frequency of hamburger consumption were the same for all consumers, if children ate hamburgers like adults, and if hamburgers in fast food establishments and other locations were cooked to medium or more, then the percent of hamburgers in all locations eaten rare would be 0.34 times the percent who usually cooked rare, plus 0.07 times the percent who usually ordered rare. We similarly estimated the percent of hamburgers in all locations eaten at each level of doneness and combined these to estimate the total percent eaten rare, medium-rare, medium-red or medium-pink. According to this method, the HPQ results suggest about 8 percent of hamburgers were eaten lightly cooked (table 3), much higher than the comparable result from the HECD.

Several factors contribute to the difference between reported usual behavior and reported actual outcome. First, children were included in the HECD but not in the HPQ, which asks about usual behavior of adult respondents. If adults are more likely than children to eat hamburgers red or pink, their responses will be overweighted, contributing to the discrepancy between these measurements.

We examined hamburgers eaten by adults and children separately to test this explanation. Of hamburgers eaten by adults in the HECD, 2.8 percent were red or pink at home, and 8.6 percent were red or pink in restaurants. Of hamburgers eaten by children (less than 18 years old), 2.1 percent were pink or red at home and 11.6 percent were pink or red in restaurants. These differences were statistically significant, but not enough (or in the case of restaurants, even in the right

Table 3—Usual doneness of hamburgers, 1996 (N=822 adult respondents)

Doneness	At home[1]	In restaurant[2]	All locations, estimated[3]
	Percent		
Rare	5.2	2.0	1.9
Medium-rare	5.5	6.2	2.3
Medium, respondent describes medium as red[4]	0.8	0.7	0.3
Medium, respondent describes medium as pink[4]	8.5	6.0	3.3
Medium, respondent describes medium as light brown, dark brown, or other	7.2	6.8	Not estimated
Total medium	16.5	13.5	Not estimated
Medium-well	21.2	16.7	Not estimated
Well done	51.6	39.3	Not estimated
Total rare, medium-rare, medium-red, or medium-pink	20.0	14.9	7.8

1) The HPQ mail questionnaire completed by adult respondents asked: When cooking hamburger patties for yourself to eat, how do you cook them (rare, medium-rare, medium, medium-well, well-done)?

2) The questionnaire asked: When ordering hamburgers in a restaurant, how do you order them (same choices)?

3) Estimates for all locations are calculated by using the proportion of hamburgers eaten at home (34 percent) and in restaurants (7 percent), based on the 1994-96 USDA Continuing Survey of Food Intakes by Individuals. Hamburgers eaten in fast food establishments, cafeterias, and other locations are assumed to be cooked to medium, medium-well, or well-done according to local food codes.

4) The questionnaire asked: Which of the following colors do you think best describes the inside of a hamburger patty that is cooked medium (red, pink, light brown, dark brown, other)? The percentages of respondents who usually cook their hamburgers medium-red and medium-pink are estimated as the percent who cooked medium (16.5 percent) multiplied by the percent of medium hamburger cookers who describe a medium hamburger as red (5.1 percent) or pink (51.5 percent). The proportions of respondents who order medium-red and medium-pink hamburgers are estimated as the percent who ordered medium (13.5 percent) times the percent of those ordering medium who describe medium as red (4.9 percent) or pink (44.3 percent).

Source: 1996 Hamburger Preparation Quiz. Responses weighted by gender, ethnicity, and education of household head.

Table 4—Summary of alternative measures of hamburger doneness

Survey	Measure	At home	In restaurants	All locations
		Percent		
1998 FDA/FSIS Food Safety Survey (national) N=1,600 adult respondents	Percent of adult respondents who serve hamburgers rare, medium-rare, or medium-pink	17.0	Not asked	Not asked
1996 Hamburger and Egg Consumption Diary (national, includes adults and children) N=5,822 hamburgers	Percent of hamburgers eaten pink or red	2.7	9.2	3.9
1996 Hamburger Preparation Quiz (national, same households as Hamburger and Egg Consumption Diary, includes only adults) N=822 adult respondents	Percent of adult respondents who usually cook or order hamburgers rare, medium-rare, medium-red or medium-pink	20.0	14.9	7.8[1]
1996-97 FoodNet Population Survey (CA, CT, GA, MN, OR) N=2,016 respondents who had eaten hamburgers in the past 5 days N=2,760 in restaurants	Percent of respondents who ate pink hamburger, out of those who ate hamburgers in past 5 days	15.8	8.3	10.8[1]
1998-99 FoodNet Population Survey, (CA, CT, GA, MD, MN, NY, OR) N=969 respondents who had eaten hamburgers in past 7 days	Percent of respondents who ate pink hamburger, out of those who ate hamburgers in past 7 days	Not asked	Not asked	11.3

1) Estimated using data from 1994-96 USDA Continuing Survey of Food Intakes by Individuals for the percent of hamburgers eaten at home, in restaurants, and in other locations.

Sources: 1998 FDA/FSIS Food Safety Survey: Fein and Riggins, 1998.

1996 Hamburger and Egg Consumption Diary: ERS estimates.

1996 Hamburger Preparation Quiz: ERS estimates.

1996-7 FoodNet: USDHHS, CDC, 1999.

1998-9 FoodNet: USDHHS, CDC, 1999.

direction) to account for the difference between the results of the HECD and the results of the HPQ. Thus, the fact that the usual behavior question was directed only at adults does not appear to account for the difference in results.

Second, the frequency of hamburger consumption could differ between respondents who preferred rare, medium-rare, or medium-pink hamburgers and those who preferred well-done. This would result in a different proportion of *hamburgers* that are cooked rare, medium-rare, or medium-pink compared with the proportion of *respondents* who said they usually cooked them that way.

In fact, we did find a small difference. Respondents who preferred rare, medium-rare, or medium-pink hamburgers reported they eat them less frequently than those who preferred them more well-done. This may be because those who preferred them less well-done are less likely to eat hamburgers in fast food establishments, where hamburgers are required to be well-done.

To examine the effect of this difference, we estimated the proportion of adult hamburger eaters who ate pink or red hamburgers, as opposed to the percent of hamburgers eaten pink or red, from the HECD. Of respondents who ate hamburgers at home during the 2-week diary period, 2.3 percent ate all of them pink or red. Of those who ate hamburgers in restaurants, 9.3 percent ate all of them pink or red. About 1 percent of hamburger eaters at home ate their hamburgers different ways at different eating occasions and about half of 1 percent of hamburger eaters in restaurants did so.

Finally, underreporting of lightly cooked hamburgers at home may also contribute to the difference between usual and actual behavior. To explore this possibility we compared the FSS, HECD and HPQ results to the FoodNet Population Survey for 1996-97 and 1998-99 by the CDC and FSIS (table 4). The FoodNet survey asked whether respondents ate a hamburger in the past 7 days and whether it was pink. These questions come closer to measuring individual hamburgers than the usual behavior questions of the HPQ and FSS. In 1996-97, the survey asked about hamburgers at home and in restaurants separately. In that survey, 15 percent of respondents who had eaten hamburgers at home had eaten pink hamburgers, and 8.3 percent of respondents who had eaten hamburgers in restaurants had eaten pink hamburgers. Using data from the 1994-96 CSFII on where hamburgers were consumed, we estimated that about 11 percent of respondents who had eaten hamburgers in either location had eaten pink hamburgers. In 1998, the location of hamburger eating was not specified, and 11.3 percent of FoodNet respondents who had eaten hamburger in the past 7 days had eaten pink hamburger (U.S. Department of Health and Human Services, CDC, 1999).

The 1996-97 FoodNet responses for hamburgers at home and in restaurants are somewhat lower than the HPQ responses, but the combined responses in both years are higher than the combined estimate for the HPQ. The FoodNet estimate is also higher than the proportion of hamburgers described as red or pink in the center (3.9 percent in all locations together) in the HECD.

FoodNet does include children, making it more comparable to the HECD, but FoodNet is not nationally representative since the survey was conducted only in selected States. In 1996-97 the survey was conducted in California, Connecticut, Georgia, Minnesota, and Oregon. In 1998-99 the survey was conducted in those States plus Maryland and New York.

Further, FoodNet did not distinguish between people who ate one hamburger in 7 days and those who ate more. Respondents who ate more than one hamburger during the week could have eaten them more well-done (or less well-done) than respondents who ate hamburgers only once during the week. In that case, the proportion of hamburgers eaten more well-done would be greater (or less) than the proportion of hamburger eaters who ate their hamburgers more well-done.

More research is needed to explain the difference between reports of actual and usual behavior. In any case, if more hamburgers were actually cooked more thoroughly than people reported as their usual behavior, this does not mean that the number of foodborne illness cases is lower than believed. Instead, the discrepancy may imply that the estimated number of foodborne illness cases resulted from a smaller number of unsafely prepared hamburgers than previously believed.

