Determinants of Consumer Awareness of Foodborne Pathogens

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Abstract

Each year, microbial pathogens cause millions of cases of foodborne disease and result in many hospitalizations and deaths. Effective consumer education programs to promote safer food handling practices and other averting behaviors may benefit from consumer awareness of microbial pathogens. This paper investigates U.S. consumers' awareness of four major microbial pathogens (*Salmonella*, *Campylobacter*, *Listeria* and *E. coli*) as food safety problems, using a multinomial probit model. The awareness varies among pathogens and the variations appear to be related to differences in the number and severity of illnesses associated with these pathogens. Our findings suggest that awareness of microbial pathogens is associated with food safety perceptions, awareness of potentially risky foods and substances associated with potential food safety hazards, food safety related behaviors and experience, and demographics. Differentiated effects of variables on awareness of the four pathogens are found to be existent.

Key Words: sample-selection model; censored dependent variables

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Each year, microbial pathogens cause as many as 76 million cases of foodborne illness, 324,000 hospitalizations, and 5,200 deaths (Mead et al.). The more common pathogens associated with foodborne illness include *Salmonella, Campylobacter jejuni, and Escherichia coli* O157:H7. Some victims of *Escherichia coli* O157:H7 caused illness, particularly the very young, have developed the hemolytic uremic syndrome (HUS), characterized by renal failure and hemolytic anemia which can lead to permanent loss of kidney function (FDA-CFSAN 2003a). Foodborne illness associated with *Listeria monocytogenes*, though lower in number, is much more lethal than the three pathogens mentioned above (CAST). Also, listeriosis in pregnant women can result in miscarriage, fetal death, and severe illness or death of a newborn infant (FDA-CFSAN 2003d). Annual costs of foodborne illness have been estimated between $10-$83 billion (FDA-CFSAN 2003c). The U.S. Department of Agriculture's Economic Research Service estimates that the costs associated with five major pathogens alone (*Escherichia coli* O157, other Shiga toxin-producing *Escherichia coli* (STECs), *Campylobacter*, *Listeria monocytogenes*, and *Salmonella*) amount to at least $6.9 billion annually (USDA-ERS).

Existing research suggests that a substantial proportion of foodborne illness is attributable to improper food handling, preparation, and consumption practices by consumers (CAST; Redmond and Griffith). Improper practices include, but are not limited to, inadequate cooking, inadequate cooling and storage of foods, cross-contamination of raw and cooked foods, inadequate personal hygiene such as hand washing, and consumption of raw, undercooked, or unsafe foods (CAST; Doyle et al.; Medeiros et al.; Redmond and Griffith). Thus, consumer food handling and preparation behaviors are important means to reduce foodborne illness.[1]

Awareness of foodborne pathogens may play a positive role in helping reduce foodborne illness. McIntosh, Christensen and Acuff reported that a higher number of five bacteria a Texan consumer had heard of was associated with (1) awareness of dangers related to the degree of doneness in cooking hamburger patties, and (2) preference toward hamburger patties prepared more than less done. The five pathogens asked were *Salmonella, Campylobacter, E. coli, Listeria*, and *Clostridium perfringens*. Similarly, U.S. adult residents who had heard of *Salmonella* as a problem in food and volunteered a probable food vehicle related to the pathogen were more likely to know than others who did not that “cooking meat until well done reduces the risk of food poisoning” (Altekruse et al.). In addition, Altekruse et al. found that those who had heard of *Salmonella* and volunteered a probable food vehicle related to *Salmonella* were more likely than others to (1) wash hands after handling raw meat, (2) wash or change cutting board after cutting raw meat or poultry, (3) think washing hands reduces risk of food poisoning, (4) think serving steak on a plate that held raw steaks increases risk of food poisoning, and (5) think cooking meat “well done” decreases food poisoning; nevertheless, the hamburgers served were no more or less “done” in either group’s homes. Hence, these studies suggest that awareness of foodborne pathogens goes hand in hand with better knowledge of safe food handling and preparation principles and safer food handling and preparation practices; both ultimately should contribute to a reduction in foodborne illness.

Consumer education programs are often used to promote safer food handling and preparation practices, and increasing the level of awareness of foodborne pathogens appears to be helpful in enhancing the outcomes of consumer education. In particular, consumer education programs may target individuals who are less likely to be aware of foodborne pathogens as a food safety problem, and thus may practice less safe food handling and preparation behaviors. This in turn requires an understanding of which consumers are aware of pathogens and what factors are associated with their awareness.

