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

$$\text{Prob (infection)} = \text{Prob (rare)} * \text{Prob (infection} \mid \text{rare)} + \\ + \text{Prob (medium-rare)} * \text{Prob (infection} \mid \text{medium-rare)} \\ + \text{Prob (well-done)} * \text{Prob (infection} \mid \text{well-done)}. \quad (6)$$

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

$$\text{Prob (rare)} = \text{Prob (home)} * \text{Prob (rare} \mid \text{home)} \\ + \text{Prob (restaurant)} * \text{Prob (rare} \mid \text{restaurant)} \\ + \text{Prob (other)} * \text{Prob (rare} \mid \text{other)}, \quad (7)$$

and so on for each level of doneness.

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

$$\Delta\ \text{Prob (infection)} = \text{Prob (infection} \mid \text{rare)} * \Delta\ \text{Prob (rare)} + \\ \text{Prob (infection} \mid \text{medium-rare)} * \Delta\ \text{Prob (medium-rare)} + \\ \text{Prob (infection} \mid \text{well-done)} * \Delta\ \text{Prob (well-done)}. \quad (8)$$

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.