Modeling the Effect of Attitudes on Usual Cooking and Ordering

Food safety messages—both direct and indirect—can affect consumer behavior by increasing the risk that consumers perceive from eating a rare or medium-rare hamburger. Yet consumers also make decisions based on palatability. We developed a model for the decision to cook or order hamburgers lightly cooked. We then used data on respondents' usual cooking and ordering behavior from the 1996 HPQ to explore the relationship between hamburger cooking behavior and attitudes about risk and palatability attributes. It would also have been desirable to estimate a similar model using hamburgers recorded in the HECD consumption diaries, but the sample of hamburgers in the HECD consumed by respondents who completed the questionnaire on risk perceptions and taste, tenderness, and juiciness perceptions was too small, given the low frequency of red and pink hamburger consumption.

Conceptual Framework for the Role of Risk and Taste

Some consumer behavior researchers have used the Health Belief Model to explain risk-avoiding behaviors, including food safety behavior (Schafer et al., 1993). That model assumes that individuals make rational decisions about health behavior based on awareness of a risk, knowledge of the risk, and judgment about the level of the risk. The Health Belief Model treats behavior as a function of a first set of beliefs that provides motivation for taking action and a second set that includes modifying factors that enhance or impede such action, such as the consumer's general motivation to improve his or her health and the belief that these efforts will be effective (self-efficacy).

McIntosh's (1994) study of hamburger preparation in Texas modified the model to include habits and attitudes that are not necessarily "rational," including hamburger style preferences. The study found that palatability perceptions of Texas consumers—how they ranked the taste, tenderness, and juiciness of hamburgers cooked to different styles—were a major determinant of hamburger preparation behavior.

In the economics literature on consumer demand for health-producing goods such as food safety and nutrition, the theory of household production (Becker, 1965) and the theory of demand for characteristics (Lancaster, 1971) have been adapted to include health as an argument in the utility function, a health production function in the constraints, and the prices of health-producing goods in the budget constraint (Pitt and Rosenzweig, 1985). Information can be conceptualized as affecting both the marginal utility of health and the perceived effect of health-producing goods on health status. The optimal use of health-producing inputs (including time devoted to health-producing activities) is then a function of the prices of these inputs and the parameters of the utility and health production functions, including information. This framework can be easily reconciled with the Health Belief Model (and McIntosh's extensions) by interpreting the utility function as a description of the consumer's desire for better health, and interpreting the health production function as a perceived function incorporating the consumer's level of self-efficacy. The economic framework of utility maximization has the advantage that it can very naturally accommodate some consumers' dislike for well-done hamburgers as a cost of safe cooking behavior. Similarly, the cost could conceptually include any extra preparation steps needed to maintain the desirable qualities of a lightly cooked hamburger or extra fat content accepted to improve the palatability of a well-done hamburger.

For further details on the economic model we used to describe doneness choice, see Appendix A.

Empirical Specification and Estimation

To identify consumers who usually cook hamburgers lightly (rare, medium-rare, or medium with pink in the center) or order hamburgers that way in restaurants, the HPQ asked respondents how they usually cooked hamburgers for themselves to eat (rare, medium-rare, etc.) and how they would describe the interior color of medium hamburgers (table 5). To measure food safety knowledge, the survey asked respondents why the amount of time a hamburger is cooked would affect a person's chances of getting sick from eating the hamburger. We counted answers as correct if they included the concept that heat kills bacteria. To measure perceived risk, the survey asked respondents to rate each hamburger style on the chances of getting sick (1=not at all likely...4=very likely). To measure perceived palatability of different hamburger styles, the survey asked respondents to rank hamburgers at each level of doneness on juici-

Table 5—Variable definitions and means of sample used in model of response to risk motivation, N=530

Variable	Questionnaire wording or variable definition	Means and proportions for model estimation sample
	Behavior	
Cooks hamburgers lightly	(Counted as lightly cooked if rare, medium-rare or medium, where respondent indicated that medium includes red or pink in the center)	24% (mean for whole sample=20%)
Orders hamburgers lightly cooked		18% (mean for whole sample=15%)
	When cooking hamburger patties FOR YOURSELF TO EAT, how do you cook them?	Rare: 6.7% Medium-rare: 5.3% Medium: 20% Medium-well: 22% Well-done: 45%
	When ordering hamburgers in a restaurant, how do you order them?	Rare: 2.6% Medium-rare: 7.5% Medium: 15.7% Medium-well: 17.9% Well-done: 34.3%
	Which of the following colors do YOU think best describes the INSIDE of a hamburger patty that is cooked MEDIUM?	Red: 7.7% Pink: 46.6% Light brown: 37.1% Dark brown: 8.6%
	Knowledge and Attitudes	
Knowledge	To the best of your knowledge, why would the amount of time hamburger patties are cooked affect a person's chances of getting sick from eating the patties? (Answers were counted as correct if they included the concept that heat kills bacteria.)	Correct: 54%
Perceived risk	How likely do YOU think it is that YOU would get sick sometime in the next 12 months from eating a rare, medium-rare, medium, medium-well, or well-done hamburger patty? Ratings for rare, medium-rare hamburgers averaged.	Average score for lightly cooked: 3.3 out of maximum 4 1=Not at all likely 4=Very likely
Perceived palatability	How would YOU rank hamburger patties in terms of the amount of JUICINESS? …TASTE? …TENDERNESS? All three rankings for rare, medium-rare and medium hamburgers averaged into single measure for palatability of lightly cooked hamburgers. (Half of respondents count some pink as medium.)	Average score for lightly cooked: 3.2 out of 5 (5 is highest ranked)
Risk importance	How important is each [of the factors listed] TO YOU in deciding how to cook or order hamburger patties FOR YOURSELF TO EAT? "How likely it is to make me sick"	Average: 3.1 out of 4 1=Not at all important 4=Very important
Risk motivation index	Perceived risk x risk importance	Average: 8.9 out of 16

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Table 5—Variable definitions and means of sample used in model of response to risk motivation, N=530 (continued)

Variable	Questionnaire wording or variable definition	Means and proportions for model estimation sample
	Knowledge and Attitudes (continued)	
Palatability importance	How important…(same as above)? “How juicy the patty is” “How tasty the patty is” “How tender it is” Importance ratings averaged for three attributes.	Average rating: 3.2 out of 4 1=not important 4=very important
Palatability motivation index	Perceived palatability x palatability importance	Average: 10.5 out of 20
Illness experience	Have you ever been sick from eating any of the following foods because they were raw or undercooked? Hamburger patties Other meats or poultry Fish or shellfish	Percent ill from any source: 33
Lower Frequency	Frequency of hamburger consumption (1=once a week or more, 2=two or three times a month, 3=about once a month, 4=less than once a month, 5=never in the past 12 months)	Average: 2.1 out of 5 (About 2-3 times a month)
	Demographic characteristics	
Male		50%
South	DE, MD, DC, VA, WV, NC, SC, GA, KY, TN, AL, MS, AR, LA, OK, TX	28%
Midwest	OH, IN, IL, MI, WI, MN, IA, MO, ND, SD, NE, KS	29%
Northeast	ME, NH, VT, MA, RI, CT, NY, NJ, PA	21%
West	CA, OR, WA, ID, NV, AZ, NM, CO, WY, MT, UT, AK, HI	21%
White	English speaking, European ancestry	90%
Other ethnic groups	Non-European ancestry, or non-English speaking	10%
College	Attended some college	50%
High school	Completed high school	28%
Grammar school	Grades 1-8	22%
Senior homemaker	Homemaker 65 or over	18%
No children	No children in the household	54%
Household size	Total number in household	Average: 2.2
Big city	Metropolitan area with 500,000 or more residents	45%
Per capita annual income	In thousands	Average: 18.5

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Table 5—Variable definitions and means of sample used in model of response to risk motivation, N=530 (continued)

Variable	Questionnaire wording or variable definition	Means and proportions for model estimation sample
	Information Sources	
	Where have you heard or read about how to cook hamburger patties so a person won't get sick from eating the patties? (Yes or No for each)	
Word of mouth	"Family, relatives, friends, colleagues"	60%
Newspaper	"Newspapers"	72%
Magazine	"Magazines"	57%
Cookbook	"Cookbooks"	33%
TV/radio	"Television, radio"	72%
Physician	"Physicians"	26%
Label	"Label or instructions on a package"	54%
Brochure	"Brochures at grocery stores"	33%
Government (such as hotlines)		33%
Other sources		14%

Source: 1996 Hamburger Preparation Quiz

ness, taste, and tenderness (1=lowest ranked...5=highest ranked). We calculated the average ranking for taste, tenderness, and juiciness for each level of doneness to get an overall palatability measure for hamburgers cooked rare, medium-rare, and so on. Then we averaged the overall palatability measures for rare, medium-rare and medium-pink to derive a measure of perceived palatability for lightly cooked hamburgers.

To measure the importance of risk and palatability, the survey asked respondents to assign an importance level to the chances of getting sick, the juiciness, flavor, and tenderness of a hamburger (1=not at all important...4=very important). We multiplied the perceived risk and risk importance ratings to create a "risk motivation index" that increases from 1 to 16 as the respondents' motivation to avoid illness increases. Similarly, we multiplied the palatability measure by the respondents' importance rating for taste factors to create a "palatability motivation index" that increases from 1 to 20 as the respondent's motivation to choose the sensory characteristics of a more lightly cooked hamburger increase.

