ABSTRACT

MOORE, CHRISTINA MELISSA. Integrating Food Safety Risk Assessment and Consumer-Focused Risk Communication. (Under the direction of Dr. Lee-Ann Jaykus).

This thesis integrates food safety risk assessment and health psychology models to produce effective, consumer-focused risk communications.

Chapter One describes a probabilistic model of the role of domestic food handling behaviors on salmonellosis risk. Undercooking was found to have a great impact on the likelihood of disease resulting from consumption of eggs and egg-containing foods. This type of quantitative analysis provides a foundation of scientific knowledge for further risk communications.

The second study, a national Web-based survey, was conducted to measure consumer awareness and knowledge of *Listeria monocytogenes*. Awareness was lower among adults aged 60 and older (an at-risk population for listeriosis) and individuals with relatively less education and lower incomes. Men, more-educated individuals, and individuals living in metropolitan areas, were more likely to engage in risky food storage practices. This study identified the need to develop targeted risk communications regarding listeriosis prevention.

The third manuscript describes how theoretical behavioral models may be applied to modify consumer food storage and handling practices. This paper introduces three types of behavior models: motivation models, behavior enaction models, and stage theories. Application of such traditional public health theories to the field of food safety education offers a means to improve the efficacy of future educational campaigns.

The fourth paper explores consumer perspectives on the levels of responsibility and control that they have over the safety of the US food supply. Respondents rated consumers as having less responsibility and control than other key food chain members. Education to empower the consumer should be focused at groups who cook infrequently and so do not have much experience with food safety procedures.

The fifth manuscript describes a public health intervention (a listeriosis prevention fact sheet) aimed at seniors, developed from multiple focus groups. Subjects discussed their impressions of the fact sheet, any changes that they made based on the information provided, and barriers to their adoption of the recommended practices. Adoption of the recommended practices was not widespread because many participants were not concerned about contracting listeriosis.

Integrating Food Safety Risk Assessment and Consumer-Focused Risk Communication

by
Christina Melissa Moore

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APPROVED BY:

Dr. Lee-Ann Jaykus Chair of Advisory Committee	Dr. Donn Ward
Dr. Peter Cowen	Dr. Toby TenEyck
Dr. Brian Sheldon	

DEDICATION

To those who follow . . . .

Icarus flew too near the sun . . . and drowned. I am a modern Icarus. I woke up one morning and found myself trapped in a labyrinth of 5-6 page papers on various assigned topics, trapped in a lecture hall, listening to a pedagogical monologue that had been rehearsed for 15 years. When I began my graduate studies, I found my wings.

It was one day in class that I first decided to strap on my wings. I glided steadily along with the lecture until at last I took courage and swooped in with a comment on real-life applications. The experience was exhilarating!

I carried my wings with me often after that first flight. Sometimes I wore them into class with me, and sometimes I made solo flights. I found myself fervent with the sensation of the wind in my face, and so I turned the pages faster. Each time I flew higher, higher into the sky. My heart beating wildly, I flapped, or flipped, swiftly, more pages.

Time was running out. I could sense it. There would be a time when I could no longer fly, but not yet. There is so much left to read! I flapped harder, at breakneck speeds, disregarding others' warnings that I must come down. It is time to write. But I knew that I couldn't stop . . . *I was already too high.*

Icarus was imprisoned in the Minotaur's labyrinth with his father, Daedalus. One day his father constructed two fine pairs of wings, which they would use to escape. "Now, Icarus," Daedalus warned, "Take heed not to fly too high or the sun will melt the wax which holds the feathers to your wings." But finding himself aloft, the miniature world at his feet, Icarus, climbing higher yet, flew too near the sun! The sun's brilliant heat melted the wax, and Icarus fell into the Aegean . . . and drowned.

I, a modern Icarus, plummeted from the sky, but when I hit the treacherous waters below . . .
I found that I could swim!

BIOGRAPHY

On May 23rd, 1976, Christina Melissa Moore was born to Mary Moore and Dr. Nathan Moore in Walla Walla, Washington. Several years later, her family moved south to Montgomery, Alabama, where she spent the rest of her childhood and high school years. In 1994, Christina enrolled at Rhodes College, a small, liberal arts college in Memphis, Tennessee. Christina spent her freshman summer in a Howard Hughes Internship working with Drs. Amarat Simonne and Nancy Greene at the Department of Food Science at Auburn University, Alabama. She presented an abstract describing her work with edible films on sweet bell peppers at the 1996 Institute of Food Science Convention in New Orleans, Louisiana. Christina spent her Junior year in Paris, France, where she studied microbiology, cell physiology, *and cheese*. During her senior year, Christina worked as an intern for six months at Flavorite Laboratories, Inc., a spice-blend ingredient company in Memphis, Tennessee. In 1998, she graduated from Rhodes College with a Bachelor of Science degree in Biochemistry and a minor in French. In the fall of 1998, she began her graduate studies in Food Science at North Carolina State University where she joined Dr. Brian Sheldon's laboratory in the Department of Poultry Science. In the year 2000, she was inducted into Phi Tau Sigma, the National Honorary Society for Food Science, and Phi Kappa Phi, the National Honor Society of North Carolina State University. She earned a Master of Science degree in Food Science in the summer of 2001 for her work studying the application of time temperature integrators (TTIs) to fresh poultry products. Subsequent to the Master's degree

Christina enjoyed herself developing three web-based courses on food microbiology, sweeteners, and sanitation standard operating procedures.

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Thank you, Toby, for bearing with all the “quick questions” that weren’t so quick after all. Thank you, Donn Ward, for introducing me to the world of web-based courses – the skills that I learned are a source of joy and pride to me. Thank you, Peter, for your whole-hearted and steady belief in me. Thank you, Dr. Hoban, for your contributions to my dissertation and my graduate career. Lee-Ann, words always fail me when I try to describe my appreciation towards you. You are my mentor and my friend, and I thank you.

My sincere gratitude extends to Dr. Jason Osborne who helped me to wade through the statistics of my work. I would also like to express my gratitude to the Department of Food Science--they gave me a home for my work and a family of friends and supporters. Susie Kall, Sue Strong, Julibeth Briseno, and Shirley Lyles, each of you performed miracles for me . . . . thanks to you all! To my fellow graduate students and colleagues, I am grateful for your encouragement and for your example. Thank you to my friends Lynette, Efi, and Carol – my own private cheerleaders.

Mother, thank you for your support and steadfast trust in my abilities. Father, thank you for teaching me always to do my best and reminding me to offer the world a “lagniappe,” that little something extra that makes my work special. I cherish you both.

My deepest appreciation is to my love, Sam. The greatest frustrations fell into the proper perspective, and the most obscure concepts magically became clear when describing them to you. With you, I am smarter . . . stronger . . . happier. —*Christina*

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INTRODUCTION

Foodborne illnesses are estimated to infect 76 million Americans each year and are often underreported. Despite extensive public health campaigns, consumers fail to take an active role in protecting themselves and their families against foodborne illness. Consumers remain unaware of their susceptibility and undermotivated to act. The role of food safety risk communication is to inform the public of the food safety risks they face, of methods to protect themselves, and arguably to motivate the public into action. Yet food safety risk communication is not as simple as knowledge dissemination.

In order to study means of reducing foodborne illness of a domestic etiology, this dissertation has taken a multidisciplinary approach, combining methodologies from the fields of risk assessment, social psychology, statistics, and epidemiology. The dissertation is funded by two grants (Human Disease Risk from RTE Foods Contaminated by Poor Handling Practices; Designing Effective Risk Communication Messages Based on Microbial Risk Assessment Outcomes) with co-investigators from multiple fields of study. The focus of the grants was to study domestic food handling practices, determine the link between the behavior and foodborne illness, and identify appropriate methods to communicate the risks to the public. How this was achieved is delineated in the chapters that follow.

Chapter 1 is a risk assessment linking salmonellosis cases to domestic food handling. This type of analysis provides the scientific knowledge foundation for further risk communications. Chapter 2 is a population-based survey of deli meat-handling practices within the American population. The result of this report is useful in identifying public knowledge gaps as well as guiding the risk communicator as to which segments of the population are using risky practices and need to be targeted for subsequent risk communications. Chapter 3 of the dissertation is a concept paper describing how theory can be used to guide the development of a risk communication. This report identifies the types of content that need to be included in a risk communication in order to motivate consumers to act. Chapter 4 explores consumers' beliefs about the responsibility and capabilities of the public to protect themselves against foodborne illness. These factors may have a significant impact on people's willingness to act on their behalf and may need to be addressed in any food safety risk communication campaign. Chapter 5 employs focus groups to probe elderly consumers' knowledge and attitudes regarding listeria and listeriosis prevention activities. Additionally, focus groups read and responded to proposed risk communication materials, evaluating the effectiveness of the planned intervention. In summary, the components of this dissertation describe key methods to developing food safety risk communications from inception to intervention.

CHAPTER 1: CONSUMER-PHASE SALMONELLA ENTERICA SEROVAR ENTERITIDIS RISK ASSESSMENT FOR EGG-CONTAINING FOOD PRODUCTS

Abstract:

We describe a one-dimensional probabilistic model of the role of domestic food handling behaviors on salmonellosis risk associated with the consumption of eggs and egg-containing foods. Six categories of egg-containing foods were defined based on the amount of egg contained in the food, whether eggs are pooled, and the degree of cooking practiced by consumers. We used bootstrap simulation to quantify uncertainty in risk estimates due to sampling error and sensitivity analysis to identify key sources of variability and uncertainty in the model. Because of typical model characteristics such as nonlinearity, interaction between inputs, thresholds, and saturation points, Sobol's method, a novel sensitivity analysis approach, was used to identify key sources of variability. Based on the mean probability of illness, examples of foods from the food categories ranked from most to least risk of illness were: (1) home-made salad dressings/ice cream; (2) fried eggs/boiled eggs; (3) omelets; and (4) baked foods/breads. For food categories that may include uncooked eggs (e.g., home-made salad dressings/ice cream), consumer handling conditions such as storage time and temperature after food preparation were key sources of variability. In contrast, for food categories associated with undercooked eggs (e.g., fried/soft-boiled eggs), the initial level of *Salmonella* contamination and the $\log_{10}$ reduction due to cooking were the key sources of variability. Important sources of uncertainty varied with both the risk percentile and the food category under consideration. This work adds to previous risk assessments

focused on egg production and storage practices, and provides science-based data to inform consumer risk communications regarding safe egg-handling practices.

1.0 Introduction

A *Salmonella enterica* serovar Enteritidis (SE) epidemic in the United States began in New England in 1978 and spread to much of the rest of the country in the next decade. The predominant source of SE is contaminated shell eggs. Despite national initiatives to control human salmonellosis caused by SE contaminated eggs, the disease remains a national health concern. The most recent FoodNet Data from CDC indicates large, statistically significant reductions in most major foodborne pathogens; unfortunately, the prevalence of salmonellosis due to SE has not been significantly reduced since FoodNet baseline data collection began in 1996-1998.[(1)] Intervention programs have largely been focused at the production (farm) and processing levels. Voluntary state or industry sponsored egg quality assurance programs (EQAPs), based on the principles of the Hazard Analysis and Critical Control Point (HACCP) system, have played a major role in reducing salmonellosis. A recent report indicates that a 1% increase in the number of eggs produced under an EQAP was associated with a 0.14% decrease in SE incidence.[(2)]

Although the number of foodservice and institutional outbreaks of salmonellosis appears to have declined due to the use of pasteurized eggs in pooled batches of eggs, CDC data suggest that domestic outbreaks and sporadic illnesses have increased.[(3)] Epidemiological studies have revealed a correlation between salmonellosis and consumer behaviors concerning egg handling and consumption.[(4-6)] However, the number of SE interventions focused at the consumer level has been relatively limited.

Morris summarized risky consumer factors associated with the transmission of SE by eggs as including poor refrigeration practices, improper storage of pooled eggs, use of raw eggs, time and temperature effects, and exposure of highly susceptible individuals.[7] Examples of unsafe egg consumption and handling practices at home include use of raw eggs in foods, holding eggs and egg-containing food at room temperature, undercooking eggs and egg-containing foods, and pooling eggs.[3,8,9] There is clearly a need to understand how consumer behaviors of eggs and egg-containing products affect the risk of salmonellosis and to determine whether control programs aimed at consumers would be effective at reducing salmonellosis incidence further.

The purpose of this study was to create a one-dimensional probabilistic model of the role of domestic storage and handling behaviors on salmonellosis risk associated with eggs and egg-containing food products. The model incorporates variability in inputs using updated information about consumer egg consumption and handling collected from a web-based consumer survey.[10] Subsequent analysis was used to evaluate the robustness of the risk estimates with respect to the assumptions made in the model and to identify critical future research needs. Sensitivity analysis was used to identify consumer handling behaviors that contribute most to salmonellosis risk or that may be used as domestic control measures. What-if scenario analyses were used to identify possible control points for reducing the risk of salmonellosis associated with these food products.

2.0 Model Development

2.1 Hazard Identification

According to the Centers for Disease Control (CDC) foodborne illness surveillance (FoodNet), *Salmonella* species remain one of the two leading causes of bacterial foodborne infection in the United States. [1] Responsible for an estimated 10% of foodborne illnesses, 26% of hospitalization, and 31% of deaths in the US, non-typhoidal *Salmonella* is the leading cause of deaths and hospitalizations associated with known bacterial foodborne pathogens .[11] FoodNet surveillance in 2004 indicates an overall salmonellosis incidence of 14.7 per 100,000 persons, compared to 12.9 for *Campylobacter* and 5.1 for *Shigella.*[1]

Ranked after S. Typhimurium, S. serovar Enteritidis (SE) has emerged as the second most common cause of salmonellosis.[1] Infection of laying hens with SE and the resultant contamination of eggs are believed to be the important sources of contamination that subsequently result in illness.[12-14] During 1990-2001, the U.S. state and territorial health departments reported 677 SE outbreaks, and among the 309 outbreaks with a confirmed vehicle of transmission, 241 (78.0%) were associated with shell eggs. The cost associated with human salmonellosis due to SE is estimated to range from $150 to $870 million annually.[15] The President's Council on Food Safety Egg Safety Action Plan (ESAP) was formulated with the goal that egg-associated SE illness should be reduced by 50% by 2005 and eliminated by 2010.[8]

Two country-specific farm-to-table risk assessments for SE illness associated with eggs were conducted by the Food Safety Inspection Service/US Department of Agriculture [15] and Health Canada[16], and a worldwide farm-to-table model was developed by World Health Organization (WHO) and Food and Agriculture Organization (FAO) based on the US and Canadian models.[17] Risk assessments performed by other researchers evaluated the risk of SE illness associated with cracked eggs, [18] pasteurized liquid eggs, [19] egg storage and transportation, [20] egg production, [21] and egg consumption and handling behaviors in the home.[7] The effects of time and temperature during egg collection, processing, transportation and storage have also been evaluated.[20, 22-24]

2.2 Exposure Assessment

In this study, the exposure to SE associated with the consumption of eggs and egg-containing foods following domestic storage and preparation was estimated for six food categories. In previous exposure assessments,[15-17] consumer preparation and handling behaviors were modeled largely by personal assumptions. In order to reduce uncertainty associated with consumer-related behaviors, several inputs (discussed later in the paper) were informed by a national, web-based consumer survey including only participants that regularly purchased eggs (n=1,076). Demographic details of survey participants are summarized elsewhere. [10]

A schematic diagram of the exposure assessment is given in Fig. 1.1. The model was coded in Matlab (The MathWorks, Natick, MA). The six food categories are summarized in Table 1.1 and further explained in Section 2.4. Inputs in the exposure assessment section include initial contamination levels and prevalence, consumer behaviors concerning egg handling and consumption, and the kinetic parameters for SE growth and inactivation. Table II summarizes the list of the inputs and their corresponding probability distributions.

2.3 Initial contamination

Shell eggs may be contaminated internally due to vertical transmission from the hen's ovaries to the egg yolk. To estimate the probability that an internally contaminated egg is used during meal preparation, first, the prevalence of internally contaminated shell eggs at home was specified as 1×10^{-5} based on the annual incidence of SE-contaminated eggs.[25]

Next, the total number *N* of eggs used during meal preparation was modeled based on data from our consumer behavior survey; the probability that *n* contaminated eggs are selected for a single food preparation that includes *N* eggs was modeled as a binomial distribution. The level of SE per contaminated egg was based on a farm-to-table exposure model for the level of SE in raw shell eggs due to vertical transmission.[20] The exposure model output, expressed as a probability distribution ($\log_{10}$ SE CFU/egg) for eggs stored in the consumer household, was used as the initial contamination level input for this model.

Most shell eggs are not internally contaminated.[25] However, egg-containing foods may be contaminated with SE located externally on the shell. Although SE organisms on eggshells die rapidly, their survival is enhanced by high relative humidity and low temperature during storage.[26,27] Limited data show that the prevalence of SE contamination on eggshells ranges between 0.3% and 19%.[28-30] A Pert (0.001, 0.1, 0.2) distribution was used to account for variability in the prevalence of SE contamination on eggshells. The number of SE cells transferred during food preparation from an individual contaminated eggshell to the egg content (CFU/egg) was expected to vary between 0 and 20 with a uniform distribution.[31]

2.4 Consumer preparation and handling

In order to evaluate the impact of consumer preparation and handling on levels of SE in egg-containing foods, the foods were classified into six categories (Table 1.1) representing combinations of three key preparation and handling behaviors, i.e., pooling of eggs, the use of the egg (as an egg dish or as an ingredient), and the degree of cooking. These three consumer behaviors have been shown to impact the final number of SE cells in the food at consumption.[15-17]

More eggs become contaminated when non-contaminated and contaminated eggs are pooled. Pooling eggs has been recognized as a major risk factor associated with SE outbreaks in foodservice and institutions.[3,8] However, the effect of pooling is relatively minor during domestic handling because of the limited number of eggs used in a single instance of food preparation. Furthermore, when multiple servings are prepared at the same time, pooling has a dilution effect with respect to the levels of SE contamination per serving. Pooling was assumed for foods in Categories III-VI, e.g., scrambled eggs and in foods for which eggs were used as an ingredient. The number of eggs pooled for a single food preparation event was modeled using a discrete distribution based on the consumer behavior survey.