This study built on existing research and investigates consumer awareness of four major foodborne pathogens, *Salmonella*, *Campylobacter*, *Listeria*, and *E. coli*. We examined the relationships between the awareness and its explanatory variables for each pathogen individually and the differential relationships among the four different pathogens. Two major features of this study distinguish it from the literature. First, we included two categories of predictors to gain a better understanding of the awareness. One category of predictors reflect consumers' perceptions related to food safety, such as whether food safety problems are most likely to occur at homes or not and how serious of a food safety problem is contamination of food by micro-organisms. The other category of predictors represents consumers' awareness of potentially risky substances in food such as mercury and potentially risky foods such as sprouts. We hypothesized that consumers with higher risk perceptions or awareness of foods and substances associated with food safety problems would generally pay more attention to food safety information and therefore more likely to be aware of foodborne pathogens. The second distinguishing feature of this study is that we used an econometric technique to simultaneously examine the relationships between each of the pathogens and a common set of predictors.

Sample and Methods

Sample

We used data from the 2001 Food Safety Survey (FSS) sponsored jointly by the U.S. Food and Drug Administration and the U.S. Department of Agriculture and conducted by a private contractor (FDA-CFSAN 2002). Eligible respondents were adults (18 years of age or older) in the 48 contiguous states and the District of Columbia. A total of 4,482 adults were successfully interviewed, yielding a response rate of 46.5%.[2] We created a sample of 2,992 observations, consisting of the respondents who provided usable responses to all survey questions included in the analysis. The data were weighted to adjust for probability of selection (number of residential telephone numbers and number of adults in the household) and to adjust the sample distribution to the race, education, and gender distributions in the 2001 Current Population Survey (U.S. Census Bureau 2001a).[3] In the current analysis, both descriptive statistics and regression results were based on weighted data. Our sample statistics (available upon request) suggest our sample closely resembles the U.S. population.

Questionnaire

The questionnaire covered awareness of pathogens as problems in food, food safety perceptions, food handling and consumption practices, perceived vulnerability from unsafe food handling and consumption practices, awareness and consumption of potentially risky foods, awareness of new food processing technologies, food allergies, foodborne illness experience, and demographics. Only the questions pertaining to the analysis of awareness of micro-organisms were used in this study.

We coded responses with either a binary scale or a continuous scale. For example, awareness of pathogens, awareness of potentially risky foods, foodborne illness experience, and demographic characteristics (e.g., race, ethnicity, age group) were coded as yes or no. Other responses were coded with scales, for example, from 1 to 4 for the perceived seriousness of food contamination as a food safety problem, and from 1 to 5 for the perceived vulnerability of unsafe food handling and consumption practices, respectively.

Methods

Our statistical model postulated that pathogen awareness is associated with food safety perceptions, awareness of potentially risky foods and substances associated with potential food safety hazards, food safety related behaviors and experience, and demographics.

Food Safety Perceptions

We hypothesized that consumers who perceive higher risk of foodborne illness are more likely to know the pathogens because they may pay more attention to food safety information and be more motivated to learn about food safety such as the causes of foodborne illness. Food safety perceptions are represented by four explanatory variables: whether homes are where food safety problems are most likely to occur (FROMHOME), how common it is for people in the U.S. to become sick because of the way food is handled in their homes (HOMERISK), how serious of a food safety problem is contamination of food by micro-organisms (GERMRISK), and perceived likelihood of getting sick from four unsafe food handling practices, such as not washing hands before beginning cooking and eating meat or chicken not thoroughly cooked

(VULNERABILITY). Variable definitions and codes are available from the authors.

Awareness of Potentially-Risky Foods and Substances

We hypothesized that consumers who are aware of potentially risky foods and substances are also more likely to be aware of the pathogens. Again, this relationship is expected because these consumers pay more attention to food safety information and are more motivated to learn about food safety. The association between awareness of pathogens and awareness of high risk foods may also arise because when consumers hear or read about certain potentially risky foods, they are likely to hear or read about the source of the risk, i.e., the pathogens. The survey asked respondents whether they had heard or read about possible health problems related to eating sprouts, such as alfalfa or bean sprouts (SPROUTS), drinking juice that has not been pasteurized (JUICES), and mercury as a problem in some fish (MERCURY). In the late 1990s and early 2000s, raw sprouts and unpasteurized juices have been implicated in a number of foodborne illness outbreaks in the U.S. For instance, from 1996 to 2000, there were four major outbreaks in the U.S. in which the food vehicle was unpasteurized juices contaminated with *Salmonella* or *E. coli* O157:H7 (USDHHS 2001). A *Salmonella*-related outbreak in four Western states in early 2001 was related to sprouts (CDC 2002). Mercury occurs naturally in the environment and can also be released into the air through industrial pollution. Mercury occurs naturally in the environment and can also be released into the air through industrial pollution; the pollutant falls from the air and can accumulate and is turned into methylmercury in the water.