Respondents also answered questions about the frequency of hamburger consumption, whether they had ever been ill from hamburgers, other meats, poultry, or seafood, and where they obtained information about safe hamburger preparation.

We modeled the probabilities of cooking hamburgers lightly at home and ordering hamburgers lightly cooked (rare, medium-rare, or medium-pink), together with risk motivation, palatability motivation, and food safety knowledge as a system of five equations. The behaviors "cooks hamburgers lightly at home" (L_h) and "orders hamburgers lightly cooked" (L_o) are modeled as functions of the consumer's risk motivation index (R), the consumer's palatability motivation index (P), the consumer's knowledge (K), and a vector of demographic variables ($\boldsymbol{D}$).

Because R, P, and K may be associated with factors influencing L_h and L_o, we modeled these variables as well. We modeled R and K as a function of exposure to food safety information from several sources ($\boldsymbol{I}$), foodborne illness experience (E), frequency of hamburger consumption (F), and demographic variables.

We modeled P as a function of demographic variables and frequency of hamburger consumption. The model is:

$$L_h = L_h (K, R, P, \boldsymbol{D}) \qquad (1)$$

$$L_o = L_o (K, R, P, \boldsymbol{D}) \qquad (2)$$

$$R = R (\boldsymbol{I}, E, F, \boldsymbol{D}) \qquad (3)$$

$$K = K (\boldsymbol{I}, E, F, \boldsymbol{D}) \qquad (4)$$

$$P = P (F, \boldsymbol{D}), \qquad (5)$$

where

L_h = Cooks hamburgers lightly at home

K = Knowledge

L_o = Orders hamburgers lightly cooked in restaurants

R = Risk motivation index

P = Palatability motivation index

$\boldsymbol{D}$ = Demographic variables

$\boldsymbol{I}$ = Safety information source variables

$\boldsymbol{E}$ = Experienced foodborne illness

$\boldsymbol{F}$ = Lower frequency of hamburger consumption

Variable definitions and sample means are included in table 5, including details on demographic characteristics (***D***) and information sources (***I***). For further details on the statistical techniques used in this report, see Appendix B.

The Roles of Palatability Motivation and Risk Motivation

Taste preferences were the most important factors affecting how hamburgers were cooked and ordered (tables 6 and 7). A 10-percent higher palatability motivation index was associated with a 76-percent higher probability of cooking hamburgers rare or medium-rare and a 52-percent higher probability of ordering hamburgers rare or medium-rare.

Table 6—Factors associated with usually preparing hamburgers lightly cooked, N=530

Household and personal characteristics	Coefficient from bivariate Probit estimate[1]	t-statistic	Effect of household and personal characteristics on probability that respondent cooks hamburgers lightly	
			Absolute[2]	*Percent*[3]
Constant	*** -3.335	-6.517		
Male (compared with female)	0.221	1.486	N/S	N/S
South (compared with West)	0.279	1.278	N/S	N/S
Midwest (compared with West)	0.197	0.952	N/S	N/S
Northeast (compared with West)	0.307	1.474	N/S	N/S
Senior homemaker (compared with homemaker < 65)	-0.045	-0.245	N/S	N/S
Per capita annual income (for an additional $5,000)	0.005	0.142	N/S	N/S
Household size (for one additional member)	** -0.168	-1.938	-0.043	-22
White (compared with all other ethnic groups)	0.154	0.534	N/S	N/S
Household head has completed some college (compared with no college)	0.135	0.877	N/S	N/S
No children (compared with households with children)	-0.157	-0.904	N/S	N/S
City larger than 500,000 (compared with rural areas, suburbs, and smaller cities)	0.135	0.871	N/S	N/S
Risk motivation index (for an additional 10%)	** -0.037	-1.930	-0.010	-5
Palatability motivation index (for an additional 10%)	*** 0.488	7.561	0.149	76
Knowledge	0.015	0.105	N/S	N/S
Pseudo R-squared	0.460			
Correlation between errors of equations 1 and 2	0.850			

1) *** indicates $p < 0.01$, ** indicates $p < 0.05$. See Appendix B for estimation details.

2) N/S indicates not significantly different from zero. Calculated as the change in unconditional probability (probability of cooking hamburgers lightly not accounting for whether respondent usually orders hamburgers lightly cooked), and only for significant determinants. For the effects of the risk motivation index, palatability motivation index, and household size, the starting probability is calculated with means for all independent variables and equals 0.197.

3) N/S indicates not significantly different from zero. Percent change in probability is calculated as the absolute change in probability divided by the starting probability.

Source: 1996 Hamburger Preparation Quiz.

Table 7—Factors associated with usually ordering hamburgers lightly cooked, N=530

Household and personal characteristics	Coefficient from bivariate Probit estimate[1]	t-statistic	Effect of household or personal characteristic on probability that respondent orders hamburgers lightly cooked	
			Absolute[2]	*Percent*[3]
Constant	*** -3.098	-5.967		
Male (compared with female)	0.178	1.205	N/S	N/S
South (compared with West)	* 0.370	1.655	0.078	83
Midwest (compared with West)	0.238	1.158	N/S	N/S
Northeast (compared with West)	* 0.380	1.698	0.081	86
Senior homemaker (compared with homemaker < 65)	-0.198	-1.032	N/S	N/S
Per capita annual income (for an additional $5,000)	0.032	0.970	N/S	N/S
Household size (for one additional member)	-0.074	-0.857	N/S	N/S
White (compared with all other ethnic groups)	0.487	1.418	N/S	N/S
Household head has completed some college (compared with no college)	0.031	0.179	N/S	N/S
No children (compared with households with children)	-0.204	-1.118	N/S	N/S
City larger than 500,000 (compared with rural areas, suburbs, and smaller cities)	** 0.362	2.152	0.085	75
Risk motivation index (per 10%)	** -0.059	-2.715	-0.013	-9
Palatability motivation index (per 10%)	*** 0.308	6.261	0.076	52
Knowledge	-0.027	-0.171	N/S	N/S
Pseudo R-squared:	0.46			
Correlation of error terms	0.850			

1) *** indicates $p < 0.01$, ** indicates $p < 0.05$, * indicates $p < 0.10$. See Appendix B for estimation details.

2) N/S indicates not significantly different from zero. Calculated as the change in unconditional probability (probability of ordering hamburgers lightly cooked, not accounting for whether respondent usually cooks hamburgers lightly) and only for significant determinants. For the effects of the risk motivation index and palatability motivation index, the starting probability is estimated with means for all independent variables and equals 0.146. For the effects of South and Northeast, the starting probability is estimated with zero for all regional dummy variables, as if all respondents lived in the West; this starting probability is 0.094. For the effect of being in a large city, the starting probability is estimated with zero for the large city variable and equals 0.112.

3) N/S indicates not significantly different from zero. Percent change in probability is estimated as the absolute change in probability divided by the starting probability. Starting probabilities are not the same for all cases, as discussed in footnote 2.

Source: 1996 Hamburger Preparation Quiz

Respondents with higher motivation to avoid getting sick were less likely to cook hamburgers rare, medium-rare, or medium-pink—5 percent less likely for each 10-percent higher risk motivation index. The response was stronger for hamburgers ordered away from home. With each 10-percent higher risk motivation index, respondents were 9 percent less likely to order hamburgers medium-rare or rare.

These results suggest that while some consumers cook or order hamburgers medium-well or well-done because of fear of illness, taste preferences factor significantly in consumers' choices. The recommendation from FSIS—to cook hamburgers to 160°F using a food thermometer—could improve the sensory characteristics of properly cooked hamburgers because some hamburgers may be safe before turning brown in the center of the patty.

Note that because we did not have data on those who do not eat hamburgers, our results may have underestimated the effects of risk perceptions and preference for rare and medium-rare hamburgers. If some people believe even a well-done hamburger is risky, or they would rather not eat a hamburger than eat it well-done, they may have stopped eating hamburgers altogether. These individuals were not included in our sample, and so our results did not measure the full effect of risk perceptions and preferences for rare or medium-rare hamburgers. Further research is needed to explore the role of risk perceptions and doneness preferences in the decision not to eat hamburgers.