Eggs may be used as eggs or as ingredients within foods. Categories I, II, and III considered eggs as egg dishes; Categories IV, V, and VI considered eggs as ingredients. Eggs used for the preparation of egg dishes comprised nearly 100% of the entire food product; when eggs were used as ingredients, they comprised a variable amount of the total food content, ranging from 5% to 85%, depending on the category. [32,33] Typically, a lognormal distribution was considered for the portion of eggs used in each food category. Each distribution was truncated between 0 and 1.

For the cooking step, three possibilities were modeled: thorough cooking, under-cooking, and no cooking. Data from our consumer behavior survey was used to determine the frequency that foods are prepared according to each of the three alternatives. For example, 51% of respondents reported thoroughly cooking foods in Category I and 98% of respondents reported thoroughly cooking foods in Category VI. Next, the effectiveness ($\log_{10}$ SE reduction) of each alternative was modeled. For all foods, thorough cooking was modeled to reduce between 6 and 8 $\log_{10}$ of SE.[15] The effect of undercooking varied for different categories (Table 1.2). For example, partial cooking for foods in Category I was expected to result in $\log_{10}$ reductions varying between 0 and 7 following a Pert distribution, with the most likely value of 4; however, undercooked foods in Category II were most likely to result in a one $\log_{10}$ reduction.[15] Foods in Category IV were most likely to contain raw egg as an ingredient.[16] Approximately 25% of respondents reported preparing Category IV foods with uncooked eggs. No reduction in SE was modeled for uncooked foods.

SE organisms were expected to be capable of growth during countertop storage and preparation prior to cooking. After the cooking step, the growth of surviving SE cells in the prepared food was modeled. Multiple predictive microbial growth models for *Salmonella* have been developed [34-37] including functions such as the Gompertz equation, [37] the exponential growth rate (EGR) model, [16] and the response surface model.[38] For this study, the latter model is used for estimation of growth.[20] The response surface model is based on previously reported growth kinetic data for *Salmonella enterica* serovar Typhimurium [38] and was used as a surrogate for SE growth in this study. The model can be mathematically expressed as:

$$\lambda = \exp(a_0 + a_1(NaCl) + a_2 \times T + a_3(NaCl \times T) + a_4(NaCl \times NaCl) + a_5 \times T^2) \qquad (1)$$

$$\mu = \exp(b_0 + b_1(NaCl) + b_2 \times T + b_3(NaCl \times T) + b_4(NaCl \times NaCl) + b_5 \times T^2) \qquad (2)$$

where,

λ = lag time (hr)

μ = growth rate $(\log(\frac{CFU}{egg \times hr}))$

$NaCl$ = the concentration of sodium chloride; 0.5% for the yolk contents

T = storage temperature (^{o}C)

a_i = parameter estimates; $a_0 = 5.911$, $a_1 = -0.2013$, $a_2 = -0.2754$, $a_3 = -0.0013$, $a_4 = 0.0333$, $a_5 = 0.0033$

b_i = parameter estimates; $b_0 = -6.2251$, $b_1 = -0.0114$, $b_2 = 0.3234$, $b_3 = 0.0020$, $b_4 = -0.0085$, $b_5 = -0.0045$

The duration of food preparation, which was assumed to take place at room temperature, was assumed for all categories to range with equal probability between 0 and 2 hours. To estimate the countertop storage time after cooking, a discrete probability distribution was developed from self-reported consumer behaviors. For foods in Categories I, II, and III, the maximum storage time was truncated at 6 hours. For foods in Categories IV and V, the maximum storage time was truncated at 24 hours in order to take into account the extra storage time for leftovers. For foods in Category VI, growth during countertop storage was not modeled as these products have low water activity and would be unlikely to support the growth of the pathogen.

Prior to preparation, the eggs were assumed to be stored in the refrigerator [39], and no growth was modeled. During meal preparation, the temperature of the eggs was assumed to range between 4ºC (directly from the refrigerator) and 21ºC (room temperature). The most likely temperature during preparation was assumed to be 10ºC. After cooking, the temperature of the foods was assumed to range between 4ºC (refrigeration temperature) and

35ºC, with the most likely temperature 21ºC (room temperature). Countertop storage temperatures lower than room temperature are considered for eggs prior to cooking because it is assumed that the eggs were taken out from the refrigerator not long before the cooking process. Consistent with reported data, no growth was modeled for eggs stored at temperatures below 10^{o}C.[40-42] The maximum level of SE was limited to 9.5 $\log_{10}$ CFU/egg [20] and 8 $\log_{10}$ CFU/g food for countertop storage before cooking and after cooking, respectively, considering that foods with more contamination will be discarded because of obvious signs of spoilage.[43]

2.5 Dose Response

The dose-response relationship used in the SE model is based on the relationship suggested by WHO/FAO.[17] The model has a Beta-Poisson functional form as:

$$P_{ill} = 1 - \left(1 + \frac{Dose}{5587}\right)^{-0.4047} \quad (3)$$

where,

P_{ill} = probability of illnesses

$Dose$ = intake of Salmonella (CFU/serving)

Probability of illness per serving for each of the six food categories is estimated. The relative consumption proportions for each food category were used to aggregate individual probabilities in order to estimate the overall probability of illness from consumption of eggs and egg-containing foods per serving.

3.0 Model Analysis

In order to estimate the probability of SE illness resulting from consumption of eggs and egg-containing food on a per serving basis, Monte Carlo simulation was used and probability distributions of inputs were propagated through the model. The number of iterations for all simulations was 10,000. Each iteration represented a single possible egg-handling scenario. The Latin Hypercube sampling technique was used to sample from probability distributions of inputs.

3.1 Bootstrap Simulation for Quantification of Uncertainty

Uncertainties in the hazard, exposure, and dose-response information may result in unrealistic risk estimates. Sources of uncertainty can include problem and scenario specification, model uncertainty, sampling error, lack of representativeness, lack of empirical basis, and disagreement of experts.(44) The first two sources of uncertainty are related to structural uncertainty, while the rest are related to uncertainty in model inputs. Probability distributions of model inputs are typically based on analysis of available data. Typically, parameters of those distributions (e.g., geometric standard deviation of a lognormal distribution) are estimated using relatively small sets of sample data. Thus, there is uncertainty in the estimates of these statistics due to sampling error. Quantification of sampling error may be done using classical statistical techniques or numerical simulation methods. We used bootstrap simulation to quantify uncertainty due to sampling error in different percentiles of the estimated risk of SE illness. Bootstrap simulation is a numerical technique originally developed for the purpose of estimating confidence intervals for statistics.(45) Typically, bootstrap simulations are repeated a number of times to evaluate numerical stability of the output distribution by comparing results among the multiple bootstrap simulations.

Bootstrap simulation uses a conceptually straightforward approach. In the case of the SE model, a random sample, referred to as the "bootstrap sample," was generated from each of the probability distributions developed or assumed for inputs. The maximum likelihood estimation (MLE) approach was used to fit a probability distribution to each of the bootstrap samples. For example, for the initial contamination with a lognormal distribution, the MLE approach was used to fit a new lognormal distribution to the corresponding bootstrap sample. The parameters of the new distribution differ from those for the original distribution, representing uncertainty due to sampling error.

The number of bootstrap replications required depends upon the information needed. For example, to calculate the standard error of a statistic, Efron and Tabshirani [(45)] suggest 200 or fewer bootstrap replications. However, for estimation of confidence intervals, more replication may be required. We considered 200 bootstrap replications to be satisfactory for this study.

3.2 Sensitivity Analysis for Identification of Key Sources of Uncertainty

In order to prioritize data collection activities, it is useful to prioritize the key sources of uncertainty. Because uncertainty results from lack of knowledge and specifically, as addressed in this paper, from lack of proper and representative data, the collection of additional data is the only viable method for reducing uncertainty. In many cases, the uncertainty in the model output may be influenced by only a subset of the model inputs and their corresponding assumptions, also known as key sources of uncertainty. It would be a poor allocation of scarce resources to spend an equal amount of time collecting data and developing probability distributions for all model inputs, if the output is sensitive to only a small number of inputs.

The key sources of uncertainty for each food category were separately identified for the mean, 95^{th}, and 99^{th} percentiles of the probability of SE illness. Spearman correlation coefficients [46-48] were used to identify the key sources of uncertainty. Spearman correlation coefficients evaluate the strength of nonlinear but monotonic association between paired rank transformed input and output values. Inputs were ranked based upon the relative magnitude of statistically significant Spearman correlation coefficients with a significance level of 5%.

3.3 Sensitivity Analysis for Identification of Key Sources of Variability

Knowledge of key sources of variability can guide the identification of significant subpopulations that merit more focused study or the targeting of risk management strategies to controllable sources of variation in exposures in the form of possible critical limits for potential critical control points in the model. The choice of a sensitivity analysis method depends on the characteristics of the model.[49] Typical characteristics of quantitative microbial food safety process risk models are nonlinearity, interaction between inputs, thresholds and saturation points in the model response, and use of both categorical and continuous inputs.[50] An ideal sensitivity analysis method is independent from assumptions about the model structure.[51] Specifically, a sensitivity analysis method should not require any assumptions regarding the functional form of the risk model and should be applicable to different model formulations.

Sobol's method [51,52] can cope with both nonlinear and non-monotonic models and does not assume any functional form for the model. Sobol's method provides a truly quantitative ranking of inputs and not just a relative qualitative measure.[53] The types of influences on an input that are captured by Sobol's method include those that are additive, non-linear and/or with interactions. Sobol's method has been used for sensitivity analysis of computationally complex models; [51,54] however, we believe this is the first application of the Sobol's method in the field of quantitative microbial risk assessment. We selected Sobol's method for identification of key sources of variability because of its unique advantages compared to the typical sensitivity analysis techniques such as regression-based methods. These advantages are further illustrated in the results and discussion sections.

The main idea behind Sobol's method is the decomposition of the function *f(x)* including *k* inputs into summands of increasing dimensionality [53]:

$$f(x_1,......x_k) = f_0 + \sum_{i=1}^{k} f_i(x_i) + \sum_{i=1}^{k}\sum_{j=i+1}^{k} f_{ij}(x_i,x_j) + ... + f_{1,2,......,k}(x_1,....,x_k) \quad (4)$$

The total variance *D* of *f(x)* and the partial variances from each of the terms in Equation (4) are computed as:

$$D = \int f^2(x)dx - f_0^{\ 2} \quad (5)$$

$$D_{i_1,......,i_s} = \int_0^1 ....\int_0^1 f_{i_1,....,i_s}(x_1,...,x_s)dx_{i_1}......dx_{i_s} \quad (6)$$

where $1 \le i_1 < \ldots < i_s \le k$, s=1,.., *k*, and *k* is the number of inputs. By squaring and integrating Equation (4) over the *k*-dimensional input space we have:

$$D = \sum_{i=1}^{k} D_i + \sum_{i=1}^{k}\sum_{j=i+1}^{k} D_{ij} + ... + D_{1,2,....k} \quad (7)$$

Thus, a sensitivity measure $S(i_1, \ldots, i_s)$ is defined as

$$S_{i_1,\ldots\ldots,i_s} = \frac{D_{i_1,\ldots\ldots\ldots\ldots,i_s}}{D} \qquad \text{for } 1 \le i_1 < \ldots < i_s \le k \tag{8}$$

where S_i is called the first-order sensitivity index for input x_i, which measures the main effect of x_i on the output representing the fractional contribution of x_i to the variance of f(x). S_{ij}, for $i \neq j$, is called the second-order sensitivity index which measures the interaction effect between x_i and x_j. The interaction effect is the part of the variation in $f(x)$ due to x_i and x_j that cannot be explained by the sum of the individual effects of x_i and x_j. The decomposition in Equation (7) has the useful property that all the terms in Equation (8) sum to one; that is,

$$\sum_{i=1}^{k} S_i + \sum_{1 \le i < j \le k} S_{ij} + \ldots + S_{1,2,\ldots,k} = 1 \tag{9}$$

Sobol's method can also provide insight regarding the total effect of each input. The total effect of an input, which includes both the main effect as well as interaction effects of any dimensionality, is defined as the sum of all the sensitivity indices involving that input.[52,55] For example, if there are three inputs x_1, x_2 and x_3, the total effect of x_1 is given by $S(x_1) + S(x_1 \times x_2) + S(x_1 \times x_2 \times x_3)$, where $S(i)$ is the sensitivity index of the term i. Thus, the total effect of x_i can be estimated as:

$$TS_i = S_i + S_{i(\sim i)} = 1 - S_{\sim i} \tag{9}$$

where $S_{\sim i}$ is the sum of all the $S_{i_i,\ldots,i_s}$ terms that does not include the index i, i.e., the total fractional variance complement to input x_i, $D_{\sim i}$. Thus, the total contribution of input x_i to the total output variation is given by:

$$TS_i = 1 - \frac{D_{\sim i}}{D} \tag{10}$$

Note that the total effects of inputs do not provide a complete characterization of the sensitivity. However, the total effects are much more reliable than the first-order (main effects) indices in order to investigate the overall effect of each single input on the output.

The algorithm for estimation of main and total effects associated with each input was coded into our model in Matlab (The MathWorks, Natick, MA).

3.5 What-If Scenario Analysis

What-if scenarios were conducted for inputs which were identified as key sources of variability. For each what-if scenario analysis, the selected input was varied and the resulting changes in the model outputs were collected. For example, countertop storage time was varied between 0 and 48 hours. Within each simulation, the values of other input variables were randomly sampled from their corresponding distributions with a total of 10,000 iterations.

4.0 Results

4.1 Probabilities of SE Illness for Different Food Categories

The first step in the SE risk assessment was to estimate the illness from consumption of eggs and egg-containing foods (illness/serving). Considering a binomial distribution for the number of contaminated eggs, the probability associated with the number of contaminated eggs depends on the total number of eggs used in a single serving. For example, if one egg is used, the probability that a contaminated egg is selected is 5×10^{-5} (data not shown). This probability is higher if more than one egg is used in a serving. Our consumer survey indicated that typically 96 to 98 percent of foods in Categories III to VI (e.g., omelets, baked foods, bread) are prepared with fewer than 10 eggs. Thus, for those food categories, the probability of using an SE-contaminated egg varies between 5×10^{-4} and 5×10^{-5}. Because of the low probability of selecting an SE-contaminated egg, typically 99.9 to 99.99 percent of food preparation scenarios in a Monte Carlo simulation were identified as having no contamination. To avoid overwhelmingly large numbers of iterations with no (zero) contamination, we modeled only food preparations containing at least one contaminated egg.

Table 1.3 summarizes the estimated illness from consumption of eggs and egg-containing foods (illness/serving) prepared using SE-contaminated eggs. The mean estimated risk is as high as 2.05×10^{-4} for Category IV (home-made ice cream) and as low as 2.59×10^{-10} for Category VI (bread). The actual probability of illness from consumption of eggs and egg-containing foods is expected to be 4 to 5 logs lower if preparation with no contaminated eggs is taken into account. Considering the mean probability of illness when SE-contaminated eggs are used in domestic food preparation, the ranking of the six food categories for the risk of SE illness is: (1) Category IV (home-made ice cream); (2) Categories I and II (fried eggs and boiled eggs; (3) Category III (omelets); and (4) Categories V and VI (baked foods and bread). Risks for foods in Categories I and II and for foods in Categories V and VI are considered to be comparable.

4.2 Quantification of Uncertainty

The results of 200 bootstrap replications are summarized in Table 1.4 for the mean, 50^{th}, 75^{th}, 95^{th}, and 99^{th} percentiles of the distribution. Typically, the bootstrap results showed a wide range of uncertainty in estimates of the probability of SE illness for the mean and selected percentiles. However, for some food categories and for selected percentiles, there was no uncertainty range. For example, while there was no uncertainty in estimates of the 50th and 75th percentiles of risk for foods in Category II (e.g., boiled eggs), the mean probability of illness for this category had a 95% probability range between 5.6×10^{-5} and 2.4×10^{-3}. Considering the range of uncertainty associated with the mean probability of SE illness, the ranking of the six food categories for the greatest uncertainty to the least was as follows: (1) Category IV (home-made ice cream); (2) Categories I and II (fried eggs and boiled eggs; (3) Category III (omelets); and (4) Categories V and VI (baked foods and breads). Thus, the mean probability of SE illness due to consumption of foods in Category IV had the highest uncertainty. In contrast, foods in Category V had the lowest uncertainty with respect to the mean probability of SE illness per serving. The ranking of different food categories based on the magnitude of uncertainty associated with mean probability of illness is similar to the ranking based on the magnitude of risk (Section 4.1), i.e. food categories with higher risk of illness have larger uncertainty associated with the risk. However, this finding is specific to our model and it may not be the same for other risk assessment models.

4.3 Identification of Key Sources of Uncertainty

The key sources of uncertainty for each food category were separately identified for mean, 95th, and 99th percentiles of the probability of SE illness using Spearman correlation coefficients (Fig. 1.2). Results shown in Fig.1.2 are consistent with those given in Table 1.4 in the sense that for food categories that have uncertainty ranges for mean and selected percentiles, key sources of uncertainty and their corresponding correlation coefficients are given. For example, all food categories had uncertainty ranges associated with their mean probability of illness. However, only foods in Categories I, II, and IV had uncertainty ranges associated with the 95th and 99th percentiles of the probability of illness.

The key sources of uncertainty for each food category were different for the mean and selected percentiles of the probability of illness. However, initial contamination, storage time on countertops after cooking, and log reduction due to cooking were typically among the key sources of uncertainty for the mean and the selected percentiles. For example, for foods in Category IV, which had the highest probability of SE illness, storage time at room temperature after cooking, log_{10} reduction in contamination due to cooking, portion of eggs used in foods, and temperature at countertop after cooking were key sources of uncertainty for the mean probability of SE illness per serving. However, for the 95th percentile, the initial level of contamination is a major source of uncertainty. Additional sources of uncertainty for this percentile include proportion of eggs used as ingredients and storage time after cooking. At the 99th percentile of risk of SE illness, key sources of uncertainty were storage time after cooking, proportion of eggs used as ingredients, and log_{10} reduction due to cooking.