Major foodborne illness outbreaks receive a lot of media attention and news stories often mention the pathogens implicated (Ollinger-Snyder and Matthews). Food safety authorities, such as the U.S. Food and Drug Administration (FDA) and the U.S. Department of Agriculture, also issue consumer advisories and food recall notices that often mention the specific pathogens related to a risk (USDHHS 1999; FDA-CFSAN 1998b; USDHHS-USEPA). Hence, consumers who have heard or read of the high risk foods or substances are hypothesized to have also heard of foodborne pathogens.

Other Explanatory Variables

Previous studies have suggested that awareness of foodborne pathogens is related to better knowledge of safe food handling and preparation principles and safer food handling and preparation practices (Altekruse et al.; McIntosh, Christensen and Acuff). Based on these findings, we hypothesized that pathogen awareness is higher among consumers who always wash hands with soap before food preparation (HANDSAFE) or among consumers who are in households where hamburgers are usually served in a safer degree of doneness (HAMBURGER). We also hypothesized that consumers are more likely to have heard of the pathogens if they have stopped buying specific kinds of food due to safety concern (STOPBUY), think they themselves or someone in the household have had suspected foodborne illness (ILLNESS), have one or more health conditions that may weaken their immunity (HEALTH), are the primary meal preparers in the household (MEALPREP), are older, are female (FEMALE), or reside in a household with young children (CHILD5). These consumers would have greater awareness of pathogens because they may pay more attention to food safety. Finally, we included in the model several demographic characteristics, i.e., race/ethnicity, household size, education, income, and geographic region.

Statistical Model

To analyze the relationships between awareness of the four pathogens and the explanatory variables, we used a multivariate probit econometric technique. Chi-square analysis has been used to investigate awareness of a single pathogen (Herrmann and Warland). McIntosh, Christensen and Acuff applied the ordinary-least-squares econometric technique with the dependent variable defined as the sum of ones ("heard of") and zeros ("not heard of") for five pathogens (*Salmonella*, *Campylobacter*, *E. coli*, *Listeria*, and *Clostridium perfringens*). Another approach would be to model each pathogen individually, i.e., using a univariate technique such as probit analysis for discrete dependent variables. Univariate techniques, however, ignore the potential correlation among the unobserved disturbances in the awareness, and thus may compromise statistical efficiency. If there are unobserved and unmeasured common factors underlying the different awareness, then the univariate technique as used in previous research would be more prone to biases caused by the common factors.

To overcome the shortcoming in univariate techniques, we adopted a multivariate probit econometric technique in this study. The multivariate probit econometric model is characterized by a set of n binary dependent variables y_i such that

$$\begin{aligned} y_i &= 1 \text{ if } \quad x'\beta_i + \varepsilon_i > 0 \\ &= 0 \text{ if } \quad x'\beta_i + \varepsilon_i \leq 0,\ i = 1, 2, ..., n, \end{aligned} \tag{1}$$

where *x* is a vector of explanatory variables, $\beta_1, \beta_2, ..., \beta_n$ are conformable parameter vectors, and random error terms $\varepsilon_1, \varepsilon_2, ..., \varepsilon_n$ are distributed as multivariate normal distribution with zero means, unitary variance and a contemporaneous correlation matrix. Estimation of the multinomial probit is discussed in Ashford and Sowden and Daganzo; also see Greene. To further quantify the marginal effects of explanatory variables, we differentiated the awareness probability for each pathogen:

$$\Pr(y_i = 1) = \Phi(x'\beta_i), i = 1, 2, ..., n, \tag{2}$$

where $\Phi(\cdot)$ is the univariate standard normal cumulative distribution probability.

Results

We estimated the multivariate probit model and, for comparison, a univariate probit model for each of the four pathogens. Based on the log-likelihood values of the multivariate and univariate probit models, a likelihood ratio test (χ^2 = 131.51, d.f. = 6, *p*-value < 0.0001) suggested joint significance of the error correlations, justifying estimation of a multinomial probit model vis-à-vis univariate probit models. This test result is consistent with significance of the error correlation coefficients between *Listeria* and *Campylobacter* (0.25), between *E. coli* and *Salmonella* (0.32), and between *E. coli* and *Listeria* (0.25).[4] A comparison of the multinomial and univariate probit results however suggests qualitatively similar effects of explanatory variables, in terms of signs and significance levels, between the two models.[5] The differences between these two models in other samples and applications are worthy of further investigation. The rest of the analysis is based on the multinomial probit estimates.

Table 1 shows the estimated relationships between pathogen awareness and explanatory variables according to the multinomial probit model. Along with the parameter estimates, we also report the marginal effects of explanatory variables on each of the awareness probabilities (2).[6] As typical in cross-sectional analysis, the pseudo *R*-squared's (Wooldridge, p. 463) for the probit equations are fairly low, ranging from 0.012 for *E. coli* to 0.143 for *Listeria.* However, for binary-choice models, it is more important to examine the predictive powers (Wooldridge, p. 463), which are fairly high, ranging from 69.35% correct predictions for *Listeria* to 96.42% for *Salmonella*.