The Role of Information

Several channels appear to be effective for communicating the risks of unsafe hamburger preparation. Respondents who said they get their information from magazines, television, cookbooks, or government hot-

Table 8—Factors associated with the risk motivation index, N=945

Household and personal characteristics	Effect on risk motivation index of a one unit change in household or personal characteristic		t-statistic
	Absolute (coefficient from Ordinary Least Squares estimate[1])	*Percent[2]*	
Constant	* 1.934		1.777
Male (compared with female)	-0.194	-2	-0.472
South (compared with West)	-0.245	-3	-0.436
Midwest (compared with West)	0.750	9	1.278
Northeast (compared with West)	-0.831	-10	-1.370
Senior homemaker (compared with homemaker < 65)	0.067	1	0.134
Per capita annual income (for an additional $5,000)	** 0.213	3	2.545
Household size (for one additional member)	** 0.510	6	2.512
White (compared with all other ethnic groups)	*** 1.711	21	2.888
Household head has completed some college (compared with no college)	-0.032	<0.5	-0.078
No children (compared with households with children)	0.086	1	0.194
City larger than 500,000 (compared with rural areas, suburbs, and smaller cities)	-0.041	-1	-0.096
Gets information about how to cook hamburgers safely from:			
…Word of mouth (compared with those who don't)	0.218	3	0.526
…Newspapers	0.018	<0.5	0.038
…Magazines	*** 1.360	17	3.171
…Cookbooks	*** 1.377	17	3.221
…Television/radio	** 1.163	15	2.500
…Doctor	-0.414	-5	-0.890
…Labels	-0.356	-4	-0.847
…Brochures	** -1.060	-13	-2.333
…Government sources (such as hotlines)	*** 1.169	15	2.624
…Other sources	-0.648	-8	-1.104
Has been ill from hamburger, other meat, or fish (compared with those that haven't)	*** 2.757	34	6.361
Adjusted R-squared	0.103		
Sample's mean risk motivation index	7.99		

1) *** indicates $p < 0.01$, ** indicates $p < 0.05$, * indicates $p < 0.10$. See Appendix B for estimation details.

2) Estimated as the coefficient divided by the sample's mean risk motivation index.

Source: 1996 Hamburger Preparation Quiz.

lines had 15 to 17 percent higher risk motivation than those who did not cite these sources of food safety information (table 8). Because a higher risk motivation index was associated with a lower probability of cooking hamburgers lightly and ordering lightly cooked hamburgers in restaurants, the results imply that respondents citing these information sources had lower probabilities of cooking hamburgers lightly or ordering them lightly cooked in restaurants. The probability of cooking hamburgers lightly was 7.5 (1.5 x 5) to 8.5 (1.7 x 5) percent lower for respondents citing information from magazines, television, cookbooks, or government hotlines, while the probability of ordering lightly cooked hamburgers was 13.5 (1.5 x 9) to 15.3 (1.7 x 9) percent lower for those respondents.

Labels by themselves did not seem to have an independent effect in our study after accounting for other factors that also increase awareness such as illness experience and demographic variables. More research is needed to explore these findings, but it is not surprising that it is difficult to separate the effects of different forms of information. Consumers are exposed to several sources at the same time, and information sources may work together to affect consumer perceptions.

Surprisingly, consumers who cited brochures had lower risk perceptions than respondents who did not, after accounting for demographic factors. If brochures contain more information about how to control pathogens, consumers who read brochures may perceive less risk because the information in the brochures helps them feel they can control the risk of foodborne illness through their behavior. There could also be a confounding relationship between brochure use and demographic variables. If some demographic groups have lower risk motivation index levels and are also more likely to read brochures, the apparently negative effect of brochures on risk motivation could actually reflect the effect of demographic variables on both brochure use and risk motivation. More research is needed to explore explanations for this result.

While food safety knowledge was not significantly associated with preparing lightly cooked hamburgers or ordering lightly cooked hamburgers, it is useful to compare the effects of information sources on food safety knowledge with their effects on the risk motivation index to show how the two measures differ. The correct answer to the survey question “To the best of your knowledge, why would the amount of time hamburger patties are cooked affect a person’s chances of getting sick from eating the patties?” was any answer including the concept that “heat kills bacteria.”

Information from newspapers was significantly and positively associated with food safety knowledge, but not the risk motivation index, while information from magazines, cookbooks, and government sources were significant positive determinants of the risk motivation index but not food safety knowledge (table 9). Information from television and radio was a significant determinant of both the risk motivation index and food safety knowledge, as was previous foodborne illness.

Table 9—Factors associated with food safety knowledge, N=1,033

Household and personal characteristics	Coefficient from Probit estimate[1]	t-statistic	Effect of household and personal characteristics on probability that respondent correctly answered that heat kills bacteria	
			Absolute[2]	*Percent*[3]
Constant	*** -1.278	5.852	-0.509	
Male (compared with female)	** 0.206	2.416	** 0.082	17
South (compared with West)	0.138	1.207	0.055	11
Midwest (compared with West)	0.147	1.214	0.059	12
Northeast (compared with West)	* 0.214	1.714	* 0.085	18
Senior homemaker (compared with homemaker < 65)	0.002	0.017	0.001	0
Per capita annual income (for an additional $5,000)	* 0.031	1.778	* 0.012	3
Household size (for one additional member)	0.009	0.206	0.003	1
White (compared with all other ethnic groups)	*** 0.363	3.007	*** 0.145	30
Household head has completed some college (compared with no college)	-0.104	-1.229	-0.042	-9
No children (compared with households with children)	0.023	0.250	0.009	2
City larger than 500,000 (compared with rural areas, suburbs, and smaller cities)	-0.062	-0.700	-0.025	-5
Gets information about how to cook hamburgers safely from:				
…Word of mouth (compared with those who don’t)	-0.081	0.954	-0.032	-7
…Newspapers	*** 0.313	3.358	*** 0.125	26
…Magazines	0.129	1.476	0.052	11
…Cookbooks	0.198	2.202	0.079	16
…Television/radio	*** 0.298	3.155	*** 0.119	25
…Doctor	-0.128	-1.333	-0.051	-11
…Labels	0.075	0.871	0.030	6
…Brochures	0.012	0.134	0.005	1
…Government sources (such as hotlines)	0.102	1.121	0.041	8
…Other sources	0.092	0.763	0.037	8
Has been ill from hamburger, other meat, or fish (compared with those that haven’t)	** 0.190	2.103	** 0.076	16
Pseudo R-squared:	0.060			
Sample’s mean probability of correctly answering that heat kills bacteria	0.479			

1) *** indicates $p < 0.01$, ** indicates $p < 0.05$, * indicates $p < 0.10$. See Appendix B for estimation details.

2) The partial derivative of the unconditional probability with respect to each independent variable.

3) Calculated as the absolute effect divided by the sample’s mean probability of correctly answering that heat kills bacteria.

Source: 1996 Hamburger Preparation Quiz.

Further research on the content of newspaper stories and magazine stories would be useful in interpreting these results. For example, if newspapers focus more on outbreak facts while magazines carry stories about the emotions of foodborne illness victims, this could explain why newspapers are associated with higher knowledge and magazines are associated with higher risk motivation. Alternatively, consumers who are more educated about bacteria may be more likely to read newspapers while those who are more concerned about food safety could be more likely to notice magazine articles about victims of foodborne illness.

The Role of Demographic Characteristics

Some household characteristics were important even after accounting for differences in risk perceptions and tastes. Respondents with smaller households were more likely to cook hamburgers lightly while respondents in the South, Northeast, and large cities were more likely to order hamburgers lightly cooked in restaurants (tables 6 and 7). Individuals with these characteristics may require more exposure to safe handling recommendations to change their behavior.

Household and personal characteristics also affect behavior through their effect on attitudes. The risk motivation index (table 8) was significantly higher for respondents with higher per capita income (3 percent for each additional $5,000), respondents in larger households (6 percent for each additional member), and White respondents (21 percent higher than all other ethnic groups combined).

The palatability motivation index, which had a strong effect on cooking and ordering behavior, was 4 percent lower for men and 8 percent lower for respondents from the Midwest (table 10). It was higher for White respondents (14 percent) and for respondents with higher income (1 percent for each additional $5,000 in per capita income).

Our results highlight the need to focus consumer education efforts to encourage ordering thoroughly cooked hamburgers on consumers in the South and Northeast. Consumers in large cities should also be encouraged to order hamburgers thoroughly cooked. Consumer education to encourage thorough cooking of hamburgers at home should be broadly dispersed, however, since household size was the only statistically significant factor influencing this behavior after accounting for risk perceptions and tastes.

Table 10—Factors associated with the palatability motivation index, N=619

Household and personal characteristics	Effect on risk motivation index of a one-unit change in household or personal characteristic		t-statistic
	Absolute (coefficient from Ordinary Least Squares estimate[1])	*Percent[2]*	
Constant	*** 9.209		13.46
Male (compared with female)	* -0.417	-4	-1.829
South (compared with West)	-0.316	-3	-0.978
Midwest (compared with West)	** -0.812	-8	-2.491
Northeast (compared with West)	-0.052	<0.5	-0.148
Senior homemaker (compared with homemaker < 65)	-0.463	-4	-1.608
Per capita annual income (for an additional $5,000)	* 0.084	1	1.868
Household size	0.172	2	1.441
White (compared with all other ethnic groups)	*** 1.447	14	3.734
Household head has completed some college (compared with no college)	0.044	<0.5	0.189
No children (compared with households with children)	-0.264	-3	-1.035
City larger than 500,000 (compared with rural areas, suburbs, and smaller cities)	0.325	3	1.338
Eat hamburgers less frequently (compared with those that eat hamburgers more frequently)	-0.024	<0.5	-0.211
Adjusted R-squared	0.030		
Sample's mean palatability motivation index	10.5		

1) *** indicates $p < 0.01$, ** indicates $p < 0.05$, * indicates $p < 0.10$. See Appendix B for estimation details.