4.4 Identification of Key Sources of Variability

Main effects and total effects of inputs based on the Sobol's method are shown in Fig. 1.3 for foods in Categories I, II, and IV. These food categories had a relatively higher mean risk of SE illness on a per serving basis. All model inputs were analyzed for their contribution to the output variance; however, only inputs that made a substantial contribution to the output variance either in the form of their main effects or total effects are shown.

Fig. 1.3 shows that inputs typically did not have substantial main effects and that their contributions to the output variance were mostly due to their total effects, especially interactions between inputs. For example, the summation of main effects for inputs in Fig. 1.3-a (Category I- fried eggs) was only 0.15; thus, only 15 percent of the output variance was attributed to the linear effects of the inputs. For foods in Category II (e.g., boiled eggs), 17 percent of the output variance was apportioned to main effects of the inputs (Fig. 1.3-b), and for foods in Category IV (e.g., home-made salad dressings and ice creams), no input had a significant main effect (Fig. 1.3-c). However, some inputs substantially affected the output via their interaction effects. For example, 82 percent of the output variance for foods in Category I (Fig. 1.3-a) was due to the interaction between the initial level of contamination and other inputs.

Important inputs based on the relative magnitude of the total sensitivity indices were $\log_{10}$ reduction due to cooking, initial level of SE contamination, storage time and temperature after cooking, the proportion of egg used as an ingredient in the food, and the serving size. For foods in Categories I and II, the initial level of contamination and the $\log_{10}$ reduction associated with cooking had relatively high total effects. Thus, reducing the initial level of contamination as well as targeting consumer education on thorough cooking would be most effective at reducing illnesses associated with eggs that are fried, boiled, and poached. Meanwhile, countertop storage conditions after preparation (i.e., time and temperature) were relatively more important for foods in Category IV than in Categories I and II. Results of our consumer survey indicated that 26 percent of servings for recipes such as dressings and ice creams may include uncooked eggs. Thus, in order to reduce illness associated with foods containing raw eggs, foods should be refrigerated immediately after preparation to control outgrowth of SE cells in the food.

4.5 What-If Scenario Analysis

What-if scenario analysis is useful for identifying possible control points for reducing the risk of salmonellosis associated with the consumption of eggs and egg-containing products. Scenarios were conducted only for inputs which were identified as key sources of variability in Section 4.4 including $\log_{10}$ reduction in contamination in under-cooked foods, SE level in contaminated eggs, and countertop storage time after cooking. We chose to focus on these inputs, which can be directly controlled via consumer advisories and recommendations.

Fig. 1.4 shows the variation in the mean probability of SE illness with respect to the $\log_{10}$ SE reduction in undercooked foods in Categories I and II. Log_{10} reduction in SE for thoroughly cooked foods are likely to be 6 to 8 logs. [15] However, our consumer survey indicated that a significant proportion of foods in these two categories may be undercooked, which is associated with lower $\log_{10}$ reductions. The what-if scenario analysis indicated that when there was more than 4.5 and 5.5 $\log_{10}$ (CFU/g) reduction in SE contamination for foods in Categories I and II, respectively, the mean probability of SE illness was limited to 10^{-9}. Additional research is required to characterize the degree of cooking that would be required to reach these reduction levels.

Fig. 1.5 shows the variation in the mean probability of SE illness with respect to the initial level of SE in contaminated eggs for all food categories. On a log-log scale, foods in Categories I, II, and IV showed approximately linear responses to variation in initial contamination level. Some servings in these food categories may be undercooked or uncooked; even with initial contamination of 1 CFU/egg, the mean probability of SE illness did not decrease to less than a level of approximately 10^{-8}. Foods in Categories III, V, and VI showed less sensitivity to low values of initial contamination because most of the servings in these categories were thoroughly cooked. Limiting the initial contamination in eggs to 0.5 and 2 $\log_{10}$ (CFU/egg) can control the risk to a low value of approximately 10^{-18} for foods in Category III, and Categories V and VI, respectively.

Sensitivity analysis results indicated that countertop storage time was an important source of variability for foods in Categories I, II, and IV. All three categories had approximately similar responses when storage time was varied between 0 and 48 hours (Fig. 1.6). Reducing the countertop storage time after cooking appeared to be less effective at reducing risk than reducing the initial contamination or increasing the $\log_{10}$ reduction which would occur as a consequence of thorough cooking. What-if scenario analysis of countertop storage time showed that the risk for foods in these categories substantially increased if servings were kept at room temperatures for more than 8 hours, which is an unlikely practice.

5.0 Discussion and Conclusions

Although previous farm-to-table risk assessment models for SE illness associated with the consumption of eggs have been developed, risk associated specifically with home and consumer behaviors has not received much attention. We developed a one-dimensional probabilistic home phase risk assessment model for SE in eggs and egg-containing products which considered variability in inputs using updated information about consumer egg consumption and handling practices collected from a nationally representative web-based survey of 1,076 consumers.

As perhaps expected, our model identified Category IV foods, such as home-made salad dressings and ice creams, as having the highest probability of SE illness on a per serving basis. This is largely because raw eggs are a relatively common ingredient in these foods, which are subsequently served either uncooked or only lightly cooked; furthermore, these foods may be stored at room temperature on a countertop for an extended period of time. However, it is important to recognize that the risk estimate for foods in Category IV also manifested the greatest uncertainty associated with choice and parameterization of input distributions. The salmonellosis risks associated with the consumption of Category I and II foods, fried eggs and poached or boiled eggs were comparable and most likely due to undercooking of intact egg yolks. Category VI foods, for example, breads, had the lowest risk of SE contamination and subsequent disease. Foods in this category are well-cooked and have low water content, meaning that the organism is largely inactivated and the resulting product is not favorable for bacterial growth.

The bootstrap technique was used to identify the range of uncertainty associated with sampling error for each risk estimate in each food category, while sensitivity analysis was used to identify those inputs that contributed the most to the quantified uncertainty. Interestingly, the uncertainty analysis revealed that the probability distributions based upon available data were more important sources of uncertainty than were personal assumptions based on expert judgment for our model. However, this might not be the case for other risk assessment models with their specific input assumptions and modeling frameworks. The probability distribution for $\log_{10}$ reduction due to cooking was based upon available data from FSIS/USDA.[15] Additional data collection can improve the probability distribution considered for this input, and therefore decrease the degree of uncertainty associated with the risk estimate. On the other hand, the model showed little reason to collect additional data on horizontal transmission of SE upon breaking of shell eggs as this input was not selected as one of the key sources of uncertainty.

The initial level of contamination was identified as a key source of uncertainty for extreme values of the estimated risk (e.g., 95^{th} and 99^{th} percentiles of the risk distribution). The input for the initial level of SE contamination in eggs stored at home was based on the results of Latimer et al.,[(20)] who modeled the risk of SE illness associated with various time-temperature scenarios that occur during processing, transportation, and storage of shell eggs. Thus, the home-phase SE model was sensitive to the results from the Latimer model, which in turn was influenced by on-farm and processing phases of the farm-to-fork continuum, in addition to consumer practices. In order to decrease uncertainty in estimated risk from consumption of eggs and egg-containing foods at home, better estimates on the level of SE in contaminated shell eggs in consumers' homes is needed. Unfortunately, such studies are complicated by the low prevalence of SE contamination in shell eggs and limits to microbiological methods which make enumeration of *Salmonella* difficult at best.

We used Sobol's method as a variance-based technique for identifying key sources of variability. Sobol's method was a valuable technique for sensitivity analysis of our model as it does not require any assumption regarding the functional form of the model. Thus, it can serve as a useful tool for sensitivity analysis of models that are substantially non-linear, have interactions between inputs, and may have non-monotonocity in the response. The use of Sobol's method for our case study was particularly appropriate because typically, the key sources of variability identified for each food category had quite low main effects. Indeed, the sum of main effects for inputs ranged between 0 and 17 percent. Thus, if a method based on a linear assumption (such as linear regression analysis) was used for sensitivity analysis, we could capture only about 17 percent of the output variation. The ordering of importance of the inputs based on a sensitivity analysis method such as linear regression analysis is only as good as the associated model coefficient of determination (R^2). In that case, a low value of R^2 between 0 and 0.17 could result in rankings that were not reliable.

Key sources of variability were $\log_{10}$ reduction due to cooking, initial contamination, proportion of eggs used as ingredients in each recipe, storage time and temperature at countertop after cooking, and serving size. Among identified key sources of variability, $\log_{10}$ reduction due to cooking, initial level of contamination, and storage time/temperature after cooking were controllable sources of variability. The substantial contribution of $\log_{10}$ reduction due to cooking to probability of SE illness suggested that the degree of undercooking had a great impact on the likelihood of disease resulting from consumption of eggs and egg-containing foods. Storage conditions before cooking were not key inputs affecting the probability of SE illness. Most people refrigerate eggs until use, and the internal temperature of eggs would be relatively low if left out on a countertop for a short period of time before cooking.

The initial level of SE in contaminated shell eggs at home, as a key controllable source of variability, is sensitive to time-temperature abuse during storage and transportation of shell eggs. Latimer et al.[20] performed sensitivity analysis on a variety of variable combinations in their on-farm and processing phases of the farm-to-fork continuum risk assessment for SE. For example, sensitivity analysis indicated that the SE contamination level at home was not only associated with the initial SE contamination level of shell eggs, but also was controlled by temperatures to which the eggs were exposed prior to the home phase. Latimer et al.[20] suggested that in order to control the contamination level at home, tighter temperature control and attention to shelf-life issues should be considered. What-if scenario analysis underscored the importance of reduction of contamination by thorough cooking for Category I and II foods such as fried or boiled eggs. Furthermore, risks posed by initial contamination cannot be reduced if foods in Categories I and II are not thoroughly cooked or if raw eggs are used in Category IV foods.

This risk assessment sought to evaluate which of the six types of egg-containing foods present the greatest risk of salmonellosis to consumers and which consumer handling practices contribute the most to risk of illness associated with SE. The analysis indicates that consumer education should focus on the need to cook egg-containing foods thoroughly in order to reduce risk. In particular, communications should be targeted at the portion of the public that makes a habit of undercooking eggs or using raw eggs in home-made salad dressings and ice creams. Alternatively, public health educators may direct those consumers who prefer partially cooked eggs to use pasteurized shell-eggs. The results of the model provide science-based data to inform consumer risk communications. However, additional research is needed both to understand why, despite knowledge of the health risks, some consumers persist in consuming undercooked eggs, as well as to identify public health communications that will be effective at protecting this population against *Salmonella* infection.

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CHAPTER 2: CONSUMER KNOWLEDGE, STORAGE, AND HANDLING PRACTICES REGARDING *LISTERIA* IN FRANKFURTERS AND DELI MEATS: RESULTS OF A WEB-BASED SURVEY

Abstract:

Proper storage and handling of refrigerated ready-to-eat (RTE) foods can help reduce the risk of listeriosis. A national Web-based survey was conducted to measure consumer awareness and knowledge of *Listeria* and to estimate the prevalence of following the U.S. Department of Agriculture-recommended consumer storage and handling practices for frankfurters and deli meats. The demographic characteristics of consumers who are unaware of *Listeria* and who do not follow the recommended storage guidelines were also assessed. In addition, predictive models were developed to determine which consumers engage in risky storage practices. Less than half of the consumers surveyed were aware of *Listeria* and most of those aware were unable to identify associated food vehicles. Awareness was lower among adults 60 years of age and older, an at-risk population for listeriosis, and individuals with relatively less education and lower incomes. Most households safely stored and prepared frankfurters. Most households stored unopened packages of vacuum-packed deli meats in the refrigerator within the U.S. Department of Agriculture-recommended storage guidelines (≤ 14 days); however, many stored opened packages of vacuum-packed deli meats and freshly sliced deli meats for longer than the recommended time (≤ 5 days). Men, more-educated individuals, and individuals living in metropolitan areas, were more likely to engage in risky

storage practices. This study identified the need to develop targeted educational initiatives on listeriosis prevention.

1.0 Introduction

Listeriosis, an infection caused by *Listeria monocytogenes*, is an uncommon but potentially fatal disease of major public health concern (*28*). Approximately 2,500 individuals in the United States become seriously ill with listeriosis each year, resulting in approximately 500 deaths per year (*19*). *L. monocytogenes* causes serious illness in high-risk populations that include pregnant women, their unborn fetuses and neonates (the perinatal population), older adults, and immunocompromised individuals but causes mild illness in the remainder of the population (*2, 22*).

Although *L. monocytogenes* can be transmitted through several routes, the primary route of transmission for the pathogen is food. Many refrigerated ready-to-eat (RTE) foods, such as frankfurters, deli meats, seafood salads, and soft cheeses, have been associated with human listeriosis and are known to support the growth of *L. monocytogenes* (*12, 23, 25*). The organism is highly resistant to adverse environmental conditions and can grow at refrigerated temperatures (*24*). Additionally, many RTE foods have long refrigerated shelf lives and are frequently consumed without reheating. The U.S. Department of Agriculture (USDA) has a zero tolerance for *L. monocytogenes* in cooked and RTE meat and poultry products such as frankfurters and deli meats (9 CFR 430.4) (*13*). However, complete elimination of *L. monocytogenes* remains a challenge for food manufacturers.

A quantitative risk assessment for foodborne *L. monocytogenes* among selected categories of RTE foods showed that keeping refrigerated foods stored at 40°F or lower and consuming refrigerated RTE foods as soon as possible can reduce the risk of illness from *L. monocytogenes* by more than 50 percent (*11*). Although the growth rates of this organism vary widely as a function of both product formulation and storage temperatures, the USDA recommends storing refrigerated RTE foods at 40°F (4.4°C) or lower for short but safe time limits to help keep foods from spoiling or becoming dangerous (*34*). For example, the USDA-recommended refrigerated (40°F) storage times for opened and unopened packages of frankfurters are ≤ 7 days and ≤ 14 days, respectively. For deli meats, the recommended storage periods (40°F) are ≤ 5 and ≤ 14 days for opened and unopened packages, respectively. Considering an average exponential growth rate for *L. Monocytogenes* of 0.28 log CFU/g per day at 41°F (5°C) for non-fermented deli meats and 0.13 log CFU/g per day for frankfurters (*38*), following the USDA recommendations for open packages should limit growth of *L Monocytogenes* in the home so as not to exceed an increase of 2 log CFU/g. However, the *L. Monocytogenes* risk assessment also demonstrated that the impact of temperature on the risk of listeriosis was significantly greater than the impact of time. For example, if consumer refrigerators could be maintained at 5°C (41°F) or lower, the estimated incidence of listeriosis could be expected to be reduced by greater than 98% (*38*).

The *L. monocytogenes* risk assessment identified several research needs, including the need for information related to consumer food preparation, storage, and consumption practices (*11*). A recent review of consumer food safety studies revealed a lack of information on consumer home refrigeration practices (*21*)˙ Consumer storage conditions and practices are highly varied and can generally either contribute to or substantially reduce the risk of foodborne illness due to *L. monocytogenes.* Thus, better data on consumer storage and handling of refrigerated RTE foods is critical for evaluating the exposure potential and health risks associated with *L. monocytogenes.*

Because *L. monocytogenes* has recently become a public health concern, there may be limited awareness of the pathogen among consumers. A national survey conducted in 1993 found that less than 10 percent of respondents were aware of *L. monocytogenes,* and only 1 percent was able to correctly identify a food vehicle for the pathogen (*1*). This lack of awareness may prevent consumers, especially those at risk, from taking proper precautions when handling RTE foods.

This study was conducted to evaluate consumer awareness and knowledge of *Listeria* and to estimate the frequency of following USDA's recommended consumer storage and handling practices for two frequently eaten RTE foods in the United States - frankfurters and deli (luncheon) meats. The demographic characteristics of consumers who are unaware of *Listeria* and who do not follow the recommended storage guidelines for frankfurters and deli meats were also assessed. Finally, predictive models were developed to determine which consumers engage in risky storage practices for frankfurters and deli meats.

2.0 Materials and Methods

A national survey of U.S. adults was conducted using a Web-enabled panel survey approach. RTI International's (RTI's) Committee for the Protection of Human Subjects, which serves as RTI's Institutional Review Board, reviewed and approved the study protocol. Prior to survey administration, the survey instrument was evaluated with eight individuals using cognitive interviewing techniques (*39*) and subsequently refined.

Sample. We surveyed a nationally representative sample of the U.S. population 18 years of age and older. We selected our sample from a Web-enabled panel developed and maintained by Knowledge Networks (Menlo Park, CA), a survey research firm. The Web-enabled panel is designed to be representative of the U.S. population (*10*) and is based on a list-assisted, random-digit-dial (RDD) sample drawn from all 10-digit telephone numbers in the United States. Households that do not have telephones (approximately 2.4 percent of U.S. households) (*32*) are not covered in the sample. As part of a household's agreement to participate in the panel, it is provided with free hardware (an Internet appliance that connects to a television) and free Internet access. All new panel members are sent an initial survey that collects information on a wide variety of demographic characteristics to create a member profile.

A total of 1,696 individuals 18 years of age and older were randomly selected from the panel of 27,098 individuals. The survey was sent via e-mail to the selected individuals. Two e-mail reminders were sent, and a telephone call was made to nonrespondents to encourage participation. We received a total of 1,212 completed surveys (71 percent completion rate).

Questionnaire. The questionnaire was designed to collect information on consumers' awareness and knowledge of foodborne pathogens, consumers' perceptions of who has responsibility for and control over the safety of the U.S. food supply, and home storage and handling practices for frankfurters and deli meats.

Respondents were asked about their awareness of various foodborne pathogens. Instead of using the scientific names for the pathogens, the questions used the common name that would be more familiar to respondents. Respondents who had heard of *Salmonella* and/or *Listeria* were asked to list the foods they consider most likely to contain the bacterium. The questions were open ended, and the responses were coded into food categories.

Respondents were asked their perceived level of responsibility and control for ensuring the safety of the U.S. food supply at different points in the farm-to-table continuum (U.S. government, farmers, food manufacturers, supermarkets, restaurants, and consumers). A five-point Likert scale was used, with 1 equal to "no" responsibility/control and 5 equal to "a lot" of responsibility/control.