According to the multinomial probit results, awareness of *Salmonella* is more likely among consumers who perceive homes are where food safety problems are most likely to occur, who perceive it is more common that people get sick from food handling or preparation at home, who consider pathogen contamination as a more serious food safety problem, or who always wash hands with soap before food preparation. Those who have heard of possible health problems related to drinking juices or mercury in some fish are also more likely to be aware of *Salmonella*. As to *Campylobacter*, consumers are more likely to have heard of it if the hamburgers served in their homes are more thoroughly cooked. In addition, awareness of health problems related to eating sprouts, drinking juices, or mercury in some fish is also associated with a larger probability of having heard of *Campylobacter*. Likewise, the same awareness is associated with the probability of having heard of *Listeria*. Meanwhile, those who perceive pathogen contamination a more serious food safety problem are also more likely to be aware of the pathogen. Having heard of the pathogen *E. coli* is more likely if hamburgers served at home are more thoroughly cooked, and if there is awareness of possible health problems related to eating sprouts, drinking juices, or mercury in some fish. But awareness of *E.*

coli is less likely among consumers who do not consider homes are where food safety problems are most likely to occur or who have stopped buying specific kinds of food due to safety concern.

Having heard of a pathogen is also associated with demographic characteristics of the consumer. Consumers with at least some college education are more likely to have heard of any one of the four pathogens than those with less education. Female consumers are more aware of *Salmonella* or *E. coli* than males. Those who have one or more children younger than 5 years old in their households are more likely to have heard of *Salmonella*, *Listeria*, or *E. coli*. Consumers age 30 to 49 or who come from higher-income households are more likely to have heard of any of the pathogens, except for *Campylobacter*. There are race/ethnicity variations in awareness. Hispanic, White, or Black consumers are less aware of either *Campylobacter* or *Listeria* than other consumers. Hispanic consumers are also less likely to have heard of *E. coli*. On the other hand, the awareness of *Salmonella* or *E. coli* is higher among White consumers. Consumers in different geographic regions also have different probabilities of having heard of any of the pathogens, with Northeast consumers more aware of *Salmonella* and *E. coli*, Midwest consumers more aware of *Listeria*, and West consumers less aware of *Compylobacter* and *Listeria*.

Discussion and Conclusion

Similar to findings by Altekruse et al. and McIntosh, Christensen and Acuff, our results suggest that awareness of pathogens is associated with safer food handling and preparation practices. Awareness of *Salmonella* is associated with safer hand washing practice before meal preparation, while awareness of *E. coli* or *Campylobacter* is associated with safer hamburgers served in the household. Therefore, raising pathogen awareness does appear to be a potentially useful approach to advocating safer food handling and preparation practices. Furthermore, it appears that even awareness of one or two significant pathogens, and not necessarily awareness of more pathogens, can be useful for reducing foodborne illness through safer practices.

Several previous studies have examined consumer awareness of foodborne pathogens. A 1990 nationwide mail survey found that 9% of respondents said they were not familiar with *Salmonella*, when asked what foods were most likely associated with the pathogen (Williamson, Gravani and Lawless). McIntosh, Christensen and Acuff asked, in a 1991 telephone survey, a sample of Texan consumers whether they had heard of five bacteria; they found that 78% of the respondents had heard of *Salmonella*, 30% *E. coli*, 21% *Listeria*, 9% *Campylobacter*, and 9% *Clostridium perfringes*. Those with more awareness of the bacteria (i.e., having heard of a larger number of bacteria) said they had made more effort to obtain information regarding safe cooking practices, said they received most of their information about food safety from television, said they preferred their degree of cooking for hamburgers because it is healthier or safer, and were better educated.

Alterkruse et al., using data from an earlier (1993) FSS, reported that 80% of U.S. residents had heard of *Salmonella* as a problem in foods (while 54% volunteered a probable food vehicle related to the bacterium), 10% had heard of *Listeria* (1%

volunteered a probable food vehicle), and 5% had heard of *Campylobacter* (0.4% volunteered a probable food vehicle). Moreover, those who volunteered a food vehicle for *Salmonella* were more likely to be female, to be in the 18-29 age group, to have more years of education, and to prepare main meals in their households all or nearly all the time.

With regard to *Listeria*, a 1999 U.S. national telephone survey found that 52% of the respondents had heard of the bacterium–defined as those who responded “yes” to the question “are you concerned about *Listeria bacteris*, or is that something you never have heard of?” (Herrmann and Warland). Based on chi-square statistics, the study reported that the respondents who were more likely to report the awareness include those who had watched television reports about food safety within the last month or who had read a newspaper or magazine story about food safety within the last month.