2) Calculated as the coefficient divided by the sample's mean palatability motivation index.

Source: 1996 Hamburger Preparation Quiz.

Recent Changes in Behavior

The model incorporating risk and taste attitudes showed risk motivation to be a smaller factor than taste in influencing consumer choices. But several surveys show consumers have changed their cooking and ordering choices, probably because their awareness of foodborne illness has increased. As we discuss below, consumers have been exposed to food safety messages from a wide range of sources in the past several years, providing both food safety advice and stories about outbreaks.

The HPQ asked a sample of consumers how they cooked and ordered their hamburgers at the time of the survey, 1996, as well as how they cooked and ordered 5 years previously. For purposes of comparison, we treat the responses about previous behavior as though it took place in 1991, although respondents' memory may not have been that clear. Twenty percent of respondents reported that in 1996 they usually prepared lightly cooked hamburgers at home, down from 24 percent in 1991 (table 11). The survey also showed a decline, from 21 percent in 1991 to 15 percent in 1996, in the share of respondents who ordered lightly cooked hamburgers at restaurants.

About 9 percent of the total sample switched from cooking hamburgers rare or medium-rare in 1991 to cooking them medium-well or well-done in 1996 (table 12). This represents 38 percent of those who reported cooking less well-done in 1991. However, about 5 percent of respondents reported switching from cooking hamburgers medium-well or well-done in 1991 to cooking hamburgers rare or medium-rare in 1996. The results were similar for hamburgers ordered in a restaurant: close to half of those who previously ordered rare or medium-rare switched to more well-done, but this shift was undermined partially by respondents who switched from more well-done to less well-done.

The findings of the HPQ are consistent with the FDA/FSIS Food Safety Survey (FSS), which showed the percent of respondents serving hamburgers rare, medium-rare, or medium-pink at home declined from 25 percent in 1988 to 17 percent in 1998 (table 11).

Reasons for Change

Most of the 1996 HPQ respondents who switched from less well-done to more well-done explained they had made the change because of the possibility of becoming ill (70 percent for cooking at home and 72 percent for eating out). Some reported making the change because of their peers (18 percent for eating at home and 36 percent for eating out), and some because of taste (47 percent for eating at home and 38 percent for eating out). One-fourth of the respondents who changed their ordering behavior reported making the change because restaurants were no longer serving lightly cooked hamburgers.

Taste was the most often-cited reason reported for cooking hamburgers less well-done than previously. Many in this group also cited nutrition as a reason for cooking less well-done. This could reflect a concern about loss of nutrients during cooking, but another

Table 11—Percentage of survey respondents reporting they cook or order hamburgers rare or medium-rare, 1988-98

Year and survey	Percent of respondents who usually cook hamburgers rare or medium-rare
1988 FDA/FSIS Food Safety Survey	25 (at home)
1991, from 1996 Hamburger Preparation Quiz, (survey in 1996 asked about behavior in that year and 5 years previously)	24 (at home) 21 (in restaurants)
1993 FDA/FSIS Food Safety Survey	24 (at home)
1996 Hamburger Preparation Quiz	20 (at home) 15 (in restaurants)
1998 FDA/FSIS Food Safety Survey	17 (at home)

Note: Medium hamburgers were counted as medium-rare if the respondent counted medium as still pink in the center, and as medium-well if the respondent counted medium as light brown or dark brown in the center.

Sources: 1988, 1993, and 1998 FDA/FSIS Food Safety Surveys, Fein and Riggins, 1998; 1996 Hamburger Preparation Quiz, ERS estimates.

Table 12—Reported changes in hamburger cooking and ordering, 1991-1996

Risk-reducing changes	Percent of all respondents	Percent of respondents who previously cooked or ordered rare, medium-rare, medium-red, or medium-pink
Switched from cooking rare, medium-rare, medium-red, or medium-pink to cooking medium-brown, medium-well, or well-done	9.1	37.7
Switched from ordering rare, medium-rare, medium-red, or medium-pink to ordering medium-brown, medium-well, or well-done	9.1	43.7
Risk-increasing changes	Percent of all respondents	Percent of respondents who previously cooked or ordered medium-brown, medium-well, or well-done
Switched from cooking medium-brown, medium-well or well-done to cooking rare, medium-rare, medium-red, or medium-pink	5.0	6.6
Switched from ordering medium-brown, medium-well or well-done to ordering rare, medium-rare, medium-red, or medium-pink	3.1	3.9

Source: 1996 Hamburger Preparation Quiz. Observations weighted by gender, ethnicity, and education of household head. N=820.

reason comes from focus groups conducted by FDA and FSIS in 1995. Some participants expressed a concern about overcooking lean hamburger because it may lose juiciness and flavor when cooked well-done (USDHHS, FDA, 1995). Therefore, some nutrition-conscious consumers may be using lower-fat ground beef and cooking it less well-done than they did in the past to preserve the juiciness and flavor.

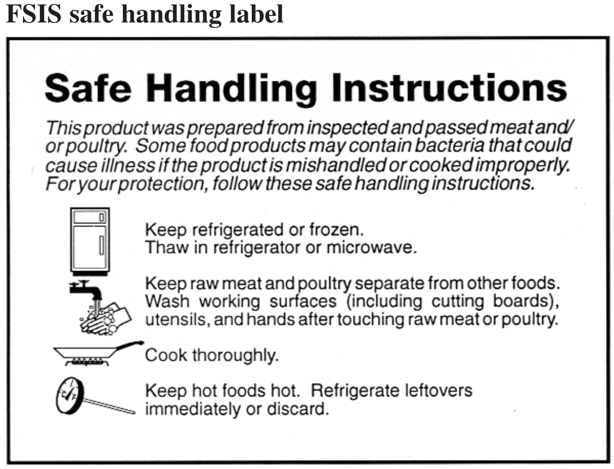
Some consumers also cited fear of illness as a reason for cooking less well-done than 5 years ago. This concern about illness may be related to fears of carcinogens from the charred surface on a well-done hamburger—a concern also discussed by participants in the FDA/FSIS focus groups. Thus, the message encouraging thorough cooking to destroy bacteria may compete not only with consumers' tastes, but also with consumers' nutritional concerns and fear of other perceived food-related risks.

Food Safety Awareness

In 1995, FSIS began requiring safe handling labels on meat and poultry (see figure 1). The label reminds consumers to cook thoroughly, thaw properly, refrigerate unused portions quickly, and wash food preparation equipment and surfaces to avoid cross-contamination. FSIS worked with supermarket chains and local health authorities to jointly produce supermarket brochures and materials for school children to draw attention to the safe handling label and reinforce its messages. In 1998, the Partnership for Food Safety Education, a coalition of industry, government, and consumer groups, began a national public advertising campaign with messages similar to those on the safe handling labels. Media coverage of foodborne illness outbreaks and recalls of contaminated food also increase consumer awareness of foodborne illness risks.

The importance of having many channels for food safety education is reflected in the diversity of sources cited by respondents to the HPQ (table 5) as providing food safety information. Newspapers and TV/radio

Figure 1
FSIS safe handling label



were cited most frequently (72 percent of the sample for each). Word of mouth, magazines, and labels were also important, cited by 60 percent, 57 percent, and 54 percent of the sample, respectively. These results were similar to findings of Buzby and Ready (1996), in which 70 and 71 percent of respondents cited newspapers and television, respectively. The 1998 FSS found similar results for labels, but lower percentages of respondents citing television or newspapers. In that survey, food labels were the most frequently cited source of "a lot of information about food safety," with 43 percent of respondents, followed by broadcast media (37 percent), print media (29 percent), and cookbooks (26 percent).

Respondents to the 1996 Trends survey by the Food Marketing Institute (FMI) and the 1998 FSS said that safe handling labels contributed to their shift in hamburger cooking behavior. The 1996 Trends survey found that 59 percent had seen the new safe handling label for meat and poultry (FMI, 1996). Of those who had seen the labels, 43 percent said the safe handling labels had caused them to change their behavior, and of those, 19 percent (8 percent of those who had seen the labels) said they had begun to follow proper cooking directions.

In the 1997 FMI Trends survey, all respondents were asked what they were doing differently as a result of the safe handling labels. Thirteen percent reported they were "cooking properly," "using correct temperatures," or "following proper cooking directions" (FMI, 1997). The large increase over the previous year could be due to the new format of the question, since it was asked of all respondents, and not just those who specifically said they saw the label.

In 1998, the FSS asked a similar question in a survey and found that 67 percent of respondents had seen safe handling labels on meat and poultry. While only 11 percent of those who had seen the label said they found some of the information new, 29 percent of those who had seen the label said they had changed their behavior as a result of the label. Of those who said they had changed their behavior, 22 percent, or 4 percent of the original sample, said they were now cooking meat properly. Note that other respondents who did not remember seeing the label may also have begun cooking meat properly. Here, the format of the question is more like the FMI survey in 1996, and the result is similar. This suggests that the large increase reported by FMI in 1997 was more likely due to the change in the format of the question.