A series of closed-ended questions were used to collect information on home storage and handling practices for frankfurters and deli meats. For each product, we asked about storage time for unopened and opened product because *L. monocytogenes* grows at refrigerated temperatures and opened packages may contribute to cross-contamination. For frankfurters, we also collected information on whether the product was stored in the freezer, whether the product was heated prior to consumption.

To encourage respondents to report their actual behavior rather than their usual behavior, the questionnaire asked about respondents' storage and handling practices for the *last time* the product was purchased for home consumption. Additionally, by asking about the actual storage time the last time the respondent purchased the product for home consumption, we obtained a distribution of values for storage time, including the minimum, most likely, and maximum.

Weighting Procedures. The survey data were weighted to reflect the selection probabilities of sampled units and to compensate for differential nonresponse and undercoverage (*18*). Because respondents provided information on storage and handling practices for their household, it was necessary to develop household-level weights in addition to individual-level weights. The appropriate weight was applied, depending on the survey question and type of analysis conducted.

The individual-level weights were based on the inverses of their overall selection probabilities with adjustments for multiple telephone lines, selection of one adult per household, non-response, and household size. Data on age, gender, race, region, education, and metropolitan status from the December 2002 Current Population Survey (CPS) (*32*) were used in a post-stratification weighting adjustment.

To develop household-level weights, we divided the individual-level weights by the number of adults in the household. Household-level weights were then created by weighting survey responders to March 2002 Census data (*33*) on household composition using a raking procedure (*26*). The raking variables were household size, race of head of household, and presence of children under 6 years old. To calculate the final weights, weighted sample distributions along various combinations of these variables were derived. Similar distributions were calculated using Census data. For each demographic variable (e.g., race), a proportional adjustment was made to the weight of respondent members for each level (e.g., Hispanic Caucasian and non-Hispanic Caucasian) to make the total weighted sample size for that level equal to that of the United States (Census totals). This raking process was repeated iteratively for all demographic variables until there was convergence between the weighted sample and benchmark Census totals. Collapsing of some raking cells was necessary.

Descriptive Analysis. Frequencies for each survey question were calculated using the SAS version 8 software package (*27*) using the appropriate survey weights. Questions concerning consumers' knowledge and perceptions used the individual-level weights. Questions on home food storage and handling practices used the household-level weights because respondents provided information on household practices. Respondents who never shop for groceries for their household and/or never prepare evening meals at home (n = 212) were excluded from the frequency calculations for these questions because they would likely have limited information about household food storage and handling practices.

We compared the characteristics of consumers who are aware to those who are unaware of *Listeria*. We included the following sociodemographic variables in the analysis: gender, education level, age, race/ethnicity, household income, and level of urbanization (metropolitan versus nonmetropolitan) based on the metropolitan statistical area for the household. We also included separate variables to describe whether a household member is at risk for listeriosis or other foodborne illnesses (child 5 years of age or younger; individual with a weakened immune system, diabetes, or kidney disease; individual 60 years of age or older; and pregnant women). As a measure of the respondents' experience with grocery shopping and cooking, we included variables to describe whether the respondent sometimes shops for groceries or cooks meals.

We compared the characteristics of households who reported following the recommended storage practices for frankfurters and deli meats to those that did not. Respondents who never shop for groceries for their household and/or never prepare evening meals at home (n = 212) were excluded from this analysis. We included the following sociodemographic variables in the analysis: gender of respondent, education level of respondent, age of respondent, race/ethnicity of respondent, household size (one person vs.

more than one person), household income, and level of urbanization for the household. We also included variables to describe whether a household member is at risk for listeriosis or other foodborne illnesses (separate variable for each at-risk population). We also included a variable on awareness of *Listeria* because individuals aware of *Listeria* may be more likely to follow the recommended storage guidelines. We performed a Chi square test for the relationship between the variable of interest and various sociodemographic and other variables. This analysis was conducted using the Stata release 8.2 software package (*30*).

Predictive Analysis. To identify predictors of risky storage practices for frankfurters and deli meats we estimated a binomial logistic regression model using the Stata release 8.2 software package (*30*). The logistic regression model assesses the effect of each characteristic on the likelihood of storing the product outside the recommended storage guidelines while controlling for all other variables (*14*). Respondents who never shop for groceries for their household and/or never prepare evening meals at home (n = 212) were excluded from this analysis. The dependent variable was defined as whether the respondent stored the product of interest within or outside the recommended storage guidelines. We included the following as independent variables: gender, education, age , race/ethnicity, household size, household income, level of urbanization, presence of an at-risk individual in the household as separate variables for each at-risk population, and whether the respondent reported awareness of *Listeria*.

In addition, variables were included to measure respondents' perception of the level of responsibility and control different entities have for the safety of the U.S. food supply. First, we defined two separate variables to measure the perceived level of responsibility and control for consumers themselves. For each respondent, we assigned a value of 0 if the respondent answered 1, 2, or 3 (i.e., consumers do not have “a lot” of responsibility or control) and a value of 1 if the respondent answered 4 or 5 (i.e., consumers have “a lot” of responsibility or control). Second, we defined two separate variables to measure the perceived level of responsibility and control for entities other than the consumers themselves. For each respondent, we calculated the average response for the five non-consumer entities (U.S. government, farmers, food manufacturers, supermarkets, and restaurants). A value of 0 was assigned if the respondent’s average response was less than or equal to the median of the average response for all respondents (i.e., entities other than consumers do not have a lot of responsibility or control) and a value of 1 if his/her average response was greater than the median of the average response for all respondents (i.e., entities other than consumers have a lot of responsibility or control).

3.0 Results

Table 1 provides the demographic characteristics of the respondents. Of the 1,212 respondents, 52 percent were women. The majority of respondents were white, non-Hispanic (73 percent). Over 50 percent of respondents had some college education or a bachelor’s degree or higher. Nearly 60 percent of respondents reported that at least one individual in the household is considered at risk for foodborne illness. About 85 percent of respondents reported shopping for groceries and preparing and eating evening meals at home at least some of the time.

3.1 Awareness and Knowledge of Foodborne Pathogens.

Table 2 presents the results of the weighted analyses for consumer awareness and knowledge of foodborne pathogens. Awareness was highest for *E. coli* and *Salmonella*, with 94 percent of consumers reporting having heard of these pathogens. Less than half reported awareness of *Listeria* (44 percent). *Campylobacter* was the least recognized of the five pathogens (11 percent) asked about in the survey.

Most consumers aware of *Salmonella* correctly identified one or more food vehicles. However, over two thirds of consumers who reported awareness of *Listeria* were unable to identify a food vehicle. Five percent or less correctly identified fruits or vegetables, seafood, cheese, milk, and processed meats as likely food vehicles for *Listeria*. Some consumers had the misconception that raw meat (17 percent) and poultry (3 percent) are likely food vehicles for *Listeria*. Table 3 compares the sociodemographic characteristics of consumers who are aware of *Listeria* to those who are unaware. Awareness of *Listeria* was generally lower among respondents with relatively less education and lower incomes. Awareness of *Listeria* was lower among seniors (≥60 years) compared to individuals younger than 60. Awareness varied significantly by race/ethnicity with awareness higher among white, non-Hispanic individuals. Respondents with young children in the household had a higher awareness of *Listeria*, and respondents with an older adult in the household had a lower awareness of *Listeria*. Awareness was also higher among individuals who shop for groceries and cook meals at least some of the time compared to those who never shop for groceries and cook meals. It is of interest to note that there was no difference in awareness among individuals with a household member who is immunocompromised or pregnant, both of which are considered at-risk populations for listeriosis.

3.2 Perceptions of Responsibility and Control for the Safety of the U.S. Food Supply.

Table 4 presents consumers' perception of the level of responsibility and control different entities have for ensuring the safety of the U.S. food supply. More than 75 percent of respondents believed that food manufacturers and restaurants have a lot of responsibility for ensuring the safety of the U.S. food supply. Consumers and farmers were viewed as not having a lot of responsibility. Likewise, 60 percent of respondents believed that food manufacturers have a lot of control for ensuring the safety of the U.S. food supply. Consumers and farmers were again viewed as not having a lot of control.

3.3 Reported Storage and Handling Practices for Frankfurters and Deli Meats.

Table 5 presents the estimated percentage of households that reported following USDA's recommended storage and handling practices for frankfurters and deli meats. For households that stored frankfurters in their home refrigerator, 96 percent stored unopened packages for the recommended time of 14 days or less. For households that stored opened packages of frankfurters, 87 percent stored them in their home freezer after opening, stored them in the refrigerator for the recommended time of 7 days or less, or discarded the uneaten product. Nearly all households reported reheating frankfurters before consumption the last time they prepared them. Of households that stored frankfurters in their home freezers, less than half defrosted the frankfurters before heating them the last time they prepared them.

For households that purchased vacuum-packed deli meats, 97 percent stored unopened packages in their home refrigerator for the recommended time of 14 days or less. Fewer households (59 percent) stored opened packages for the recommended time of 5 days or less or discarded the uneaten product. For households that purchased freshly-sliced deli meats, 66 percent reported storing the product in their home refrigerator for the recommended time of 5 days or less.

Table 6 compares the characteristics of households who stored unopened and opened packages of frankfurters and deli meats within the USDA-recommended storage guidelines to those who did not follow the guidelines. The prevalence of storing frankfurters outside the recommended guidelines was significantly higher among households in which the respondent was male ($p = 0.012$) and among households in metropolitan areas compared to nonmetropolitan areas ($p = 0.020$). The prevalence of storing frankfurters outside the recommended guidelines varied significantly by education level ($p = 0.028$); the findings suggest that adherence to the guidelines was lower among households in which the respondent had some college or a Bachelor's degree or higher.

Regarding deli meats, the prevalence of storing deli meats outside the recommended guidelines was significantly higher among households in which the respondent was male ($p = 0.0002$). The prevalence of storing deli meats outside the recommended guidelines varied significantly by age of the respondent ($p = 0.009$). The findings suggest that adherence to the guidelines was lower among households in which the respondent was aged 18 to 29 or 45 to 59 compared to other age groups. Of particular concern is the finding that the prevalence of storing deli meats outside the recommended guidelines was significantly higher among households in which there was a pregnant woman (p = 0.042), an at-risk population for listeriosis.

Table 7 presents the results of the logistic regression analysis for storing unopened and opened packages of frankfurters and deli meats outside the USDA-recommended storage guidelines. Men are 2.5 times more likely than women to store frankfurters outside the recommended guidelines (p = 0.000). The findings suggest an inverse relationship between education and the likelihood of following the USDA-recommended storage guidelines; that is, the more educated the individual, the less likely the individual is to follow the recommended guidelines. For example, individuals with a college degree are 6.1 times more likely than those without a high school education to store frankfurters outside the recommended guidelines (p = 0.007). Individuals living in metropolitan areas are 6.8 times more likely than individuals living in nonmetropolitan areas to store frankfurters outside the recommended guidelines (p = 0.001). While not significant at the p = 0.05 level, the findings suggest there may be a relationship between certain age categories and the likelihood of storing frankfurters outside the recommended guidelines, with individuals 18 to 29 more likely to store frankfurters outside the guidelines compared to individuals 60 years or older (O.R. = 2.630, p = 0.086) .

Regarding deli meats, men are 2.1 times more likely than women to store deli meats outside the recommended guidelines (p = 0.000). While not significant at the p = 0.05 level, the findings suggest there may be a relationship between age and the likelihood of storing deli meats outside the recommended guidelines, with individuals 18 to 29 more likely to store deli meats outside the guidelines compared to individuals 60 years or older (O.R. =

2.13, p = 0.070). While not significant at the p = 0.05 level, it is worth noting that individuals with a pregnant woman in the household may be more likely to store deli meats outside the recommended guidelines compared to households without pregnant women (O.R. = 2.19, p = 0.073).

4.0 Discussion

An analysis of the survey results shows that gender, education, age, urbanization, and pregnancy status were significant determinants of whether or not an individual engaged in risky storage practices for frankfurters and deli meats.

4.1 Awareness and Knowledge of Listeria.

Despite limited awareness of *Listeria* (44 %), many respondents are following the recommended storage guidelines for frankfurters and deli meats. According to national surveys conducted by the Food and Drug Administration (FDA), awareness of *Listeria* is increasing (*36*). The percentage of consumers aware of *Listeria* increased from 9% in 1993 to 14% in 1998 and then doubled to 31% in 2001. This increase in awareness may be due to media coverage of *Listeria* outbreaks between 1998 and 2000 (*8, 9*). Although awareness of *Listeria* is increasing, it is still much lower than awareness of *E. coli* and *Salmonella*. Also, we found that most individuals who were aware of *Listeria* had limited knowledge about the pathogen and were unable to identify possible food vehicles. Thus, a need to educate consumers about *Listeria* and possible food vehicles exists, so consumers will know to safely handle and store RTE foods such as frankfurters and deli meats to help prevent listeriosis.

We found that awareness of *Listeria* is lower among seniors (≥60 years) compared to individuals younger than 60. This finding is of particular concern because seniors are an at-risk population for listeriosis. We found that awareness of *Listeria* is higher among households with young children compared to households without young children. Although young children are not an at-risk population for listeriosis, they are an at-risk population for other foodborne illnesses. We found that awareness of *Listeria* is generally lower among those with relatively less education and lower incomes, but individuals with more education generally had poorer storage practices compared to those with less education.

4.2 Perceptions of Responsibility and Control for the Safety of the U.S. Food Supply.

Respondents believed that food manufacturers and restaurants have a lot of responsibility and that food manufacturers have a lot of control for ensuring the safety of the U.S. food supply. Consumers and farmers were viewed as not having a lot of responsibility and control for ensuring the safety of the U.S. food supply. In national surveys conducted by the FDA, respondents reported that they believe foodborne illness most likely stems from food-handling procedures in food manufacturing plants and restaurants rather than in their homes (*36*). These findings suggest that consumers worry more about how food products are handled prior to purchase than about how they are handled at home.

Consumers' belief that food manufacturers and restaurants have the most responsibility and control for the safety of the food they eat might reduce their level of concern for food safety. As a result, consumers may not be motivated to follow the recommended safe practices for storing, handling, and preparing food at home. For example, in focus groups with pregnant women, researchers found that participants expressed confidence in their ability to safely handle and prepare food at home. However, many participants did not always follow safe practices when cooking at home (e.g., did not refrigerate leftovers immediately or did not use a food thermometer to check the doneness of meat) (*35*).

4.3 Adherence to Recommended Storage and Handling Practices for Frankfurters and Deli Meats.

We found that most households safely stored and prepared frankfurters. The percentage of consumers reheating frankfurters prior to consumption appears to be increasing. In a survey sponsored by the American Meat Institute Foundation (AMIF) in 2001, 72% surveyed said they always reheat their frankfurters prior to consumption (*4*). In our survey, 99% of households reported reheating frankfurters the last time they were prepared. Most households reported storing unopened packages of vacuum-packed deli meats in their home refrigerators within the USDA-recommended storage guidelines of ≤14 days; however, about two-thirds of households reported storing open packages of vacuum-packed deli meats in their refrigerators for longer than the USDA-recommended time of ≤5 days. Because *L. Monocytogenes* can grow at refrigerated temperatures, it is important that these products are not stored for longer than the recommended time and then consumed. Some consumers may rely on product dates to guide decisions about storage time. Currently, there is no uniform or universally accepted food product dating system in the United States (*17*). Some manufacturers voluntarily provide a sell-by or use-by date (*5*); however, these dates are generally established by manufacturers to indicate a product's shelf life and are not meant to be indicators of microbiological food safety. Interest in establishing safety-based dates has increased in response to the *L. monocytogenes* action plan. The federal government is currently exploring the feasibility of establishing safety-based use-by dates for refrigerated RTE foods such as frankfurters and deli meats (*37*).

We found that men are more likely than women to store frankfurters and deli meats outside the recommended storage guidelines. Other researchers have similarly found that unsafe food handling practices and risky food-consumption practices were reported more often by men (*1*, *3, 20*). The findings also suggest that relatively less-educated individuals are more likely to follow the recommended storage guidelines for frankfurters compared to individuals with more education; however, a similar finding was not observed for deli meats. This is consistent with the findings of other researchers that the prevalence of risky food handling and food consumption practices generally increased with increased education (*3, 20*). We found that individuals living in metropolitan areas are more likely to store frankfurters outside the recommended storage guidelines, but we did not observe this finding for deli meats. Other researchers have found that individuals living in metropolitan areas had lower use of some food safety practices compared to individuals living in nonmetropolitan areas (*20*). Additional research is needed to understand why storage practices vary based on these demographic characteristics.

The strengths of the present study include the large sample size and nationally representative survey design. Limitations of the study include the small sample sizes for populations at risk for listeriosis, such as seniors and pregnant women. Also, the logistic model of deli meats storage practices used the combined results for vacuum-packed deli meats and freshly sliced deli meats because of the small sample sizes. Combining the two products may have contributed to the lack of a statistical relationship between storage practices and some of the variables included in the model.

Finally, our study used self-reported behaviors which may not reflect actual practices *(21)*. When completing surveys, people tend to report their usual behavior rather than their exact behavior (*15*). For example, Lessler (*16*) found that when asked how many times they visited the dentist last year, people tended to report the usual pattern of two visits, rather than what they actually did. Likewise, when reporting dietary intake over a period of days or weeks, people tended to report what they think they usually eat, rather than recalling what they actually ate (*29*). To help minimize self-reporting bias, we asked respondents to consider what they actually did the last time they purchased the product, thus, we were more likely to elicit respondents' actual behavior instead of their knowledge of recommended storage times or their usual practice. This approach is used in the National Longitudinal Study of Adolescent Health (*31*) to collect information on sensitive behaviors such as sexual practices and drug use.

In summary, educational initiatives on listeriosis prevention are needed; in particular there is the need to develop initiatives targeted to seniors and those with limited income and higher levels of education. Enhanced education efforts on listeriosis prevention should continue to target pregnant women (*7*). Educational efforts should inform at-risk populations about the risks of listeriosis and practices to mitigate these risks. Knowledge of the consequences of unsafe practices can motivate consumers to follow the recommended practices *(6)*. Specifically, consumers need to be educated about the recommended storage times for unopened and opened packages of frankfurters, deli meats, and other refrigerated RTE products. Because both storage time and temperature are important, the need to educate consumers about the proper refrigerator temperature and use of refrigerator thermometers cannot be overemphasized.