Compared to previous studies, our findings suggest two things. First, more U.S. consumers had heard of *Salmonella*, *E. coli*, and *Listeria* in 2001 than in the early 1990s. As high as 94% consumers had heard of *Salmonella* in 2001, while the corresponding figure for 1993 and 1991 (a Texas sample) was approximately 80%. The awareness of *E. coli* was 90% in 2001, according to our sample, and this figure is much higher than the 30% reported in McIntosh, Christensen and Acuff, based on responses from Texan consumers. A smaller difference between this study and McIntosh, Christensen and Acuff (32% vs. 21%) also exists in the awareness of *Listeria*.[7] Second, the percentage ranking in awareness among the four pathogens remained relatively stable between the early 1990s and 2001. *Salmonella* has consistently been the most widely known pathogen, *E.*

coli second, *Listeria* next, and *Campbylobacter* least. The availability heuristic is a possible explanation of the difference over time in the awareness of *Salmonella*, *E. coli*, and *Listeria* and the consistent pattern of order ranking in the awareness.

Food safety incidents, especially those affecting many consumers and those resulting in deaths, are often reported by the media (IFICF; Ollinger-Snyder and Matthews). Many consumers receive information about food safety through mass media such as newspapers, magazines, and television (ADA/ConAgra 2000a). The availability heuristic, a simplified judgmental rule, posits that, in assessing the frequency of a risk, individuals often base their decisions on how easy it is to recall the risks and how recent occurrences of the risks are (Tversky and Kahneman). Accordingly, it is possible that, when asked whether they have heard of a subject, individuals would report awareness if the subject is readily available in the memory (i.e., easily recalled) and there are recent events related to the subject.

It is reasonable to expect that consumers would have easier cognitive access to these pathogen names in 2001 than in 1993. Specifically, the potential influence of highly publicized food safety incidents on pathogen awareness appears to be a plausible explanation for *E. coli*; our result (90%) was obtained in 2001 and after the 1993 *E. coli* outbreak, while the result by McIntosh, Christensen and Acuff was obtained in 1991 and prior to the 1993 outbreak.[8] In addition, pathogen awareness may have been higher in 2001 than in 1993 due to the number of outbreaks, cases involved in the outbreaks, and food recalls in the recent past. *Salmonella* outbreaks numbered 80 in 1992 and 112 in 2001, *E. coli* outbreaks 3 in 1992 and 26 in 2001, and *Listeria* outbreaks none in 1992 and 2 in 2001; there was also a significant difference in the cases involved in *E. coli* outbreaks, from 19 in 1992 to 1293 in 2001 (CDC 2004). Pathogen awareness in 2001 may have also been aided by several recent large and highly publicized foodborne illness outbreaks associated with these pathogens. Examples of these outbreaks include: (1) the 1993 *E. coli* O157:H7 outbreak associated with undercooked hamburgers in which four children died (CDC 1993),[9] (2) the 1994 *Salmonella* outbreak associated with contaminated ice cream (CDC 1994), (3) the 1996 *E. coli* O157:H7 outbreak associated with apple juice in which one child died, (4) the 1999 *Salmonella* outbreak associated with unpasteurized juice in which one child died (CDC 1999), (5) more than two dozens of *Salmonella* and *E. coli* O157:H7 outbreaks associated with sprouts since 1995 (CDC 2002), (6) the1998 *Listeria* outbreak associated with hot dogs (CDC 1998), and (7) the 2000 *Listeria* outbreak associated with deli turkey meat (CDC 2000b). In addition, the number of voluntary recalls of foods due to potential risk of pathogen contamination was also higher in 2000, the year before the 2001 FSS, than in early 1990s, such as 1994. For example, there were 21 recalls of FSIS-inspected meat and poultry products due to *E. coli* contamination in 2000, while there were only 3 recalls in 1994 (USDA-FSIS 1994, 2000). Similarly, recalls doubled from 1994 to 2000 for FSIS-inspected meat and poultry products due to *Listeria* contamination (USDA-FSIS 1994, 2000).

Furthermore, based on the availability heuristic, the numbers of outbreaks, cases, and recalls may also explain why *Salmonella* is most heard of, *E. coli* second, *Listeria* next, and *Campbylobacter* least. Among the four pathogens examined in this study, epidemiological data show that, from 1993 to 2000, the annual numbers of outbreaks and cases are highest for *Salmonella* (706 and 41,470, respectively), second for *E. coli* (171 and 1,485, respectively), third for *Campylobacter* (57 and 1,313, respectively), and lowest for *Listeria* (12 and 274, respectively). Although there were more outbreaks and cases related to *Campylobacter* than *Listeria*, the awareness of *Listeria* could have been higher because the death rate is higher among Listeriosis victims than among campylobacterosis victims. The latest available data indicate that, during 1988–1997, three individuals died from four *Listeria*-related outbreaks while the same number of individuals died from 52 *Campylobacter*-related outbreaks (Bean et al.; CDC 2000a).