Several well-publicized incidents of foodborne illness or recalls have also contributed to the shift in consumer behavior. Sixty-eight percent of respondents to the 1998 FSS had heard of the 1993 outbreak of foodborne illness associated with the Jack-in-the-Box fast food chain. Of those, 70 percent recalled that it was related to hamburger, 38 percent recalled that it was caused by a strain of *E. coli*. Twenty-eight percent of those who recalled the Jack-in-the-Box outbreak said the incident affected their behavior even though only 5 percent identified *undercooked* hamburger as the culprit. Further analysis of the FSS data will be required to determine how respondents changed their behavior in response to the incident. Forty percent of respondents had heard about a 1997 incident involving Hudson Foods (the 1997 recall of frozen hamburger patties), and of those, 40 percent recalled it was associated with hamburger, and 42 percent could name the bacteria involved (*E. coli* O157:H7). Twenty-five percent of those who remembered the Hudson Food recall in some form said they had changed their behavior as a result of the news, although again, researchers have not yet determined what respondents are doing differently.

It is difficult to separate the effects of labels and brochures from the effects of publicity surrounding foodborne illness outbreaks and recalls. In fact, the two are intended to work together because food safety officials work with the media to incorporate food safety education into news, magazine, and television stories, and to increase awareness of safe food handling recommendations. Thus, food safety messages often reach consumers indirectly through newspapers, magazines, and cookbooks rather than directly from consumer education materials such as labels and brochures.

Estimating the Reduction in Illness and Medical Costs from Changes in Behavior

Data from both the HPQ and the FSS suggest that consumers are cooking and ordering hamburgers more well-done, and this change means there were fewer cases of foodborne illness than would otherwise have occurred. The data needed to estimate the reduction in illness are limited, but do give some insights into the magnitude of the benefit. Predictive microbiology models for *E. coli* O157:H7 in hamburger allow us to estimate the change in risk of infection from this pathogen due to changes in hamburger cooking practices. Other pathogens are also destroyed with thorough cooking, thus lowering the risk of infection from these pathogens as well, but the necessary models have not been developed for other pathogens in hamburger.

To estimate the change in risk of infection from *E. coli* O157:H7, we modeled the risk of *E. coli* O157:H7 infection as

$$\begin{aligned}&\text{Prob (infection)} = \text{Prob (rare)} * \text{Prob (infection} \mid \text{rare)} + \\ &+ \text{Prob (medium-rare)} * \text{Prob (infection} \mid \text{medium-rare)} \\ &+ \text{Prob (well-done)} * \text{Prob (infection} \mid \text{well-done)}. \qquad (6)\end{aligned}$$

The probability of a hamburger being eaten in a given style, in turn, is the sum of probabilities that the hamburger is eaten rare at each possible location, so that

$$\begin{aligned}&\text{Prob (rare)} = \text{Prob (home)} * \text{Prob (rare} \mid \text{home)} \\ &+ \text{Prob (restaurant)} * \text{Prob (rare} \mid \text{restaurant)} \\ &+ \text{Prob (other)} * \text{Prob (rare} \mid \text{other)}, \qquad (7)\end{aligned}$$

and so on for each level of doneness.

The change in the probability of infection due to changes in cooking practices is then

$$\begin{aligned}&\Delta\ \text{Prob (infection)} = \text{Prob (infection} \mid \text{rare)} * \Delta\ \text{Prob (rare)} + \\ &\text{Prob (infection} \mid \text{medium-rare)} * \Delta\ \text{Prob (medium-rare)} + \\ &\text{Prob (infection} \mid \text{well-done)} * \Delta\ \text{Prob (well-done)}. \qquad (8)\end{aligned}$$

The assumptions we used for each component of this model are summarized in table 13. For the probability of infection at each level of doneness, we used a model of risk for hamburgers cooked to different internal temperatures (Marks et al., 1998). This risk model is based on the contamination rate, the density of contamination, the growth rate of the organism, and the decline in organism viability with increased internal temperature. The model predicts a distribution of risks at 130°F, 145°F, and 155°F, which cor-

Table 13—Assumptions used in model of *E. coli* O157:H7 infection risk

	1991	1996
Probability that hamburger is cooked rare–home[1]	0.037	0.052
Probability that hamburger is ordered rare–restaurant[1]	0.036	0.020
Probability that hamburger is cooked medium-rare–home[1]	0.202	0.148
Probability that hamburger is ordered medium-rare–restaurant[1]	0.171	0.128
Proportion of hamburgers eaten at home[2]	0.540	0.344
Proportion of hamburgers eaten in restaurants[2]	0.052	0.070
Proportion of hamburgers eaten in other locations[2]	0.408	0.586
Probability of infection given hamburger is rare[3]		51 per million
Probability of infection given hamburger is medium-rare[3]		0.88 per million
Probability of infection given hamburger is well-done[3]		0.07 per million
Proportion of change in probability of ordering rare in restaurants due to concern over foodborne illness (and not restricted choice)[4]		0.770
Proportion of change in probability of ordering medium-rare in restaurants due to concern over foodborne illness (and not restricted choice)[4]		0.710

1) Estimated from the 1996 Hamburger Preparation Quiz. These estimates of rare and medium-rare are higher than estimates from the 1996 Hamburger and Egg Consumption Diary, but give an indication of respondents' reported changes in behavior between 1991 and 96.

2) Estimates for 1991 are from the 1989-91 Continuing Survey of Food Intakes by Individuals (CSFII). Estimates for 1996 are from the 1994-96 CSFII.

3) From Marks et al. (1998). Estimated risk reported is the median of the estimated distribution of risk. While the distribution of risk at each temperature spans several orders of magnitude, the risk reduction from one temperature to the next is nearly the same for the mean, median, and 5th and 95th percentiles. At the median of the risk distribution the relationship between the logarithm of the risk and the temperature is nearly linear.

4) Estimated from the 1996 Hamburger Preparation Quiz.

respond roughly to rare, medium-rare, and well-done. While USDA recommends that hamburgers be cooked to 160°F, we used the results at 155°F as the best available data. We believe this is a reasonable approximation because the 1999 FDA Food Code required heating hamburgers to 155°F for 15 seconds in food service establishments (U.S. Department of Health and Human Services, Public Health Service and Food and Drug Administration, 1999).

While the estimated distribution encompasses a very wide range of risk estimates, the estimates of risk reduction for increases in cooking temperature are closer together. The model's authors recommend the median of the distribution as the most realistic. The model's median probabilities of infection from *E. coli* O157:H7 are 51 per million at 130°F, 0.88 per million at 145°F, and 0.07 per million at 155°F. The risk reduction for a given hamburger cooked to 155°F instead of 130°F is 50.93 per million (51 - 0.07), and for a hamburger cooked to 155°F instead of 145°F is 0.81 per million (0.88 - 0.07).

Note that the model is based on research under controlled conditions. For example, the effect of temperature on pathogen destruction was based on hamburgers with 27 percent fat, at a specific thickness of the patty, and for a specific cooking method. Variation in these factors would affect the results, so refining the results would require further research on the effects of cooking under different conditions.

We used data from the HPQ to estimate the change in probability that a hamburger cooked at home was rare or medium-rare, and the change in probability that a hamburger cooked in a restaurant was cooked rare or medium-rare. From 1991 to 1996, the percentage of respondents that cooked medium-rare at home decreased from 20.2 percent to 14.8 percent, a reduction of 5.4 percentage points. This was the net decrease, reflecting consumers who switched from medium rare to well-done, as well as those switching from rare to medium-rare.

During the same period, the percentage of respondents reporting they cooked rare hamburgers at home actually increased from 3.7 percent to 5.2 percent, an increase of 1.5 percentage points. This could have occurred because consumers unable to order rare hamburgers in restaurants chose to prepare rare hamburgers for themselves at home. Reasons for the change included taste (cited by 82 percent of those who gave any reason), nutrition (cited by 61 percent) and worries about becoming ill (cited by 56 percent) Some consumers are using lower-fat ground beef in an effort to reduce fat intake, and are cooking hamburgers less well-done because they believe leaner ground beef is not palatable if cooked longer. Other consumers are concerned about cancer-causing chemicals created in the charred surface of a well-done hamburger.

Because the increase in hamburgers consumed rare at home was not risk-reducing, we excluded it from the estimate of risk reduction due to *beneficial* changes in consumer behavior. In so doing, we assumed this change was independent of consumers' concern about illness from foodborne pathogens.

Corresponding to the changes in cooking rare and medium-rare at home was an increase in cooking well-done at home from 76.1 percent to 80 percent of respondents.

The percentage of respondents that reported ordering hamburgers rare in restaurants decreased from 3.6 percent in 1991 to 2.0 percent in 1996, a 1.6-percentage-point decrease. In the same period, the percentage of respondents ordering medium-rare in restaurants decreased from 17.1 percent in 1991 to 12.8 percent in 1996, a decrease of 4.3 percentage points. The share of those ordering well-done increased from 79.3 percent to 85.2 percent.