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CHAPTER 3: AN INTRODUCTION TO HEALTH BEHAVIOR THEORIES FOR CONSUMER FOOD SAFETY BEHAVIORS

Abstract:

Extensive food safety campaigns have promoted simple hygiene and storage practices as a means to reduce an individual's risk of foodborne illness. However, the scientific consensus is that in the American population, consumer food safety knowledge is inadequate and consumers continue to practice risky food handling behaviors. As such, food safety health education is not yet a mature field. Borrowing from traditional public health research, this paper introduces three types of behavior models (motivation models, behavior enaction models, and stage theories) created to identify modifiable cognitive factors which predict the likelihood of an individual to adopt protective health-related behaviors. An expanded discussion of the Health Belief Model and the Theory of Planned Behavior are provided as frameworks for future food safety educational research. Application of traditional public health education theories to the field of food safety education offers a means to improve the efficacy of future educational campaigns. The use of health education models in a food safety context offers unique opportunities to develop and test health education theory.

1.0 Introduction

Despite claiming the world's safest food supply, the United States still recognizes foodborne illness as a significant concern. Foodborne diseases cause approximately 76 million illnesses, 325,000 hospitalizations, and 5,000 deaths in the US each year (Mead, et al. 1999). In economic terms, costs in the Year 2000 associated with five major bacterial foodborne pathogens were estimated by the US Department of Agriculture, Economic Research Service (ERS) at $6.9 billion (ERS, online); this estimate excludes costs associated with foodborne illness caused by other bacterial pathogens, as well as by viruses and parasitic protozoa.

Food production is often described in terms of the "farm-to-table" continuum. The latter portion of the continuum refers to food handling and storage that occurs by the consumer, sometimes referred to as the "consumer phase." Under the current dynamics of food regulation and production, foodborne illness is largely a result of lapses during the consumer phase (Redmond and Griffith, 2003). Up to 87% of reported outbreaks in the UK, Europe, Australia, Canada, US, and New Zealand have been associated with food prepared or consumed in the home. In addition, the majority (>95%) of cases of foodborne disease are believed to be sporadic, not outbreak in nature, implying a domestic origin (Redmond and Griffith, 2003). Interestingly, while the consumer takes control of the food at the point of purchase, s/he does not always take responsibility for maintaining safe food- handling behaviors.

Scientists and educators have indicated that by practicing simple good food hygiene and storage practices, consumers can reduce their chances of foodborne illness. Using an expert panel of epidemiologists, microbiologists, food safety educators, and food safety policy makers, Medeiros et al. (2001) identified critical consumer behaviors to avoid foodborne disease, namely (i) practice good personal hygiene; (ii) cook foods adequately; (iii) avoid cross-contamination; (iv) keep foods at safe temperatures; and (v) avoid foods from unsafe sources (Medeiros *et al.*, 2001). Four of these five behaviors correspond to the ongoing Fight Bac! Campaign in the US which emphasizes *Clean! Separate! Cook!* and *Chill!* (U.S.Department of Agriculture Food Safety Inspection Service, 1997). The Fight BAC! Campaign was created by the Partnership for Food Safety Education in 1997. Its goal has been to reduce the incidence of foodborne illness in the home by educating Americans about safe food-handling practices (U.S.Department of Agriculture Food Safety Inspection Service, 1997). Despite this and other extensive food safety public education campaigns, the scientific consensus is that consumer food safety knowledge is inadequate, and consumers continue to practice risky food handling behaviors (Redmond and Griffith, 2003;Wilcock *et al.*, 2004).

As government, academic, and public health researchers, we have a responsibility to reduce the burden of foodborne illness. Currently, in the farm-to-table continuum, consumers are the weakest link. The implication is a need to change consumer behaviors in order to promote safety. A critical first step in promoting safe food handling behaviors is ensuring that consumers are aware of the threat of illness following improper domestic handling and storage and that they are aware of the procedures by which to protect themselves. In the Healthy People 2010 report, the US Department of Health and Human Services defines health communication as the art and technique of informing, influencing, and motivating individual, institutional, and public audiences about important health issues. (United States Department of Health and Human Services, 2001). However, information dissemination alone has not proven effective. The immediate question is why?

In this paper, we introduce basic concepts involved in modeling behavior changes in order to guide future food safety public health interventions. These concepts have been used for decades in public health fields, and their application to consumer food handling behavior is promising. Risk communication can no longer be as simple as public education.

2.0 Food Safety and Health Promotion Research

Why doesn't everybody use a seatbelt? Why does a smoker continue to smoke even after multiple attempts to quit? Considering the risk of cancer, why not wear sunscreen lotion? As a society, we are aware of multiple risks to our health and how we might prevent them, yet this awareness is not always sufficient to motivate protective behaviors. Health behavior research attempts to identify the factors that motivate and guide our actions in an effort to understand human behavior and in so doing, facilitate behavioral change.

Since the early 20th century, researchers have proposed that attitudes could be used to predict behaviors (Armitage and Christian, 2003). For example, a positive attitude towards chocolate cake ("I like chocolate cake!") would predict that, given an opportunity to eat chocolate cake, an individual would, in fact, eat the cake. However, other factors (dieting, desire not to look piggish, etc.) may intervene such that the individual chooses not to eat the cake. Any one individual's attitudes are a complex function of socio-demographics, culture, personal knowledge and experiences. Furthermore, attitudes are dynamic, changing with new experiences. Finally, in different contexts, certain attitudes are more salient than others.

In an effort to capture this complexity, researchers have proposed dozens of behavior models. Currently, at least 65 predictive behavior theories have been proposed in the literature (Glanz *et al.*, 2002), and no single theory dominates the field. Some are specific to health behaviors such as the Health Belief Model (Rosenstock, 1960; (Janz *et al.*, 2002) and some apply more generally, such as the Theory of Planned Behavior (Ajzen, 1991). This paper describes the state of the art of food safety research into health education and then describes a series of models that may be used to develop interventions designed to prevent foodborne illness.

3.0 Behavioral Epidemiology Framework

Redmond and Griffith (2003) report that consumer food safety research is largely anecdotal, and these authors argue that a more complete understanding of why certain food safety practices are implemented and others are not may aid in the development of future food safety education initiatives. While consumer knowledge and attitudes toward food safety have been explored extensively, there is still a basic inability to effect behavior change. The behavioral epidemiology framework (BEF) would suggest that this is because food safety health education is not yet a mature field (Sallis *et al.*, 2000). The BEF describes five phases of research on health promotion and disease prevention: (I) establish links between behaviors and health; (II) develop measures of the behavior; (III) identify influences on the behavior; (IV) evaluate interventions; and (V) translate research into practice. The framework progresses from information gathering, through hypothesis generation and testing, ultimately to effective application. Arguably, behavior research in the field of consumer food safety lacks important development in each of these phases.

The work in Phase I, establishing links between behavior and health, has largely been summarized in recent reviews of consumer food safety studies (Redmond and Griffith, 2003;Wilcock *et al.*, 2004). While there remains a great deal for scientists to learn about the relationship between consumer behaviors and subsequent health outcomes, food safety educators and the public have access to an immense amount of information in the form of nationally- and internationally-funded risk assessments. However, risk assessments have traditionally been used to inform government and industry actions, and relatively less attention has been paid to the consumer phase of the farm-to-fork continuum in these documents. The challenge to food safety health educators is to wade through the available information and identify the information that is most motivating and pertinent to consumers, as well as to identify information gaps that could be pursued by future risk assessments.

Considering Phase II, work on measure development in the food safety arena is only very recent. Kendall et al. (2004) have developed a set of food safety behavior questions that have been evaluated for reliability and validity. Medeiros et al. (2004) propose and test food safety knowledge and attitude scales, evaluating them for internal consistency, test-retest reliability, face validity, and construct validity. Hanson and Benedict (2002) introduce measures of food safety susceptibility and severity, but note that the scales were in the early stages of development and only moderately reliable. More work needs to be done to improve the quality of the established measures and to develop new ones for other important constructs such as perceived behavioral control and self-efficacy.

Phase III calls for hypothesis testing about correlates, influences, or determinants of behavior. The goal is to use or develop a theory, a formalized conceptualization of the relationship between variables, in order to predict or explain an observed phenomenon. Theories are expected to be broadly applicable and capable of prediction. However, it is important to recognize that theoretical models are constantly subject to testing and modification, even refutation, as new evidence and ideas emerge (Rimer, 2002).

Again, very limited work has been published in this area when it comes to food safety risk reduction. Hanson and Benedict (2002) identified that exposure to educational and media coverage of food safety concerns correlated both with perceived threat from foodborne illness and food handling behaviors. McIntosh et al. (1994) proposed and tested a model predicting that habits and preferences generated over a lifetime will also impact the decision to change food safety behavior. Interestingly, 52% of their respondents cited taste or texture as the reason for their cooking preference; however, the data generally failed to support the proposed model, explaining only 3% of the variance in willingness to change. In a report on food safety behaviors, the USDA ERS sought to model consumers' likelihood to prepare or order a rare or medium-rare hamburger as a function of knowledge, risk motivation, palatability and demographics. They found that taste preferences were the most important factors affecting how hamburgers were cooked and ordered. For example, an increase of 10% in palatability motivation was associated with a 76% higher probability of cooking hamburgers rare or medium rare; whereas, a 10% increase in risk motivation resulted in a 5% reduction in likelihood to cook hamburger lightly (Ralston *et al.*, 2002b). Haapala and Probart (2004) used the Protection Motivation Theory to predict self-reported food handling behaviors among teens. Self-efficacy and knowledge were found to correlate significantly with behavior. However, many of the findings at this phase have been correlational; experimental rather than observational research needs to be completed in order to demonstrate causation.

Published research in Phases IV and V is an indicator of a "mature" field (Sallis et al. 2000). Phase IV activities include developing and testing interventions. Phase V calls for active implementation of interventions in the appropriate communities. Recent articles have addressed the last two phases. Cates et al. (2007) detail the use of focus groups to develop an informational handout targeted at the elderly regarding listeriosis. This research describes both the development of the intervention as well as implementation and evaluation of its usefulness. Similarly, Dixon et al. (2006) report a multilingual intervention focusing on personal hygiene targeted at hard-to-reach populations. In the field of food safety, there is little published material describing the development, use or dissemination of public health interventions. A key consideration is that implementation of proper food safety behavior interventions may be inadequately represented in the published literature. That is, in addition to developing public health interventions, researchers should also publish the results, positive or negative.

4.0 Health Psychology Models

"All models are wrong, but some are useful." – George Box. Since no single behavioral model can be expected to explain all behavior, researchers should draw upon and combine elements from multiple models to create the most applicable model for the specific behaviors being researched. Once a core theory has been established, it can be used to guide

development of risk communication programs. Theory is useful in defining objectives for the research program, identifying and determining which constructs/theories/models best accomplish the program objectives, translating the models into practical strategies and intervention programs, anticipating problems, and designing evaluations (Kok and Schaalma, 1998). Models are a basis not only for explanation but intervention design, and evaluation of theory-based interventions can provide a test of the validity of the antecedents specified by the models (Abraham *et al.*, 1998). For those variables that can be manipulated, interventions can be focused on enhancing motivators or reducing deterrents. Many variables such as demographics cannot be changed; however, these variables may be useful for targeting communications.

In the field of health education, behavior models are roughly characterized into three types: motivational models, behavior enaction models, and stage theories (Armitage and Conner, 2000a). All of these models attempt to explain the adoption of health protective behavior in the individual and also guide development of health education and promotion programs.

4.1 Motivational Models

Consumers are typically unaware of their role in maintaining food safety (Worsfold and Griffith, 1997). For example, individuals tend to assign more responsibility for food safety assurance to the government and food industry and less to consumers (Rosati and Saba, 2004). Less than 30% of respondents (n=1006) felt that it is "very common" for people in the US to become sick because of the way that food is handled or prepared in the home

(Cody and Hogue, 2003). In a UK survey of 18 food safety issues (n=1092), domestic food handling hygiene was reported as causing the least amount of worry (Miles *et al.*, 2004). Further, consumers feel optimistic that they personally will not be the one to fall ill. For these reasons, consumers are likely to find traditional food safety campaigns personally irrelevant. In order to develop effective health communications regarding food safety, we must first understand the important cognitive elements that might motivate a consumer to take action. That is the role of the motivational models.

Of the three types of models, motivational models are the oldest and represent the greatest volume of research. Motivational models predict the likelihood of behavior change. The likelihood of behavior change can be considered as a continuum where a given individual is more or less motivated to change. The focus of motivational models is modifiable cognitive elements or "constructs" which may directly or indirectly influence behavior. In order to demonstrate the application of health education models to the field of food safety research, two of the most prominent motivational models, the Health Belief Model (HBM) and the Theory of Planned Behavior (TPB), will be discussed at length later in the text. Glanz et al. (2002a) provide a basic text describing these and other important health behavior theories.

4.2 Behavioral Enaction Models.

There are many reasons why "good" intentions may not be translated to actual behavior. According to Ajzen and Fishbein, measuring intentions immediately before measuring behavior is critical, because the longer the time interval between the two measures, the greater the opportunity for individuals to change their intentions (as reported in (Cooke and Sheeran, 2004)). The focus of the behavioral enaction models is to bridge the gap between intention and behavior. These models are not so much formal frameworks (as are the motivational models), but theories of cognitive processes that might enhance translation of intentions to behaviors.

We briefly introduce goal theories as a means of enhancing the intention-behavior relationship. An extensive review of goal theories is provided in Austin and Vancouver (1996, and see Abraham and Sheeran, 2003).

Instead of focusing on single behaviors, goal theorists view behaviors as serving longer-term goals. A goal represents an internal desire, and as such, people have multiple goals. Goal theorists might explain the discrepancy between intention and behavior as goal conflict. For example, the goal to prepare safe and nourishing meals may conflict with the goal to provide meals quickly. In addition, situational contexts may make goals more or less salient. The goal of providing a safe and nourishing meal may be more salient when preparing a traditional holiday meal for friends and family; however, in the context of a daily meal, the goal of speed may be more relevant. The purpose of goal theories is to provide a framework for understanding when and why individuals choose to prioritize some goals over others. Clearly, goal theories offer a powerful perspective on understanding what factors ultimately determine behavior. However, work still remains to identify the underlying cognitive elements which determine which goals will be acted upon.

4.3 Stage Theories

Stage theories suggest that (i) people in different cognitive stages will behave in qualitatively different ways and (ii) the kinds of interventions and information needed to effect behavioral change vary from stage to stage (Armitage and Conner, 2000a). As such, these models are an important departure from traditional sociocognitive models of behavior.

The most prominent stage model is the Transtheoretical Model of Change (TTM), which describes behavior change as a process, as opposed to an event (Redding *et al.*, 2000). The TTM describes six stages of change: (i) Pre-contemplation (individuals have no intention of changing behavior); (ii) Contemplation (individuals are thinking about changing behavior in the next 6 months); (iii) Preparation (individuals are planning to change behavior within the month); (iv) Action (individuals are actively engaged in changing the behavior); (v) Maintenance (individuals are attempting to maintain the behavior change); and (vi) Termination (individuals no longer participate in the negative behavior or consistently participate in the positive behavior).

Individuals are expected to progress through the stages at different rates. Further, it is likely that an individual may fail and recycle through the stages multiple times before consistent implementation of the behavior. For example, a consumer may become aware of the importance of handwashing to prevent foodborne illness (pre-contemplation). Next, the consumer might discover the proper handwashing methods and determine to begin washing his/her hands for the prescribed time period (contemplation and preparation stages). The consumer may actually wash his/her hands correctly for a month (action), but then lapse due to a hurried lifestyle (contemplation). Nevertheless, the consumer may restart in the contemplation stage, planning to begin proper handwashing again, work through the action stage and remain in the maintenance stage until the point where correct handwashing is a habit, done automatically (termination).

An important implication is that at each stage, the individual may require different types of public health information: At the pre-contemplation and contemplation stages, consumers would require knowledge of the benefits of handwashing. At the preparation stage, as in the example, consumers may benefit from information or tools that facilitate the behavior. Latter stages may require positive feedback such as social approbation.

The stages of change have been evaluated over at least twelve behaviors, including smoking cessation, weight control, radon gas exposure, safer sex, and sunscreen use. Results indicate that for all twelve behaviors, the decisional balance between pros and cons of committing to the behavior reversed in favor of pros by the action stage (Prochaska *et al.*, 1994). Additional research suggests that perceived pros must increase by at least one standard deviation and cons must be reduced by at least one half of one standard deviation before individuals progress from contemplation stages to action stages (Prochaska, 1994). For the areas where the TTM has been applied, studies indicate that typically 50% of at-risk populations are in the pre-contemplation stage and do not intend to take action in the foreseeable future (Prochaska, 1994).

The key advances that stage theories provide are the potential for enhancing the effectiveness of interventions by separating individuals into groups and then providing those groups with the most pertinent information. For example, in order to move ahead to the next stage, individuals in the pre-contemplation stage may need to evaluate the problem, recognize the negative outcomes of their behavior, consider their ability to change, and ultimately decide that the problem is their own responsibility (Oldenburg *et al.*, 1999). A second advantage to this approach is the ability to bridge multiple motivational models, providing an integrated model of behavior change. Currently, however, there is little research indicating key cognitive elements that distinguish one stage from another (Armitage and Conner, 2000b).

5.0 Health Behavior Model and the Theory of Planned Behavior

The Health Belief Model (HBM) is generally regarded as the beginning of systematic, theory-based research in health behavior. The model was developed by social psychologists Hochbaum, Rosenstock, and Kegels in the 1950s in response to the failure of a free tuberculosis health screening program, and has since been used to predict the use of vaccination, adolescent fertility control, cycle helmets, and safe sexual practices (Witte *et al.*, 2001). The aim of the HBM is to predict the likelihood of an individual's performing a precautionary behavior. Fundamentally, the formal constructs of the HBM are (i) perceived susceptibility, one's belief in the chances of getting a condition; (ii) perceived severity, one's belief of how serious a condition and its consequences are; (iii) perceived benefits, one's belief in the efficacy of the advised action to reduce risk or seriousness of impact; (iv) perceived barriers, one beliefs in the tangible and psychological costs of the advised behavior; (v) cues to action, strategies to activate "readiness;" and (vi) self efficacy, confidence in one's ability to take action. The threat of failure to act is thought to be comprised of the individual's perceived severity and susceptibility to foodborne illness in the absence of the behavior (Figure 3.1). Demographic variables are believed to indirectly affect behavior by influencing an individual's perceptions of susceptibility, severity, benefits, barriers, cues to action, and self-efficacy (not pictured).