In contrast to the other three pathogens, the awareness of *Campylobacter* appears to be persistently low in both 1993 and 2001, and much lower than that of *Salmonella* or *E. coli*. Here, again, the availability heuristic may provide a partial answer to the disparity. CDC data have shown that, during the period of 1973–2000, *Campylobactor*-related outbreaks in the U.S. were consistently less frequent than outbreaks associated with the other two pathogens (Bean and Griffin; Bean et al.; CDC 2000a). Hence, consumers were more likely to recall information about *Salmonella* or *E. coli* than *Campylobactor*.

Our findings suggest that awareness of different pathogens is related to some common factors, such as awareness of potentially high risk foods and substances, college education, and higher household income. There is a strong and consistent relationship between the awareness of possible health problems related to eating sprouts, drinking juices, and mercury in some fish and pathogen awareness. Since consumers who have heard of these potentially risky foods and substance may pay more attention to food safety news and issues, they are also more likely to have heard of the four pathogens. The associations with college education and household income suggest that less educated consumers or those in lower-income households may put themselves under higher risk of foodborne illness due to lack of basic knowledge of microbial food safety. How to increase the awareness of these consumers therefore calls for more attention in food safety education.

The correlations between awareness suggest that the awareness of different pathogens is possibly related to some common factors not available in our data. For example, if the consumers who are more concerned about microbial food safety are more likely to look for information about the subject in the mass media, then they would also be more likely to have heard of more pathogens, especially the ones commonly mentioned. This may be a reason why the awareness of *Salmonella* and *E. coli* is correlated, because both have been frequently mentioned in the mass media (IFICF). On the other hand, the correlation between the awareness of *Campylobacter* and *Listeria* may be due to the fact that fewer outbreaks have been associated with these two pathogens, so they both are less likely to be recognized by consumers. Meanwhile, foodborne illness characteristics may also be a common factor that relates to the awareness of different pathogens. In particular, since deaths, especially among children, are more likely than mild symptoms (such as diarrhea) to attract consumer attention, then consumers would remember pathogens that are more often associated with deaths. Such is the case with both *Listeria* and *E. coli*; hence, the awareness of both pathogens is found to be correlated in our analysis.

Two other demographic subgroups appear to have less awareness of pathogens – males and those residing in a larger household. The finding that male consumers are less likely to have heard of *Salmonella* or *E. coli* is not surprising as previous food safety studies have repeatedly shown that male consumers, in general, are less interested in food safety issues and less likely to handle or prepare food safely (Albrecht; Adu-Nyako, Kunda and Ralson; Altekruse et al.; Klontz et al.). But the finding does signal a potential area that deserves more attention in food safety education. Since these two pathogens are major sources of foodborne illness and male consumers handle a lot of food preparation and grilling in the summer (ADA/ConAgra 2000b), increasing these consumers' awareness would be helpful in reducing foodborne illness. Consumers in a larger household may be less aware of the pathogens because there are more household chores that prevent them from paying more attention to food safety issues.

White, Black, and Hispanic consumers are less likely than others to have heard of *Campylobacter* or *Listeria*. Most notable is that among all race/ethnicity groups, Hispanic consumers are the least likely to have heard of three of the four pathogens, except for *Salmonella*. This phenomenon may be due to language barrier or different coverage of microbial food safety issues in Spanish media. While the reasons are worth investigation, the effectiveness of food safety education may benefit from paying special attention to these consumers as more Hispanic consumers may become vulnerable to foodborne illness. First, they are now the largest minority in the U.S. and their number is expected to grow rapidly (Pew Hispanic Center). Second, there is evidence that food safety information may not reach Hispanic consumers and they may be more likely to engage in risky food consumption practices than other race/ethnic groups (FDA-CFSAN/USDA-FSIS).

The age variation indicates that middle-age consumers, 30 to 49 years old, are more aware of these pathogens, except for *Campylobacter*. Meanwhile, there is a significant association between *Salmonella* and *Listeria* awareness and the presence of children younger than 5 years of age. These findings suggest that many consumers who have just started a family or are raising children have some knowledge of microbial food safety. Since these consumers may be preparing foods for multiple household members, including young children, their food handling and preparation practices can affect their own health and the health of other household members. Thus, it is important for food safety education to maintain or even increase food safety knowledge among these consumers, including awareness of pathogens that may cause foodborne illnesses.

In summary, this study found that there are noticeable variations in U.S. consumers' awareness of four major foodborne pathogens. Awareness of these pathogens also changed over time. It appears that the variations and changes are related to the number and severity of illnesses associated with these pathogens. The study also found that the awareness is associated with food safety perceptions, awareness of potentially risky foods and substances, food safety related behaviors and experience, and demographics. These findings suggest that increasing consumer awareness of major foodborne pathogens is a potentially useful way to help promote adoption of safe food handling practices. In addition, foodborne illnesses may be reduced by targeting consumer food safety education toward certain consumer subgroups such as males, Hispanic consumers, and middle-aged consumers.