The changes in restaurant ordering behavior may have occurred for reasons other than consumer choice. Some of the drop in hamburgers ordered rare or medium-rare in restaurants resulted from the fact that some restaurants no longer serve rare hamburgers because of local regulations or liability concerns. We used the HPQ data on why consumers made changes in their behavior to isolate the reduction in rare hamburger consumption in restaurants due to concern over illness and not due to restricted cooking choices in restaurants.

Seventy-seven percent of those who no longer ordered hamburgers rare in restaurants and 71 percent of those who no longer ordered medium-rare reported they did so out of worry over foodborne illness. Thus, we attributed a 1.2-percentage-point (1.6 x 0.77) reduction in ordering rare hamburgers and a 3.1-percentage-point (4.3 x 0.71) reduction in ordering medium-rare hamburgers to concern over foodborne illness rather than restricted choices in restaurants.

We assumed hamburgers in fast food establishments were cooked well-done both in 1991 and 1996. While this may not be the case, the consumer does not have control over it, so it is not included in estimating the change in risk resulting from changes in cooking and ordering behavior.

We used USDA's 1989-91 Continuing Survey of Food Intakes by Individuals (CSFII) to estimate how many hamburgers were eaten at home, in restaurants, and in fast food establishments in 1991. We used the proportions for 1991 only because changes in how many hamburgers were eaten at home and in restaurants were probably not greatly affected by food safety attitudes. Thus, we did not include the reduction in risk that occurred between 1991 and 1996 due to increased eating in fast food restaurants, where hamburgers are required to be cooked well-done. During 1989-91, 54 percent of hamburgers were eaten at home, 5.2 percent in restaurants, and 40.8 percent in other locations, mostly fast food establishments. We combined the estimated changes in cooking and ordering hamburgers with estimates of where hamburgers were eaten to estimate the changes in probabilities that a hamburger was eaten rare, medium-rare, or well-done from 1991 to 1996. The change in probability that a hamburger was eaten medium-rare is the sum of changes at home and in restaurants, weighted by the fraction of hamburgers eaten in those locations in 1991.

The reduction in ordering rare hamburgers in restaurants due to concern over foodborne illness reduced the probability that a hamburger was eaten rare by 0.00064. The increase in cooking rare at home was not included because it probably did not result from concern over foodborne illness. The reductions in cooking medium-rare at home and ordering medium-rare in restaurants (due only to concern over foodborne illness) reduced the probability that a hamburger was eaten medium-rare by 0.0308. Correspondingly, the probability that a hamburger was eaten well-done increased by 0.0314.

We applied these values in equation 8 (p. 19) to derive the change in the probability of infection and divided by a baseline estimate of the risk of infection from *E. coli* O157:H7, which was 1.28 per million. **Note that the baseline risk of infection is intended only as a point of comparison and is not intended as an estimate of the true risk of infection in the population**. In particular, it is based on estimates for the percentage of hamburgers that are eaten rare or medium-rare that may be overestimates. Since the overestimated proportion is used in both the "before" and "after" scenario, the percentage change in behavior provides some indication of the magnitude of the change in hamburger cooking and ordering behavior.

We estimated that a 4.6-percent reduction in the probability of illness can be attributed to reductions in rare and medium-rare hamburger consumption due to concern over foodborne illness (as distinct from restricted choices in restaurants). The estimated reduction in the risk of *E. coli* O157:H7 infection translates to $7.4 million annually in saved medical expenditures and productivity.

These savings are based on an estimated $654.6 million in total costs of foodborne *E. coli* O157:H7 (Crutchfield and Roberts, 2000), which represents an estimated 85 percent of all *E. coli* O157:H7 cases (Mead et al., 1999). Thus, the total cost of all *E. coli* O157:H7 is estimated to be $771.1 million ($654.6 million ÷ 0.85). Powell (1999) estimates that 21 percent of the total *E. coli* O157:H7 cases are caused by ground beef, so that the total cost of *E. coli* O157:H7 cases caused by ground beef can be estimated at $161.7 million ($771.1 million x 0.21). The estimate for cost reduction ($7.4 million) is obtained by multiplying $161.7 million by 0.046, the reduction in the probability of illness.

Powell's estimate of 21 percent is based on outbreak data from 1982-98 and on case control studies (where individuals with diagnosed cases and "control" individuals are interviewed about exposure to possible risk factors) from 1990-92 and 1996-97. The proportion of cases from ground beef appears to have fallen over that period, as cases attributed to other vehicles such as apple cider, raw milk, lettuce, and contaminated water increased. Thus, 21 percent applies to the entire period and is probably appropriate for the period referred to as "5 years ago" in the HPQ interview, around 1991, though the current proportion may be much less.

It is worth clarifying that the change in *E. coli* O157:H7 risk can be attributed largely to changes in risk perception as opposed to changes in demographics. While there are no national data on risk perceptions at different points in time, 70 percent of respondents to the HPQ who switched to more well-done hamburgers at home did so out of fear of foodborne illness. The model incorporating risk and taste attitudes showed that respondents with 10-percent higher risk motivation index values were 5 percent less likely to cook hamburgers rare or medium-rare and 9 percent less likely to order rare or medium-rare in a restaurant.

While demographic factors also were significant determinants of behavior, these factors changed little over the period, and not in the direction required to explain the change. Larger households were significantly less likely to cook hamburgers rare or medium-rare at home, but the average number of persons per household declined from 2.64 in 1988 to 2.62 in 1998 (U.S. Department of Commerce, Bureau of the Census, 1990 and 2000). Residence in the South and Northeast were positive determinants for ordering lightly cooked hamburgers, but during 1988-1998 the population ratios of South to West and Northeast to West declined from 1.65 to 1.58 and 1 to 0.86, respectively (U.S. Department of Commerce, Bureau of the Census, 2001). Changes in definitions of urban areas make comparisons between 1988 and 1998 difficult, but the percentage of the population in metropolitan areas over 500,000 from 1990-96 was unchanged at 80 percent (U.S. Department of Commerce, Bureau of the Census, 1990 and 2000).

The estimate of $7.4 million in reduced medical costs and productivity losses refers only to avoided *E. coli* O157:H7 infections. Other illnesses are likely to have been avoided as well, since other bacteria, such as *Campylobacter* and *Salmonella*, can also be present in undercooked hamburger. Estimating the reduction in illness from a change in behavior requires research to model the relationship between cooking and the probability of illness. Studies for these other pathogens have not yet been performed.

Specific food safety messages about cooking and ordering hamburgers may help educate consumers about the role of safe handling and preparation in controlling foodborne pathogens. Thus, these messages may also encourage consumers to handle other foods more safely, and the benefits of individual messages may be larger than those due solely to the change in hamburger cooking and ordering. While food safety messages about individual foods are bundled in some cases, such as in supermarket brochures and the Fight-Bac!™ campaign, food-specific messages are also delivered individually. For example, seasonal messages about grilling hamburgers are often delivered during the summer, and messages about proper thawing and cooking of turkeys are presented before Thanksgiving. Further research is needed to explore the spillover effects of individual food safety messages.

Conclusions

Consumers do act on their perceptions of the risk of foodborne illness. Our results showed a significant association between risk motivation and cooking and ordering choices. The reasons respondents gave for changing their hamburger cooking and ordering choices in the previous 5 years (between 1991 and 1996) also support the link between risk perceptions and behavior. The $7.4 million annual savings from estimated reductions in medical costs and lost productivity due to a single pathogen, *E. coli* O157:H7, illustrates the benefits of investing in changing consumer behavior. Further, specific food safety messages about cooking and ordering hamburgers may encourage consumers to handle other foods more safely as well, so benefits of individual messages may exceed their original scope.

Our results provide the basis for several recommendations for the design and targeting of food safety education efforts. First, when we combined a model of the risk of infection with estimates of changes in cooking and ordering behavior data, we found that convincing consumers to stop eating rare hamburgers contributes much more to reducing the risk of infection than doing the same for medium-rare hamburgers, even though rare hamburgers are eaten less often than medium-rare. Because the destruction of *E. coli* O157:H7 organisms increases logarithmically with temperature (Marks et al., 1998), moving from rare to medium-rare provides a much larger reduction in absolute risk of *E. coli* O157:H7 infection than a change from medium-rare to well-done—a reduction of 50.12 cases per million for switching from rare to medium-rare, compared to a reduction of 0.81 cases per million for switching from medium-rare to well-done. Thus, while rare hamburger eaters may be more difficult to convince, the benefits of targeting this group should be explored further.

Second, our results highlight the need to target consumers in the South and Northeast regions and in large cities for consumer education to encourage ordering thoroughly cooked hamburgers. Consumer education to encourage thorough cooking of hamburgers at home should be broadly dispersed, since cooking hamburgers lightly was not significantly different across different regions, ethnicities, incomes, or metropolitan sizes after accounting for risk perceptions and tastes. Household size was the only significant household characteristic associated with cooking hamburgers lightly.