By way of example, consider the positive food preparation behavior of using a thermometer to check for hamburger doneness. The consequences of eating undercooked hamburger meat that is contaminated with harmful bacteria range from mild gastroenteritis to a severe health condition leading to death.

According to the HBM, a person is likely to use a thermometer if s/he believes that s/he may contract a foodborne illness from undercooked hamburger and that that foodborne illness is serious enough to avoid. Further, the consumer must believe that using a thermometer can help them avoid contracting a foodborne illness. Finally, the consumer must feel capable of using a thermometer on a regular basis to check doneness of the hamburger patty. Barriers to action such as lack of a thermometer, ignorance of how to use the thermometer, or feeling that using a thermometer takes too much time, should be addressed by health educators. Similarly, health educators should provide cues to action such as reminder messages on packages of raw hamburger meat. (ReCAPP, http://www.etr.org/recapp/theories/hbm/, 1/8/2009)

Perceived susceptibility. Due to the inconsistent nature of foodborne illness (one may eat raw hamburger meat and not fall sick, or may eat it one time and fall ill), consumers may not feel personally susceptible to foodborne illness. Additionally, some populations are at greater risk than others, yet are unaware of their status. Therefore, once the populations at risk and their risk levels have been identified (microbial risk assessment may be useful), the health educator's goal is to heighten the perception of susceptibility (if too low) in the affected populations.

However, other cognitive elements may *reduce* the perceived susceptibility of illness; for example, the phenomenon of "optimistic bias," where an individual perceives that s/he is less likely than other people to experience negative events (Miles *et al.*, 1999). When asked to rate their food safety behaviors on a scale from A to F, most consumers (85%) gave themselves "A" or "B" grades (Cody and Hogue, 2003). Consequently, while consumers report bacterial contamination as an important food safety threat (Rosati and Saba, 2004), many appear to underestimate their personal risk. A UK food safety survey (n=100) measured consumer perceptions of control, responsibility, and risk (Redmond and Griffith, 2004). Respondents felt themselves to be at less risk than "other people" from food related hazards and to have more control over food safety than "other people" (Redmond and Griffith, 2004). Similarly, in a case-control study (n=269), Parry et al. (2004) demonstrated significant optimistic bias even among respondents who had previously experienced *Salmonella* food poisoning. These findings corroborate those of Frewer et al. (1994) who found that respondents felt that they had high control over food risks and perceived low personal risk and high knowledge surrounding food safety concerns. The significance of these findings is that if people perceive themselves to be in control of the hazard and at less risk than other people, then they may be inattentive to risk communications efforts (Miles *et al.*, 1999).

Perceived severity. Most foodborne illness may be categorized by mild gastroenteritis; however, a significant number of cases may result in hospitalization and even death. For this reason, a consumer's perception of severity of foodborne illness may be conflicted and depend largely on previous experience with the illness. Many of the most serious foodborne illnesses threaten specific at-risk populations (the elderly and the very young). The goal of the health educator is to communicate the severity of the foodborne illness that threatens this population, describing the consequences of the risk. The consequences of foodborne illness are underappreciated: pain, discomfort, time lost from work, expenses, possible death, etc.

Perceived benefits. The benefit of using a thermometer (or conducting any positive food safety behavior) is reducing the risk of contracting a negative health condition. To apply this concept of the HBM in an intervention, health educators should provide science-based evidence of the effectiveness of the action. Because they can include what-if scenarios designed to evaluate the effectiveness of risk mitigation steps, microbial risk assessments can be used as science-based sources of information.

Perceived barriers. Perceived barriers refer to a consumer's beliefs about obstacles to changing the behavior. For example, seniors in focused interviews reported barriers such as resistance to change, lack of resources, and problematic situations as impediments to proper food handling procedures (Gettings and Kiernan, 2001). Focus group data indicated that while respondents felt that handwashing and drying were very important, the recommended handwashing and drying procedures are “too time consuming” (Redmond and Griffith, 2003). Other barriers may be hunger status (that is, more or less hungry) or cooking preferences (Wilcock *et al.*, 2004). Furthermore, as barriers are discovered, research may be directed toward their reduction. Overall, in the HBM, perceived barriers have been found to be the strongest predictor of behavior adoption (Witte et al. 2001).

Cues to action. According to the HBM, perceived threat will also be affected by cues to action. A cue to action acts as a precipitating force that makes a person feel the need to take action. Cues to action may include educational materials, personal experiences with foodborne illness, public health interventions, media exposures, etc.

Self-efficacy. Stemming from Bandura’s social cognitive theory (Bandura, 1986) self-efficacy is typically defined as a measure of confidence in one’s ability to take action (Janz *et al.*, 2002): “I believe that when cooking hamburgers, I can regularly use a thermometer.” As a construct, the addition of self-efficacy to behavioral models has repeatedly been demonstrated to be predictive of the actual likelihood of success (Abraham *et al.*, 1998). At present, it remains unclear whether consumers feel that they are capable of incorporating new behaviors into their food handling routine. However, the clear implication is that low consumer self-efficacy may result in self-doubt and other self-defeating attitudes. Thus, encouraging consumers’ abilities would result in improved food handling behaviors.

In essence, the Health Belief Model (HBM) proposes that consumers consider benefits and barriers to action as well as the perceived threat associated with failing to act.

While, when contemplating behavior change, perceived benefits refer primarily to the consumer's belief in the effectiveness of the behavior to protect them from illness, tangential benefits may also play an important role in determining behavior. For example, for an obese individual weight loss is important to maintaining health; however, personal appearance may be a motivating benefit as well. In food safety, using a thermometer is important to preventing foodborne illness; however, an additional motivating benefit may be assurance that the food is not overcooked (Ralston *et al.*, 2002a). The challenge for researchers is to convey to consumers not only the risks associated with improper food handling, but also the benefits.

5.1 Indirect antecedents

The discussion thus far has focused on direct antecedents to behavior. The next level of complexity refers to variables that *indirectly* affect behavior. Sociodemographic factors, personal experience, or personality tendencies, of which sociodemographics are by far the most widely studied, work by shaping the knowledge and attitudes that individuals draw upon when deciding how to handle their food.. Demographic variables are believed to indirectly affect behavior by influencing an individual's perceptions of susceptibility, severity, benefits, barriers, and self-efficacy—In general, there is evidence that gender, years of education, number of children in the household, and income are all significant predictors of food safety risk perception (Dosman *et al.*, 2001; Knight and Warland, 2004). Gender appears to be the most robust among the sociodemographic factors at predicting risk perceptions (Dosman *et al.*, 2001), with women being more concerned than men. In addition, a number of sociodemographic factors have been demonstrated to predict actual behaviors. Interestingly, the prevalence of some risky behaviors (failure to wash hands and cooking surfaces, consumption of undercooked hamburgers and raw oysters) may increase with socioeconomic status (Altekruse *et al.*, 1999). One meta analysis of nine consumer behavioral studies indicated that males and young adults were more likely to engage in poor hygienic practices than other demographic groups (Patil *et al.*, 2004).

While demographics in and of themselves are not readily modifiable, information gathered from understanding how sociodemographics affect attitudes can be used as a basis for targeting interventions. For example, listeriosis has often occurred in Hispanic populations where consuming raw milk cheeses is prevalent. Currently, efforts are directing information to Hispanics using approaches that resonate within this population (MacDonald et al., 2005).

In addition to demographics, prior experience with foodborne illness may indirectly affect behavior through multiple paths. Weinstein (1989) lists several mechanisms through which experience may affect behavior, including affecting perceptions of illness severity, personal vulnerability, and awareness of preventive measures. Most people have had some prior experience with foodborne illness. It would be interesting to learn how long, if at all, this experience alters behavior. For example, experience with listeriosis may *increase* perceived personal threat by making it more vivid and salient, or it may *decrease* perceived personal threat/severity by reducing fear of the unknown. Parry et al. (2004) found that individuals who had experienced salmonellosis perceived greater personal risk from food poisoning compared to those who had not. If personal experience with even mild illness does facilitate improved food handling behavior, methods which capitalize on this effect might be particularly useful, given the relative frequency with which mild cases of foodborne illness are experienced.

Intuitively, *knowledge* of the threat of foodborne illness, as well as means to control it, might be expected to affect behavior indirectly through perceptions of threat, attitudes, self-efficacy and other factors. In fact, this is the basis of most public health campaigns. However, experience shows that knowledge alone is not entirely effective. For example, from a telephone survey of US residents, 86% of respondents indicated knowing that handwashing reduces the risk of foodborne illness, yet only 66% reported washing their hands after handling raw meat or poultry (Altekreuse 1996 as cited in (Wilcock *et al.*, 2004).

6.0 Theory of Planned Behavior

Originating in social psychology, the Theory of Planned Behavior (TPB) (Ajzen, 1991) and its predecessor, the Theory of Reasoned Action (TRA) (Ajzen and Fishbein, 1980; Fishbein and Ajzen, 1975), are among the most widely used of the behavioral prediction theories. The TPB has been associated with exercise behavior, smoking and drug use, alcohol abuse, HIV risk behaviors, mammography screening, and others (Montano and Kasprzyk, 2002). The theory predicts the likelihood of behavioral change, e.g., from a poor health behavior to a protective health behavior. Most importantly, the TPB claims that a behavior change can reliably be predicted by intentions to act. According to this model, *behavioral intentions* are influenced by *attitudes toward the behavior*, *social pressure* regarding the behavior, and *perceived control* over the behavior. The Theory of Planned Behavior (TPB) predicts that individuals are likely to use a meat thermometer (i) if they have a strong positive attitude toward using meat thermometers; (ii) if they do not feel social pressure against using a thermometer (or else social pressure to use a thermometer); and (iii) if they feel capable (perceived behavioral control) of consistently using a meat thermometer during meal preparation (Figure 3.2).

Attitudes. A consumer's attitude toward performing a behavior (i.e., using a meat thermometer) is the degree to which performance of the behavior is positively, neutrally, or negatively valued. Our attitudes are influenced by beliefs about the likely outcome of the behavior (what is likely to occur if I use a meat thermometer?), and the desirability of these outcomes (is this outcome a good or bad thing?). Health educators can address attitudinal beliefs by considering factors that could affect a consumer's attitudes such as science-based information. For example, a consumer may feel that "using a meat thermometer is not effective to protect my family from becoming ill, if the meat already contains harmful bacteria."

Social Pressure. Social pressure (or social norms) refers to whether the individual believes that people generally approve or disapprove of the behavior. For example, a consumer may feel that friends would approve of using a meat thermometer because it demonstrates concern in protecting one's self and family. Alternatively, a consumer may feel that friends would criticize using a thermometer as acting overcautiously. The model predicts that the effect of social pressure is moderated by the individual's motivation to comply—if the consumer cares little about what friends think of his or her preparation of hamburgers, then social pressure will not play an important role in determining whether to use a thermometer. While the effects of social pressure have been established for several health behaviors (condom use, drug use, etc.), it remains unclear how important this element is in predicting food handling behaviors. Nonetheless, it is conceivable that a caretaker/food preparer who is not intrinsically motivated by the threat of foodborne illness may be motivated by social influences (friends, family members, colleagues, doctors, etc.) to appear concerned and protective of their family.

Perceived behavioral control. Perceived behavioral control refers to an individual's belief that they are capable at performing the beneficial behavior (meat thermometer example) or refraining from the harmful behavior. The constructs of self-efficacy (SE) and perceived behavioral control (PBC) are similar, and there is considerable debate whether the terms can be used interchangeably (Armitage and Conner, 2001). Some argue perceived behavioral control additionally incorporates measures of perceived barriers and difficulties (Abraham *et al.*, 1998). For example, I know that using a meat thermometer is adding a new step to my routine, but I believe that I can develop this behavior.

Intention. The immediate antecedent to behavior in the TPB, behavioral intentions, are a useful proxy for measuring future behavior (Ajzen, 1991). Behavioral intention is the individual's perceived likelihood of performing the suggested behavior, and is generally measured directly through an individual's response to a statement such as "I intend to use a thermometer the next time I prepare hamburgers." In the health literature, intentions have been consistently demonstrated to be reliably correlated to behavior (Armitage and Conner, 2001), but this is less clear in food safety; in their review of consumer food safety studies, Redmond and Griffith (2003) indicate that TPB was good for predicting food handlers' intentions, the authors remark that when considering food safety behaviors, measured intentions are a poor predictor of actual behavior. This may be due to measurement artifacts such as demand effects, where participants respond with the socially correct answer. Alternatively, in the context of a food safety survey, the consequences of risky behavior are salient and motivating; however, in the household kitchen, consumers may prioritize convenience over proper food handling procedures (Collins, 1997). Nevertheless, measuring intentions remains a practical means of evaluating future behavior and should not be discounted. Future work should focus on methods, such as indirect measures, to improve accurate estimations of consumer intentions.

One important strength of the Theory of Planned Behavior model is the extent to which measures for attitude, social pressure, and perceived behavioral control have been carefully constructed. One important limitation to the model is that there is no prescribed measure to capture demographics and their role in beliefs, attitudes, social pressure, and personal control. Demographics and other similar factors are considered background factors and are not directly measured. They are considered to work indirectly in the model.

In order to develop a TPB-based intervention, the intervention designed to change behavior may be directed at one or more of its determinants. Changes in these factors should produce changes in behavioral intentions and consequently behavior change. Typically, questionnaires are used to directly measure each of the components of the model: attitudes toward the behavior, social norms, behavioral control, behavioral intentions and actual behavior. Multiple regression (or structural equation modeling) is used to determine the relative contributions of each of the model components to intentions and actual behavior.

Looking at the relevant weight of each of the components, the greater the weight a component has, the greater opportunity that a change in that component will result in a change in behavior. (Ajzen, 2009 . http://www.people.umass.edu/aizen/pdf/tpb.intervention.pdf). The intervention itself may take multiple forms including pamphlets, public service announcements, product labels, and others.

7.0 Caveat . . . rationality and awareness

It is important to recognize that most health behavior models assume rational and volitional behavior. In other words, if consumers are given the information that a behavioral change will in fact reduce a food safety risk, that they will, in turn, act to reduce that risk (rationality); and individual behavior is a result of conscious decisions (volition). However, considering meal preparation, one must question whether consumer actions are rationally or even consciously motivated. Food is a complex arena, providing nourishment, pleasure, and social interaction; it is part of our everyday experience. Therefore, we suggest that other factors such as convenience, palatability and habit may also play into a consumer's decision to change (or not to change) his/her current behavior. As Fischoff and Downs (1997) suggest: "emerging foodborne pathogens are of primary concern to some specialists but one more thing to worry about for ordinary citizens". In order for a conceptual model to be applicable, it is important (albeit difficult) to capture these other elements that are specific to the food arena. The roles of habit and palatability in food safety behavior have already begun to be evaluated (Mcintosh *et al.*, 1994;Ralston *et al.*, 2002c), but there is room for much more work in this area.

8.0 Conclusions

Currently, the field of food safety health behavior lacks an understanding of what factors influence food handling behavior, and therefore lacks the basis for effective interventions. As discussed in this paper, models of behavior change from the traditional public health arena can be applied to the task of improving the national food safety agenda.

Additionally, food safety offers a unique and fertile proving ground for testing and developing both established and new behavior models. The corollary is that food handling behavior represents a fertile research area for understanding precautionary health behaviors. Food handling is in large part performed automatically, and so is useful for studying other largely automatic behaviors (Ouellette and Wood, 1998;Verplanken and Orbell, 2003). Food preparation typically occurs privately; however, there are relatively frequent contexts where food preparation is conducted before an "audience," i.e., picnics, intimate social gatherings, and holiday meals. Comparison of behaviors and salient attitudes or goals under both contexts may yield insights into the role of social pressure in determining behavior. For logistic reasons, much research on healthy and unhealthy behaviors is limited to certain sociodemographic profiles (e.g., drug use and teens, mammographies and women), which has the potential of excluding certain populations. Food preparation, however, is represented by virtually every demographic, and as such provides a broad spectrum under which to study determinants of health behavior. In this situation, the fields of food safety research and public health research offer a mutual beneficence.

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CHAPTER 4: CONSUMER PERCEPTIONS OF RESPONSIBILITY AND CONTROL

Abstract:

The current food chain is complex, resulting in unclear food safety responsibilities and a concern for who holds control over the safety of the US food supply. Despite numerous public education campaigns, many cases of foodborne disease are associated with food prepared or consumed in the home. At the domestic level, personal responsibility for and control over the safety of one's food are deemed as necessary prerequisites for good consumer food handling and storage behaviors. This paper characterizes consumer perspectives on the levels of responsibility and control they have over the safety of the US food supply. Data from a consumer survey (n=1,212) were used to report ratings of consumer, government, and industry responsibility and control for the safety of the US food supply. Respondents rated consumers as having the least responsibility for and control over the US food supply compared to other key food chain members. Factors related to concern for food safety, such as age and belief in the frequency of foodborne illness, increased ratings for consumer responsibility. Additionally, those who cooked regularly rated consumers as having both more responsibility and control for food safety than those who cook infrequently. Findings indicated that some groups (aged 31-40 and 61-70) may harbor lower feelings of control for food safety matters than other age groups. This may result in poorer adherence to good food handling and storage behaviors. Interventions designed to increase levels of personal responsibility and control over food safety are suggested. Education to engage and empower the consumer should be focused at groups who cook infrequently and so do not have much experience with food safety procedures and to those who are

unconcerned with food safety such as those who think that foodborne illness is infrequent. Additional research should search for a better understanding of which populations are likely to feel incapable of managing food safety in their homes.