Footnotes

1 Practices of food suppliers and food service establishments also play an important role in reducing foodborne illness. Examples of the inadequate practices that have been associated with foodborne illness outbreaks in the U.S. include cooking, cooling, reheating, cross-contamination, personal hygiene, cleaning of equipment or utensils, and contamination of raw food or ingredients (CAST 1994).

2 Per the Response Rate 5 defined by the American Association for Public Opinion Research, the response rate was computed as (completed cases (4,482)) / (completed cases (4,482) + initial refusals (2,170) + quits (1,724) + call-backs to complete cases (765) + respondents not available (480)) (AAPOR 2004).

3 The weight used in the study consists of two components: the design weight and the Census weight. The design weight is inversely proportional to the probability that an adult is selected; it takes into account the number of telephone lines and the number of adults in the household. The Census weight matches the sample distribution of 32 gender × education × race/ethnicity cells to the distribution in the 2001 U.S. Census Bureau's March Current Population Survey (U.S. Census Bureau 2001b). Finally, a weight is constructed to first account for the design weight and then the Census weight.

4 The univariate probit models together can be viewed as a restricted version of the multinomial probit with all error correlations set to zeros. The restricted log-likelihood is the sum of the univariate probit log-likelihood values.

5 Complete set of error correlation estimates for the multinomial probit and parameter estimates for the univariate probit models are available upon request from the authors.

6 The marginal effects of continuous explanatory variables on each awareness probability are derived by differentiating the probability (2) and evaluated at the weighted sample means of all explanatory variables. The effects of each binary explanatory variable are calculated by simulating a finite change in the variable (i.e., from 0 to 1) while holding all other variables at the sample means.

7 Although there is a noticeable difference in *listeria* awareness between our survey (32%) and Herrmann and Warland (52%), the reason is not clear. Our survey question was "have you heard of *Listeria* as a problem in food?" and theirs was "are you concerned about *Listeria* bacteria, or is that something you never have heard of?" Research has suggested that the percentage of survey respondents who say they are concerned about a subject matter is higher without first ascertaining awareness of the subject matter than otherwise (Sterngold, Warland and Herrmann). Hence, the difference between the two studies could be attributable to question wording differences.

8 Note, however, we used a national sample while McIntosh, Christensen and Acuff used a sample of Texans.

9 The outbreak occurred when the 1993 FSS had interviewed most respondents.

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Table 1. Multinomial Probit Estimates of Consumer Awareness of Foodborne Pathogens

	Salmonella		*Campylobacter*		*Listeria*		*E. coli*	
	Coefficient	Marg. effect	Coefficient	Marg. effect	Coefficient	Marg. effect	Coefficient	Marg. effect
CONSTANT	–0.416		–2.581***		–1.085***		–0.761**	
	(0.424)		(0.373)		(0.215)		(0.317)	
Risk perceptions								
FROMHOME	0.285**	0.010**	0.152	0.017	0.045	0.016	–0.145*	–0.033
	(0.157)	(0.004)	(0.108)	(0.013)	(0.067)	(0.024)	(0.089)	(0.021)
HOMERISK	0.174***	0.007***	0.057	0.006	0.032	0.011	0.026	0.006
	(0.055)	(0.003)	(0.061)	(0.006)	(0.032)	(0.013)	(0.043)	(0.009)
GERMRISK	0.114**	0.005**	0.048	0.005	0.056**	0.020**	0.050	0.011
	(0.048)	(0.002)	(0.051)	(0.005)	(0.027)	(0.010)	(0.041)	(0.009)
VULNER	0.009	0.000	0.027	0.003	0.041	0.015	0.025	0.005
	(0.043)	(0.002)	(0.052)	(0.005)	(0.030)	(0.010)	(0.037)	(0.008)
Food safety practices								
HANDSAFE	0.371***	0.019***	0.134	0.013	0.037	0.013	–0.077	–0.016
	(0.105)	(0.007)	(0.103)	(0.009)	(0.054)	(0.019)	(0.074)	(0.015)
HAMBURGER	–0.102	–0.004	0.105*	0.011*	–0.044	–0.016	0.113**	0.024**
	(0.068)	(0.003)	(0.056)	(0.006)	(0.032)	(0.011)	(0.048)	(0.011)