Third, the importance of foodborne illness experience suggests that conveying the consequences of foodborne illness can help motivate consumers to follow food safety recommendations. Fourth, our results also suggested that television and magazine stories may be effective channels for increasing consumers' risk motivation. More research is needed, however, to determine whether the information sources cited by respondents with higher risk motivation are likely to be effective channels for increasing risk motivation, or whether individuals with higher risk motivation are more likely to seek out certain information sources.

Finally, the importance of palatability motivation suggests that food safety education must convey not only the risk of lightly cooked hamburgers, but should include information on how to retain juiciness and flavor in a thoroughly cooked hamburger. The recommendation to use a thermometer may help retain desirable palatability characteristics in safely cooked hamburgers.

Our results also suggest directions for future research. First, the discrepancies among different measures of hamburger cooking behavior must be resolved. A more accurate measure of the frequency of consumption of unsafely cooked hamburgers will improve models of the risk from pathogens found in ground beef and be useful in monitoring changes in behavior. This is true for other unsafely prepared foods as well.

Second, further data on dose-response relationships for several pathogens will enable researchers to refine the estimates of *E. coli* O157:H7 illness reductions and incorporate reductions in other illnesses as well. This will improve estimates of the benefits of changes in consumer behavior.

Third, further research is needed to provide more refined measures of the proportion of hamburgers consumed rare rather than rare or medium-rare combined, and the effects of risk and taste preferences on this behavior. Accurate estimates of the proportion of hamburgers consumed rare and identification of factors that affect consumption of rare hamburgers are important in estimating the impact of efforts to change behavior. Consumption of rare hamburgers is infrequent, however, so a larger sample size is required to study this behavior in more depth.

Fourth, research is also needed to study differences in awareness of food safety information from different sources. For example, respondents citing magazines as a food safety information source reported higher risk perceptions for lightly cooked hamburger, but this could be because people who may already have higher risk perceptions may be more likely to notice food safety information in magazines.

Finally, the issue of palatability in hamburger cooking behavior suggests palatability may be an important factor to add to research in nutrition as well. For example, consumer preferences for fiber content could be an important determinant of diet that should be accounted for in measuring the effect of nutrition knowledge on fiber intake.

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Appendix A. An Economic Model of Risk and Palatability in Doneness Choice

To develop the model of behavior estimated for this study, we assumed that consumers maximize utility by choosing hamburger doneness, where health contributes positively to utility, but palatability (taste, tenderness, and juiciness) also contributes to utility. The perceived relationship between palatability and doneness may be bell-shaped for many consumers, with palatability rising to a maximum somewhere between rare and well-done, and then declining past that point. Consumer *i* chooses doneness (*T* for internal temperature) to maximize utility as a function of the palatability of the hamburger (*P*) and the probability of getting sick from the hamburger (*S*). We assume that this decision is separable from other arguments of the utility function, that is, other goods the consumer consumes.

The consumer's problem is:

$$\max_{T} E[U] = E[U(1 - S(T;I)), P(T)] \quad \text{(A1)}$$

where

$E[U]$ = consumer *i*'s expected utility;

T = the internal temperature of the hamburger, an indicator of doneness;

I = information;

$S(T;I)$ = the perceived probability of sickness as a function of the hamburger's doneness, given information I; and

$P(T)$ = the perceived palatability of the hamburger at doneness level T.

The utility-maximizing choice, then, trades off between palatability and the risk of illness so that

$$(\delta E[U]/\delta P)(\delta P/\delta T) = (\delta E[U]/\delta S)(\delta S/\delta T) \quad \text{(A2)}$$

That is, the utility lost from a marginal decrease in palatability is offset by the utility gained from the marginal decrease in the probability of getting sick. The terms $\delta E[U]/\delta P$ and $\delta E[U]/\delta S$ can be interpreted as the importance of palatability and illness probability, respectively, while the derivatives of palatability and illness probability with respect to doneness describe the consumer's perceptions about the relationships between palatability and doneness and the probability of illness and doneness. The model predicts that consumers with higher perceptions of the risk of illness and/or those who attach greater importance to the risk of illness, will be more likely to cook hamburgers thoroughly, given their preferences for a given level of doneness. Similarly, the model predicts that consumers who perceive a less well-done hamburger as more palatable and/or those who consider palatability more important, will be more likely to cook hamburgers less thoroughly.

Note that the model does not account for the decision to stop eating hamburgers because of fear of foodborne illness. Thus, the model reflects only individuals who currently consume hamburgers. Further research is needed to explore the role of risk perceptions and doneness preferences in the decision not to eat hamburgers.

Appendix B. Estimation of the Model of Usual Doneness

We estimated knowledge as a Probit model and estimated the risk motivation index and palatability motivation index using Ordinary Least Squares (OLS). The original survey questions for risk perception, risk importance, rankings of taste, tenderness, juiciness, and the importance of these attributes were answered in ordered categories; equations explaining those variables would have been more appropriately estimated using a limited dependent variable technique. But the index variables were created as products and averages of more than one category, resulting in distributions that were closer to continuous. Thus OLS estimation was acceptable.

If the errors of L_h, L_o, R, P, and K are uncorrelated, they form a triangular system since risk motivation and food safety knowledge are not modeled as a function of cooking and ordering behavior. However, if the errors are correlated then the knowledge, risk and palatability variables are correlated with the error terms of the cooking and ordering equations, and the unadjusted Probit estimates of these equations will be biased. Further, the estimates of all the equations will be inefficient.

To test the correlation of errors across equations, we used the test suggested by Greene (1993): the sum of squared correlation coefficients for all errors in the system is asymptotically distributed as chi-squared with M(M-1)/2 degrees of freedom, where M is the number of equations in the system (in our case, df=3). We tested for correlation of errors in the following systems:

1) all five equations together,
2) two subsystems consisting of R, P, K, and either L_h or L_o,
3) just L_h and L_o together.

Errors across the equations of the five-equation system were significantly correlated. Errors were significantly correlated in the subsystem consisting of L_o, R, P, and K, but not in the system consisting of L_h, R, P, and K. Errors for equations for ordering and cooking hamburgers lightly, L_h and L_o, were significantly correlated.

The ideal solution to this problem is a simultaneous nonlinear equations technique (such as Newey, 1987). However, the simultaneous equations estimator may also be biased if the available instrumental variables are poor predictors of the endogenous variables (for the linear case, see Bound et al., 1995). The R-squared values for the risk motivation index and palatability motivation index equations were 0.10 and 0.03, respectively. The pseudo R-squared value for the Probit knowledge prediction equation was 0.06. These values suggest poor predictive power.[1]

Given the low predictive power of the equations for knowledge, the risk index, and the palatability index, results using predictions for these variables are likely to be difficult to interpret. Thus, we applied the Davidson and MacKinnon (1993) test for the significance of the difference between the unadjusted Probit estimates and the estimates from a simultaneous equations technique. In our case, this test is the likelihood ratio test of the significance of the residuals of the knowledge, risk motivation index, and palatability motivation index equations in the cooking and ordering equations. The chi-squared values were 3.57 ($p = 0.68$, 3 degrees of freedom) for the ordering equation, and 2.18 ($p = 0.46$, 3 degrees of freedom) for the cooking equation, indicating that estimation using predicted values for knowledge, the risk motivation index, and the palatability motivation index would not be significantly different than the unadjusted equations.

Thus, we estimated the equations for L_h and L_o together as a bivariate Probit model but estimated the equations for knowledge, the risk motivation index, and the palatability motivation index separately.

We multiplied the coefficients of the risk motivation index and the palatability motivation index by multiplying 1.6 and 2 respectively to convert the effects of 1-unit increases to effects of 10-percent increases. A 1-unit increase in the risk motivation index represents 6.25 percent of the maximum scale value of 16, so multiplying the coefficient by 1.6 gives the effects of a

[1] Bound et. al. (1995) shows that for the linear case, the bias in the instrumental variables estimates of the second stage equation is approximated by 1/F times the bias of the OLS estimates, where F is the F-statistic for the prediction equation. Since this system is not linear, the bias cannot be estimated using this approximation.

10-percent increase. Similarly, a 1-unit increase in the palatability motivation index represents 5 percent of the maximum scale value of 20, so multiplying the coefficient by 2 gives the effect of a 10-percent increase.

We also multiplied the coefficient on per capita income in each equation by 5 to convert the effect of a $1,000 increase to the effect of a $5,000 increase.

As in the models for hamburgers recorded in the diary, we estimated the marginal effects of each factor on the dependent variable in absolute and percentage terms. For the bivariate Probit model, however, LIMDEP does not report the marginal effects on the unconditional probabilities. Thus, we estimated the marginal effects by calculating the probability with and without a one-unit change in the independent variable. In the case of dummy variables, we calculated effect as the probability calculated using 1 for the dummy variable minus the probability calculated using 0 for the dummy variable. Again we divided the absolute marginal effect by the sample's average probability to obtain the effects in percentage terms.