1.0 Introduction

For most developed nations, food travels a long way before it reaches the plate. The so-called farm-to-table continuum or food chain (FC) encompasses pre-harvest production at the farm, processing by the manufacturer, distribution to wholesalers and retailers, and finally consumer or restaurant storage and handling. Factors that contribute to the risk of foodborne diseases, such as microbial contamination, time-temperature abuse, and inadequate preparation, may be introduced at any point in this continuum. Thus, each FC member has some impact on food safety and therefore, some responsibility to protect the food supply. However, the current FC system is complex and it is not always clear who is responsible for maintaining safety in the US food supply. This paper addresses consumer perceptions of responsibility and control over food safety and across the food chain.

1.1 Responsibility for the safety of the US food supply

Most research involving food safety responsibility focuses on culpability for a problem (after an incident), rather than on an obligation to prevent problems. In many cases, consumers indicate that others are to blame. For example, consumers consider responsibility for food safety failures lies with food manufacturers or restaurants (Green, et al., 2005; Roseman, Kurzynske, & Tietyen, 2005; Worsfold, 1997) and that the home and farm are the least likely sources of foodborne pathogens ((Penner et al., 1985) cited in (Lechowich, 1992)). However, little research addresses who *should* be responsible for maintaining the safety of the food supply. Many actors are seen as having responsibility for food safety but as voiced in one focus group, there are no neat attributions of responsibility – it is not clear who *should* be responsible versus who *would* be held responsible (Pellizzoni, 2005). This study examines consumer perspectives on the degree to which several key actors, particularly consumers, have responsibility for the safety of the US food supply. In this paper responsibility for the safety of the food supply refers to an obligation to provide safe foods to consumers.

Consumers often hold the government and food industry responsible. A recent nationwide survey (n=1014) indicated that respondents felt that the federal government should be most responsible for insuring food safety, followed by food processors, consumers, state government, farmers, grocery stores and finally restaurants (Harris, 2006). However it remains clear that the public attributes responsibilities for food safety to all stakeholders along the food chain (Sargeant, et al., 2007).

Individuals assign responsibility to the agency best situated to respond to the issue, that is, agency by proxy (Bandura, 2001). In our busy lives, individuals look to the state to ensure that the default food choice is safe ((Halpern, Bates, Mulgan, & Aldridge, 2004; Lalwani & Duval, 2000). It may be that most consumers relegate authority to the government as a proxy because they have an expertise and they have the organizational power to provide a default minimum level of safety. While the government is not a formal food chain member and has no direct contact with food during production, processing, and preparation, it provides regulation and oversight to assure that critical food safety practices are being followed, as well as passing legislation on the broader procedures to follow if there are problems. Critical government activities include inspections, documenting the burden of foodborne disease, identifying food safety problems through epidemiology, conducting research to understand the problems, and enforcing regulations to prevent future problems (Tompkin, 2001).

However, more and more Western governments are transferring some responsibilities to the food industry. There are trends in government deregulation of business activities and a gradual shift towards self-regulation (Dixon, 2003b). The relationship between public and private institutions is changing from exclusive focus on the state to include other societal actors in the analysis of policy (Halkier & Holm, 2006; Henson & Caswell, 1999).

In addition, governments emphasize the responsibility of the consumer to protect him or herself, i.e., personal responsibility. Up to 87% of reported outbreaks in the UK, Europe, Australia, Canada, US, and New Zealand have been associated with food prepared or consumed in the home. In addition, the majority (>95%) of cases of foodborne disease are believed to be sporadic, not outbreak in nature, implying a domestic origin (Redmond & Griffith, 2003b). Scientists and educators have emphasized that by practicing practical good food hygiene and storage practices, consumers can reduce their chances of contracting foodborne illness.

Consumers are assumed to have control over lifestyle practices and as such have control for their own well-being (Ziff, Conrad, & Lachman, 1995). Personal responsibility discussions stem from the new awareness that lifestyle practices (smoking, physical inactivity, excessive alcohol intake) are significant contributors to morbidity and mortality (Minkler, 1999). This concept can be extended to practicing safe food handling and storage behaviors. Thus, consumers are held responsible for maintaining the safety of their own food.

Since the 1990s there has been a shift toward societal approaches to public health (Kim & Willis, 2007). For example, ***VERB™ It's what you do.*** (2002-2006) was a national, multicultural, social marketing campaign coordinated by the U.S. Centers for Disease Control and Prevention (CDC). Social marketing campaigns apply commercial marketing strategies to influence the voluntary behavior of target audiences to improve personal and social welfare. Additionally, the Public Health Agency of Canada's diabetes project stresses personal behaviors: *"Eat well. Be active. Have Fun. You can prevent Type II diabetes."* (ThePublicHealthAgencyofCanada, 2007) The Fight BAC! Campaign was created by the Partnership for Food Safety Education in 1997. Its goal has been to reduce the incidence of foodborne illness in the home by educating Americans about safe food-handling practices (U.S.Department of Agriculture Food Safety Inspection Service, 1997). Despite this and other extensive food safety public education campaigns, the scientific consensus is that consumer food safety knowledge is inadequate, and consumers continue to practice risky food handling behaviors (Redmond & Griffith, 2003b; Wilcock et al., 2004).

1.2 Control over the safety of the US food supply

One of the aims of regulatory institutions is to maintain and enhance consumer confidence (J. de Jonge, van Trijp, Renes, & Frewer, 2007). A component of consumer confidence is consumers' perceptions of the degree of control that actors have over the safety of the US food supply. In this context, control refers to the capability to produce (industry) or provide (government, consumers) food that is generally safe and does not cause harm to the health of consumers. Additionally, consumer perceptions of control determine the extent to which they trust and rely on institutional management (van Kleef, et al., 2006). It is important to monitor consumer perceptions of control as much as consumer confidence in order to evaluate and adjust policy measures. This study explores consumer perceptions of actor, particularly consumer, control over food safety across the food chain.

2.0 Methods

Sampling Methodology. Data for this study came from a national survey of food safety knowledge, attitude, and handling sponsored by the Research Triangle Institute (RTI, Research Triangle, NC) (Cates, et al., 2006) and administered in 2000. The sample population was selected from a web-enabled panel developed and maintained by Knowledge Networks (Menlo Park, Ca), a survey research firm. The web-enabled panel is based on a list-assisted, random-digit-dial (RDD) sample drawn from all 10-digit telephone numbers in the United States. Households that do not have telephones (approximately 2.4 percent of U.S. households) were not covered in the sample. As part of a household's agreement to participate in the panel, they were provided with free Internet access (an Internet appliance that connects to a television). All new panel members were sent an initial survey that collected information on a wide variety of demographic characteristics to create a member profile. A total of 1,696 individuals 18 and older were selected to participate in the survey, and 1,212 surveys were completed (71 percent). The survey was sent and completed via e-mail to the selected individuals.

Survey Instrument. The survey collected information on (1) food-related attitudes; (2) awareness of foodborne pathogens; (3) perceptions of who has responsibility and control for the safety of the U.S. food supply; and (4) home storage and handling practices. Results associated with home storage and handling practices have been reported elsewhere (Cates, et al., 2006).

Respondents were asked about several food preparation and safety related behaviors and attitudes. For example, respondents were asked to indicate their weekly cooking frequency and their belief in the frequency of foodborne illness. Additionally, respondents were asked to indicate their two most important sources of information for food handling/preparation among the following options: television and radio, government, newspaper/magazines, family and friends, food labels/packaging, school/your children's school, health care providers, the Internet, and/or cookbooks. Responses to this question were categorized as *professional* (health care, government, food labels/packaging), *traditional* (family/friends, school, cookbooks, common sense), or *mass media* (TV/radio, news/magazines, Internet). Write-in answers were also accepted (4%), but were omitted from analysis.

Respondents were asked separate questions about the level of responsibility and the amount of control that six members of the farm-to-table continuum had for ensuring the safety of the US food supply within the FC. For example, questions were worded such as: "How much responsibility (control) does each have for the safety of the US food supply?" The six FC constituents were the U.S. government, farmers, food manufacturers, supermarkets, restaurants, and consumers. A five-point Likert-type scale was used for both sets of questions, with 1 being no responsibility or control and 5 equal to a high degree of responsibility or control.

Data Analysis:

Descriptive analyses were used to calculate the means for each of the responsibility and control variables. Demographic and attitudinal variables were tested for significance using the univariate GLM procedure (SPSS v.17). To simplify analysis, only three of the six constituents were used as dependent variables: the US government, consumers, and manufacturers (manufacturers were used as representative of the food industry). Post-hoc analysis was conducted using LSD (least-squares differences). Contrast coding was used to test the linearity of the model (SPSS v.17).

3.0 Results

3.1 Survey respondent profile

The demographics of the respondents were designed to approximate current US demographics (Table 4.1). In addition, information was gathered about relevant health, cooking and reading behaviors, and awareness and belief characteristics (Table 4.2). Greater than half the respondents indicated very good or excellent personal health status. Similarly, 55% of the respondents reported preparing 3 or more of their evening meals at home each week. Most respondents reported that their two most important sources for information regarding food handling were mass media or a combination of mass media and professional sources, such as the government or a health-care provider. Respondents were generally aware of important foodborne pathogens; of the five foodborne pathogens listed, ninety-eight percent of respondents were aware of at least two (*Salmonella* and *E. coli*) and greater than two-thirds of respondents were aware of three. About forty percent of respondents believed that foodborne illness was "not very frequent," while nearly fifteen percent stated that foodborne illness is "very frequent."

3.2 Ratings of responsibility and control

Overall, respondents indicated greater than neutral levels of responsibility and control for the safety of the US food supply across all members of the food chain (Fig. 1). For each continuum member, responsibility ratings were greater than control ratings ($p<0.05$). Consumers and farmers were seen to have the least responsibility and consumers were to seen to have the least control. Manufacturers and restaurants were rated as having the greatest responsibility, and manufacturers were rated as having the greatest control ($p<0.05$).

Means comparisons were conducted for socio-demographic and relevant health, behavior, and belief variables for the US government, manufacturers, and consumer. Significant predictors are listed in Table 4.3. For the consumer, age and cooking frequency were consistent predictors of responsibility and control ratings. Responsibility ratings increased linearly with age ($p < 0.001$), cooking frequency ($p < 0.001$), and belief in the frequency of foodborne illness ($p = 0.002$). Younger respondents rated consumers as having less responsibility for food safety than did their older counterparts (Fig. 2). Those who reported seldom or never cooking at home reported lower consumer responsibility than those who regularly cooked at home (Fig. 3).

When predicting control ratings, there was an interaction between age and cooking frequency (Fig. 4). For those respondents who cooked regularly, control ratings were directly related to age, with respondents aged 61-70 years rating consumer control higher than the other groups. For those who cooked rarely, the relationship between age and control ratings was complex (Order 4 polynomial). Groups aged 31-40 and 61-70 years dropped lower than would have been expected with a linear upwards trend.

4.0 Discussion

Individuals' perceptions of who holds responsibility and control for one's health are key concepts across several fields of study including health psychology, marketing, and policy. In this paper, responsibility is interpreted as an obligation to prevent foodborne disease, and control is interpreted as the capability to prevent foodborne disease. However, there is considerable variation as well as overlap in the literature in what is meant by these terms (see for example (Ziff et al., 1995; Skinner, 1996; Pellizzoni, 2004). Our work has focused on providing an analysis of consumer views of responsibility and control, borrowing from the perspectives of multiple disciplines. In so doing, we hope to offer a better understanding of how consumers think about these issues, as well as provide insight into how to develop materials to help consumers understand their role in food safety.

A general definition of safe food is one that does not cause harm to the consumer when it is prepared and/or eaten according to its intended use. However, it is important to note that the definition of "safe" is subjective and may not refer simply to microbiologically safe, but may include food security threats, pesticide concerns, bio- and nano-technology issues, hormones and others (Miles, et al., 2004).

4.1 Responsibility

Responsibility ratings were high for all agents across the food chain. Consumers typically found themselves somewhat responsible for the safety of the food supply. It is not clear whether they were considering responsibility for personal food storage and preparation, or a more global responsibility, for example, interacting with the government to shape policy debates.

Behaviors usually associated with personal responsibility are performed for internal as opposed to external reasons. Increasing intrinsic motivation, leads to the use of more complex decision strategies and greater investment of time and energy in decisions (Bartunek, 1986). Internal attributions for the motives for behavior change are positively correlated with the adoption of health behaviors: fluoride mouth rinsing, smoking cessation, and high blood pressure screening. On the other hand, external attributions for the causes of a behavior change are associated with poorer adherence to recommendations and poorer maintenance of new behaviors (Alexander J. Rothman, Salovey, Turvey, & Fishkin, 2003). Notably, educational presentations emphasizing personal responsibility led to mammogram usage in women who did not normally adhere to national guidelines for mammography (A. J. Rothman, Salovey, Turvey, & Fishkin, 1993; Alexander J. Rothman, et al., 2003).

Ironically, it remains unclear whether perceptions of personal responsibility *actually* lead to healthier behaviors and better health (Ziff, et al., 1995). Formalized theories about responsibility, personal or societal, are few and underdeveloped (Pellizzoni, 2004, 2005). In a study regarding health-related behaviors, personal responsibility was not a predictor of health status or health-related behaviors such as exercising and performing breast self-examination (Ziff, et al., 1995). Additionally, personal responsibility may encourage the individual to engage in healthy lifestyle behaviors; however, it may evoke feelings of guilt or self-blame that serve as obstacles to good health practices (Brickman, et al., 1982; Ziff, et al., 1995). Care needs to be taken when basing health campaigns on personal responsibility.

Nonetheless, recognition of responsibility for food safety is considered to be a prerequisite for implementation of appropriate food safety behaviors (Redmond & Griffith, 2004). In the end, multiple food safety responsibilities are required by the consumer. Failure to assume personal responsibility may result in increased potential for unsafe food-handling behaviors and consequential increased risks of foodborne illness (Redmond & Griffith, 2004).

Considering the consumer base, generally the US population does assume some level of responsibility for food safety. Redmond and Griffith (2004) report that only 5% of respondents considered consumers as having no or very small amount of responsibility at all. This is consistent with our finding of 7% (data not shown). However, consumer ratings were significantly lower than those for the government or the food industry. This is consistent with the focus group finding that consumers' attributions of responsibility were partly personal and partly addressed toward others because of a perceived difficulty of having total personal control over exposure to food safety risks. Additionally some may feel that 'consumers should not become experts' (Pellizzoni, 2005). The more influence one is perceived to have in preventing a food risk from occurring, the greater is responsibility for health protection (van Kleef, et al., 2006). Although demographic data related to government and manufacturer ratings are reported (Table 4.3), the focus of this paper is ratings of consumer responsibility and control and additional discussion about consumer ratings for government and manufacturer responsibility is beyond the scope of this discussion.

Consumer responsibility ratings tended to be related to age and cooking frequency. The older the respondent, the higher the responsibility ratings were. Additionally, Redmond and Griffith (2004) report that perceived responsibility food safety increased with age. This finding may not be restricted to food safety but extend to other domains as well. As people age they become responsible for more aspects of their life, e.g., children, home, etc. This may be an example of a projection bias, where one anchors based on one's own situation and then extends it to others.

Individuals who cook often tend to hold consumers more responsible for food safety than those who cook less often. Those who cook regularly may already take personal responsibility for their own food choices, preparation, and storage behaviors and may extend this expectation to others. Again, as in age, this may be a projection bias. One hypothesis to explain this observation is that people who cook less often may be more likely to hold restaurants responsible, because that may be where they are purchasing their food. However, the data were evaluated and do not support this hypothesis.

People who perceived foodborne illness as common held consumers more responsible than those who did not. Perhaps, those who perceived foodborne illness as common were also more concerned with foodborne illness. These people may feel a need for additional responsibilities in the system in order to control apparent food safety hazards. In that case, those people would tend to attribute more responsibility to all parties. However, this finding would be indistinguishable from a mere scale usage bias to anchor on the answers to the right side of the scale. For this reason and in the absence an explanatory underlying mechanism, it is difficult to draw conclusions from the data.

Each of these explanations is in fact supposition. The ratings indicate respondents' perceptions about the amount of responsibility consumers hold to protect themselves from foodborne illness. These results do not provide any insight into why consumers feel the way they do. Additional work could be conducted to clarify the reasoning behind the ratings that respondents offered. For example, focus groups segmented by age could be used to discuss consumer responsibilities. Questions may address if and why consumers should be held responsible for food safety. They could explore other domains to see if the responsibility findings hold across other domains such as personal responsibility for health or whether these findings are specific to the topic of food safety.

There was a general tendency to cede responsibility to food safety away from the consumer. A consequence of consumer's misattribution of responsibility is that when they become ill, they may (inappropriately) attribute blame to restaurants and manufacturers (Green, et al., 2005). In this way, they may neglect food handling mistakes that they have made (or even be unaware that mistakes have been made). Furthermore, since consumers believe that responsibility and control lie with manufacturers/restaurants, they may fail to look for ways that they may personally prevent foodborne illness.

4.2 Control

One key psychological construct is agent efficacy. There are two related concepts: perceived self-efficacy and collective efficacy. Perceived self-efficacy is an individual's belief in her ability to perform behaviors that bring about desired outcomes. On the other hand, perceived collective efficacy is a group's shared belief in its conjoint capabilities to organize and execute the courses of action required to produce given levels of expectation (Bandura, 1997).

When individuals responded to the question about consumers, it is unclear as to whether they were referring to the consumer base or to individual consumers. If they were talking about consumers as a whole, then the survey results measured *collective efficacy*. That is, we are dealing with the individual and his perceptions of the collective capacity of the consumer base to provide itself with food that it considers safe. If respondents were referring to consumers as individuals, the survey measured *self-efficacy*. In this case, we are talking about a consumer's ability to purchase and prepare foods she thinks are safe to eat. In both cases, high levels of efficacy would predict self-protective and self-promotional behaviors (Bandura, 1997). In the following discussion, we will address self-efficacy beliefs. In fact, collective efficacy is simply an extension of self-efficacy to involve the group dynamic. The benefit of characterizing perceived efficacy of consumers is that the construct is grounded in a theory and a body of knowledge about its psychosocial determinants and mechanisms of operation. Thus, it provides explicit guidelines for how to structure interventions (Bandura, 1997).