STOPBUY	–0.165	–0.008	0.130	0.014	–0.026	–0.009	–0.134*	–0.030*
	(0.103)	(0.005)	(0.094)	(0.011)	(0.055)	(0.019)	(0.075)	(0.018)
Awareness of other food safety issues								
SPROUTS	0.119	0.005	0.453***	0.061***	0.576***	0.218***	0.298**	0.057**
	(0.215)	(0.007)	(0.095)	(0.018)	(0.070)	(0.027)	(0.147)	(0.026)
JUICES	0.308**	0.011***	0.215***	0.024**	0.286***	0.104***	0.347***	0.068***
	(0.130)	(0.004)	(0.085)	(0.011)	(0.053)	(0.020)	(0.100)	(0.018)
MERCURY	0.759***	0.045***	0.196*	0.019*	0.200***	0.069***	0.572***	0.138***
	(0.101)	(0.009)	(0.110)	(0.011)	(0.057)	(0.020)	(0.078)	(0.021)
Foodborne illness and other diseases								
HEALTH	0.105	0.004	–0.005	0.001	0.130***	0.047***	0.085	0.018
	(0.097)	(0.004)	(0.091)	(0.009)	(0.050)	(0.018)	(0.080)	(0.017)
DISEASES	–0.136	–0.006	–0.106	–0.010	0.002	–0.001	0.031	0.006
	(0.120)	(0.006)	(0.148)	(0.013)	(0.072)	(0.025)	(0.086)	(0.018)
Meal preparation								
MEALPREP	0.039	0.002	0.012	0.001	0.085*	0.030*	0.025	0.005
	(0.095)	(0.004)	(0.090)	(0.009)	(0.051)	(0.018)	(0.071)	(0.015)

Demographics								
INCOME	0.191***	0.008***	0.085	0.009	0.140***	0.050***	0.174***	0.037***
	(0.053)	(0.003)	(0.056)	(0.006)	(0.029)	(0.010)	(0.041)	(0.009)
HHSIZE	–0.151***	–0.006***	–0.007	–0.001	–0.111***	–0.039***	–0.073*	–0.016*
	(0.058)	(0.003)	(0.058)	(0.006)	(0.031)	(0.011)	(0.044)	(0.009)
CHILD5	0.421***	0.013***	0.045	0.005	0.163***	0.059***	0.146*	0.030*
	(0.142)	(0.004)	(0.118)	(0.013)	(0.065)	(0.024)	(0.089)	(0.017)
FEMALE	0.484***	0.021***	0.149	0.015	–0.055	–0.020	0.206***	0.044***
	(0.106)	(0.005)	(0.094)	(0.010)	(0.055)	(0.019)	(0.078)	(0.017)
COLLEGE	0.203*	0.009*	0.568***	0.060***	0.279***	0.098***	0.266***	0.057***
	(0.111)	(0.005)	(0.097)	(0.013)	(0.048)	(0.017)	(0.082)	(0.019)
HISPANIC	–0.427	–0.026	–0.797***	–0.050***	–0.285**	–0.095**	–0.311*	–0.076*
	(0.266)	(0.022)	(0.215)	(0.012)	(0.136)	(0.042)	(0.166)	(0.046)
WHITE	0.659**	0.040*	–0.590***	–0.078***	–0.215**	–0.078*	0.375**	0.089**
	(0.272)	(0.023)	(0.144)	(0.025)	(0.111)	(0.041)	(0.168)	(0.042)
BLACK	–0.011	–0.000	–0.806***	–0.052***	–0.582***	–0.180***	–0.069	–0.015
	(0.275)	(0.012)	(0.192)	(0.011)	(0.126)	(0.033)	(0.172)	(0.039)
AGE1829	0.173	0.006	0.110	0.012	–0.045	–0.016	0.148	0.030
	(0.147)	(0.005)	(0.125)	(0.014)	(0.073)	(0.025)	(0.100)	(0.020)
AGE3049	0.399***	0.016***	0.059	0.006	0.175***	0.062***	0.157*	0.033*
	(0.132)	(0.005)	(0.099)	(0.010)	(0.057)	(0.021)	(0.089)	(0.019)

MWEST	0.123	0.005	–0.076	–0.008	0.098*	0.035*	–0.008	0.002
	(0.122)	(0.004)	(0.108)	(0.011)	(0.060)	(0.022)	(0.085)	(0.018)
WEST	–0.069	–0.003	–0.240**	–0.022**	–0.358***	–0.119***	–0.051	–0.011
	(0.112)	(0.005)	(0.122)	(0.010)	(0.072)	(0.022)	(0.101)	(0.023)
NEAST	0.237*	0.008**	–0.007	–0.001	0.008	0.003	0.217**	0.043**
	(0.138)	(0.004)	(0.115)	(0.012)	(0.064)	(0.023)	(0.103)	(0.019)
% predicted	96.42		90.68		69.35		93.01	
Pseudo R^2	0.139		0.073		0.143		0.012	

Note: Log-likelihood = –3455.034. Asymptotic standard errors in parentheses. Levels of statistical significance: *** = 1%, ** = 5%, * = 10%.