In the field of food safety, a person with high self-efficacy is likely to be creative and persistent to achieve their goal. A perception of high collective efficacy implies that the individual/public believes that the consumer base has the power to effect changes which produce and maintain a safe food supply. A public (or person) with high collective (or self) efficacy is likely to be engaged in government and industry food safety planning and will probably engage in personal good food safety habits. Strong relationships between self-efficacy and health behavior change and maintenance have been documented (Strecher, Devellis, Becker, & Rosenstock, 1986).

Low self-efficacy in the domain of food safety implies that the consumer believes that she cannot be relied upon to provide safe food, whether it be through appropriate purchasing choices or proper food storage and handling procedures (i.e., a lack of training and a feeling that handling food safely actually matters). It is possible that the person can't afford or get to a location that provides 'safe' food. Those with low self-efficacy in the domain of food safety may exert little effort to succeed and may fail to persist in the face of obstacles (Bandura, 1997). A perception of low collective efficacy in the domain of food safety implies that the individual/public does not feel capable of influencing the government and food industry toward the will of the people. A public or person with low collective efficacy is unlikely to engage in behaviors to improve food safety. This may even extend to domestic food safety behaviors.

Through their choice consumers have a great power, being able to influence the market. Consumers can use their knowledge, buying power, and organizing capacity to demand certain attributes of the market. Moreover, recent increases in information through labeling initiatives and the vast variety of choice, work together to increase consumer power (Pellizzoni, 2005) more now than ever.

Respondent ratings show that consumers believe that they have the least capability of preventing foodborne illness relative to other members of the food chain. One reason for this finding may be the scope of the question: respondents were asked about responsibility/control for the safety of the "US food supply." Concerning safety of their home-prepared food, 66% of respondents considered themselves as having control over food safety (Redmond and Griffith 2004), but there is no indication of consumer ratings of responsibility/control of the food they purchase and bring into their homes.

Other reasons that consumers may feel they have little control include the following. Consumers can not always judge whether food is safe during the course of normal consumption – they have to rely upon others such as regulators and the food industry to develop and maintain effective consumer protection activities (Janneke de Jonge, et al., 2004). Consumers may feel they have little impact on government and industry control processes. Some consumers believed that if bacteria or germs were present in the food that was brought into the domestic kitchen, it was beyond their control to prepare the food safely (Redmond and Griffith 2004). Finally, the consumer may feel that acquiring foodborne illness is simply a case of bad luck.

Self- efficacy expectations are learned from 4 major sources. Of the four, personal experience (or mastery experiences) is the most important source of efficacy expectations (Goddard, Hoy, & Hoy, 2004). That is, the more experience you have with the behavior, the more efficacious you perceive yourself. This is consistent with the finding that increased cooking experience was correlated with increased ratings of consumer control.

Similarly, ratings of control increased linearly with age, but only for those with regular cooking experience. For those groups with limited cooking experience, respondents aged 31-40 and 61-70 years exhibited the lowest sense of consumer control over the safety of their foods. Younger respondents (age <30) reported cooking less frequently than older respondents ($p<0.01$). It is possible that younger people have less cooking experience and therefore, less of a sense of control. It is unclear why a second dip in control ratings should occur for people in their sixties; however it is of great concern because, as they age, this group will become increasingly susceptible to foodborne illness. The finding could be due to less concern about food safety. One finding is that consumers aged 55-64 years are less likely to think about food safety when they shop for food than younger or older respondents. Additionally, those aged 55+ were less concerned about food safety than the middle-aged demographic (35-54 years) (Harris, 2006). Or it could be due to a general loss of confidence in the safety of the food supply. Compared to the other age groups, older consumers more often indicated a decrease in their confidence in the safety of food over the past few years (de Jonge, et al., 2004). One consideration are the many life changes occurring at age 60, including retirement. These changes may undermine a general sense of efficacy which may be reflected in these ratings. Thus, it is unclear that these findings are domain specific to food safety issues or are a general trend for that life stage. Also, the trend toward eating away from home may reduce food safety learning opportunities (Altekruse & Swerdlow, 1996). Nonetheless, it is clear that whatever the cause, provided that the respondent had limited current cooking experiences, it does spill over to perceptions of consumer control over food safety. Some authors conclude that the association of frequent food preparation and age with safe hygienic practices suggests that safe food handling skills may be acquired through factors related to training, experience with handling food, or maturation (Altekruse, Street, Fein, & Levy, 1996)

This study has provided some context for understanding consumer attitudes about the distribution and structure of responsibility and control across the farm-to-table continuum.

However, several factors limit the wide applicability of these findings. While many of the predictors that were tested showed highly significant effects ($P<0.01$), the effect sizes were consistently limited. Eta squared values for all factors were less than 0.05. Similarly, absolute differences between the responsibility and control ratings of the FC members, while significant, were often very small. These limited effect sizes could be due, in part, to ceiling effects, highlighting a need for more sensitive scales in future work. Further, control in this study was operationalized as collective consumer control. Publications regarding collective control are limited, and it is has not been established how beliefs in collective control relate to personal behavior (Skinner, 1996). Nonetheless, the fact that an individual believes that consumers have little control over food safety is clearly relevant to personal food handling behavior. Finally, the survey did not address specific subcomponents of consumer attitudes toward government, farmer, industry, and consumer responsibility and control. For example, while it is clear that respondents viewed farmers as different than the food industry, it is unclear what underlying attributes of farmers caused this differentiation.

Responsibility and control could be interchangeable corollaries or could be independent constructs with different effects on lifestyle and health (Ziff, et al., 1995). A person may feel a great deal of responsibility to engage in healthful practices, but ultimately feel little control over health due to family history (cancer, heart disease, food safety application) (Ziff, et al., 1995). Personal degree of control over a situation determines, at least in part, the extent to which responsibility will be attributed to self (Brickman, et al., 1982; Lalwani & Duval, 2000). The two can be linked because 1) personal degree of control over a situation determines in part the extent to which responsibility will be attributed to self;

and 2) the way that responsibility is thought to act is that feeling a sense of personal responsibility provides individuals with a sense of control and empowerment, thereby leading to a behavior change (Williams-Piehota, et al., 2004). This is a little cyclical, but suggests that the more you empower consumers, the more control they feel. In turn, the more control they feel, the more they feel responsible for. Once they are responsible, they feel even more in control of the behavior.

Behaviors are based upon many factors: individual dispositions, family upbringing, societal customs/habits, previous lifestyle choices and others. Health messages emphasizing social responsibility convey a realistic sense of control taking place in the real social world (Williams-Piehota, et al., 2004). Since control beliefs are modifiable (Bandura, 1997), if control beliefs are low, measures can be taken to increase them; i.e., consumers can be empowered. Behavioral models suggest that domain-specific efficacy beliefs promote good (food safety) behaviors (Bandura, 1997). Public education campaigns should be developed to facilitate consumer understanding of their role in preventing foodborne illness. Health education campaigns addressing consumer responsibility should consider utilizing targeted messages designed to resonate with focal communities such as those who are unconcerned about domestic food safety due to belief in the low frequency of foodborne illness or infrequent cooking. This may be difficult because one may be changing long established cultural norms. However, behavior-based interventions can be more cost-effective than traditional service delivery, i.e., Medicare or Medicaid, after an illness has occurred (Halpern, et al., 2004). Helping individuals to help themselves is expected to result in greater public engagement and therefore greater benefits (Halpern, et al., 2004).

This leads to the notion of co-production: Government may have a more important impact on key policy outcomes by using its resources to engage, involve, and change the behavior of citizens rather than on traditional modes of providing services (Halpern, et al., 2004). Additionally, it supports the evolving expectation of governance rather than government which is based on the interaction, partnership, and cooperation between public and private actors, or the self-regulation of the latter (Pellizzoni, 2004). In short, a shift from command and control regulations to loose handling of interactions between interdependent actors.

We have provided some evidence regarding consumer attitudes of responsibility and control across the food chain in the year 2000. However, it is unclear how stable these attitudes are over time and how sensitive they are to current events. Future studies may use this information as baseline data to evaluate the stability of these attitudes or to determine the effects of current events, such as foodborne disease outbreaks, on consumer attitudes. Moreover, experimental research should be generated to determine whether attitudes of personal responsibility may be manipulated to promote good food handling practices in the home (see Rothman et al., 1993). Another promising research focus would be the identification of sociological and psychological factors contributing to consumer attitudes of food safety culpability. There is a clear need for additional work addressing social and cognitive elements of consumer food safety behavior before we attempt to educate. Finally, it would be useful to supplement this research with work describing consumer attitudes toward individual members of the farm to table continuum.

5.0 Conclusions

According to the current media outlook, food safety in the United States is at a crisis stage. After foodborne disease outbreaks, many turn to the government and to the industry to blame. But many more cases of foodborne illness are sporadic in nature, implying domestic origins. During everyday food purchase and consumption, who should be held responsible? Additionally, who actually maintains control over food safety? This paper addresses consumer perspectives on who holds the control over food safety in the US and who should be responsible for US food safety.

Considering the many actors in the food chain, consumers allocate responsibility across the farm-to-table continuum from farmers to consumers. However, there is a tendency to cede responsibility and control to manufacturers and the government and away from the consumer. In terms of food safety behavior, this perspective could be problematic, resulting in limited adherence to proper food handling and storage procedures.

There is evidence that the level of concern with food safety may be a predictor of the level of personal responsibility and control held by the consumer. Those who did not see foodborne illness as common did not report high ratings of responsibility. Demographics associated with less concern for foodborne illness such as younger constituents are also related to lower levels of consumer responsibility. Additionally, there was information to suggest that those people with limited cooking experience hold individuals less responsible than those who do cook regularly. From another perspective, regular cooking appears to entail a personal level of responsibility that was projected onto other consumers in this survey.

With trends moving toward minimal food preparation, there may be a large segment of the population who is not in control of the safety of their food because they are simply unaware of how to handle food safely. New types of food safety information focused more on correct storage and reheating procedures may need to be implemented. Additionally, characterization of the 'unconcerned' segment of the population is a necessary first step to educating this population. It is important that people be made aware that food safety is a topic of personal concern and requires action on their part. In the end, the goal is to empower the individual to behave consciously to maintain the safety of the food they eat.

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CHAPTER 5: CHANGES IN OLDER ADULTS' KNOWLEDGE, ATTITUDES, AND PRACTICES AFTER RECEIVING INFORMATION ON LISTERIOSIS PREVENTION

Abstract:

Older adults can reduce their risk of contracting listeriosis from consumption of deli meats by keeping their refrigerator at 40°F or lower and storing deli meats for the recommended time or less. A fact sheet with information on listeriosis prevention was distributed to 48 adults 60 years of age or older. Participants' food safety knowledge, attitudes, and practices were assessed before and after receiving the fact sheet. The subjects participated in focus groups to discuss their impressions of the listeriosis prevention fact sheet, whether they made any changes based on the information provided, and barriers to adopting the recommended practices. Prior to the study, most participants had not heard of *Listeria* and were unaware of possible food sources and prevention practices for listeriosis. After receiving information on listeriosis prevention, participants' awareness of *Listeria*, potential food sources, and recommended prevention practices and their understanding that older adults are at greater risk for listeriosis increased. Adoption of the recommended practices was not widespread because many participants were not concerned about contracting listeriosis. Reaching older adults with multiple messages on listeriosis prevention through multiple delivery mechanisms will help to increase awareness and adoption of the recommended practices.

1.0 Introduction

Consumption of food contaminated with *Listeria monocytogenes* can cause listeriosis, an uncommon but potentially fatal disease [26]. Approximately 2,500 Americans contract listeriosis each year; of these, one out of five dies from the illness making *L. monocytogenes* the second most common cause of death among foodborne pathogens [16,5]. Recent FoodNet data from the Centers for Disease Control and Prevention (CDC) shows encouraging declines in the prevalence of listeriosis in humans, meeting national health goals for 2010 [6]. Pregnant women, their unborn fetuses, neonates, older adults, and individuals with weakened immune systems are most susceptible to contracting listeriosis [20].

Refrigerated ready-to-eat (RTE) foods, such as frankfurters, deli meats, seafood salads, and soft cheeses, have been associated with human listeriosis and are known to support the growth of *L. monocytogenes* [10,21,24]. The pathogen is highly resistant to adverse environmental conditions and can grow at refrigerated temperatures [22]. The U.S. Department of Agriculture (USDA) has a zero tolerance for *L. monocytogenes* in cooked and RTE meat and poultry products (9 CFR 430.4) [12]; however, complete elimination of *L. monocytogenes* remains a challenge for RTE food manufacturers.

A quantitative risk assessment revealed that the most important factor increasing the risk of listeriosis from consuming deli meats is the amount of *L. monocytogenes* already present in the product when purchased by the consumer. Other risk factors include the amount of time the product is stored and the temperature at which the product is stored [34]. These results are similar to the findings from a ranking of the relative risk to public health from foodborne *L. monocytogenes* among selected categories of RTE foods conducted by the Food and Drug Administration and USDA [30].

Because adults 60 years or older are more likely than the general population to have severe complications from listeriosis and other microbial foodborne illnesses [3], this subpopulation warrants special consideration with regard to communicating the risks of listeriosis and ways to mitigate these risks. Older adults are at an increased risk of complications from foodborne illness because of decreased immune functioning; decreased stomach acid production (a natural defense against foodborne pathogens); and increased use of antibiotics, antacids, and antimotility drugs [3,7,27].

To evaluate the effectiveness of educational materials at increasing knowledge and use of the recommended practices for listeriosis prevention, focus groups were conducted with 48 adults 60 years or older. Focus groups, a qualitative research method, are often used for health communication message development and testing [23,32]. A focus group generally consists of 8 to 10 participants who discuss selected topics with a moderator for approximately 1 to 2 hours. The moderator introduces topics and serves as the discussion facilitator [14]. The educational information was presented in a one-page fact sheet (printed front and back). The fact sheet provided information on the two specific risk reduction practices identified by the consumer phase risk assessment for reducing the risk of listeriosis from deli meat consumption: (1) use a refrigerator thermometer to ensure the home refrigerator is at 40°F or below and (2) store deli meats for the recommended time or less [34]. This paper presents changes in participants' food safety knowledge, attitudes, and practices after receiving the fact sheet on listeriosis prevention.

2.0 Methods

2.1 Focus Groups

We conducted six focus groups with adults 60 years or older in Raleigh, North Carolina in August 2005. RTI International's (RTI's) Committee for the Protection of

Human Subjects, which serves as RTI's Institutional Review Board (IRB), reviewed and approved the study protocol. A market research firm recruited participants who met the following eligibility criteria: were 60 years or older, had primary or shared responsibility for grocery shopping and cooking in their households, prepared food and cooked at home at least three times a week, and ate deli meats at home at least once a week. Additionally, so that we could measure behavioral change, we recruited individuals who did not own a refrigerator thermometer and who stored deli meats for longer than the recommended storage time. Each focus group consisted of eight individuals, for a total of 48 participants, and included a mix of men and women of different races. As suggested by Greenbaum [14], the groups were segmented by education to increase homogeneity of the groups and improve participation. We conducted three focus groups with individuals with a high-school education and three focus groups with individuals with a college education.

Individuals recruited for the focus groups completed a questionnaire by telephone to measure their baseline food safety knowledge, attitudes, and practices. They were then mailed a copy of the fact sheet on listeriosis prevention and asked to read the information provided. In developing the fact sheet, we reviewed government food safety educational materials [29,31]. Approximately 4 weeks later, the same individuals participated in focus group discussions. Prior to the discussion, participants completed a written questionnaire to measure their food safety knowledge, attitudes, and practices after exposure to the fact sheet.

Two trained moderators conducted each focus group. Each focus group started with a general discussion on food safety. Focus group participants discussed their knowledge of food safety, their interest in food safety, and their concerns about contracting foodborne illness. The moderators then led participants in a discussion to identify any changes in their knowledge, attitudes, and food safety practices after receiving the fact sheet on listeriosis prevention. Participants also discussed possible barriers to following the recommended practices for listeriosis prevention.

The moderator introduced a third recommendation for listeriosis prevention that was not included in the fact sheet and asked how likely participants would be to follow the recommendation. This recommendation was stated in the focus groups as follows: "Because of the possible risk of foodborne illness, USDA recommends older adults reheat deli meats to steaming hot before eating. If reheating is not possible, then USDA recommends that older adults should not eat deli meats [31]."

Each focus group discussion was professionally videotaped and audio recorded and the discussions transcribed. The moderators reviewed the videotapes and transcriptions to prepare a four- to five-page detailed summary of each focus group. The detailed summaries were systematically analyzed to identify common themes within and across groups and any exceptions to these trends [15]. Because the number of participants in each segment (high school versus college educated) was small, we did not analyze the results by education level.

2.2 Analysis of Pre- and Postquestionnaire Data

We assessed changes in participants' food safety knowledge, attitudes, and practices after receiving the fact sheet by analyzing the responses to the pre- and postquestionnaires, as described below. The analysis was conducted using SAS version 8 [25].

2.2.1 Changes in Food Safety Knowledge and Attitudes

The pre- and postquestionnaires collected information on participants' general knowledge of food safety, interest in learning more about food safety, and level of concern about contracting foodborne illness. To measure changes in these constructs, we collapsed the response items into three categories: (1) not at all /not very, (2) somewhat, and (3) very. An increase in the construct was defined as moving from response category 1 to 2, 1 to 3, or 2 to 3. Conversely, a decrease in the construct was defined as moving from response category 3 to 2, 3 to 1, or 2 to 1.

To measure whether participants believed they are at an increased risk for foodborne illness because of their age, in the pre- and postquestionnaires we asked how strongly they agree or disagree with the following statement: "Because of my age, I am at an increased risk of getting food poisoning or foodborne illness from the food I eat at home." To measure changes in this construct, we collapsed the response items into two categories: (1) disagree or strongly disagree and (2) agree or strongly agree. An increase in this construct was defined as moving from response category 1 to 2.

The pre- and postquestionnaires also collected information on participants' awareness of *Listeria* (participants selected the pathogens they had heard of from a list of pathogens); knowledge of processed meats, such as deli meats and frankfurters, as possible food sources for *Listeria* (open-ended response for prequestionnaire, participants selected response(s) from list of food sources for postquestionnaire); and knowledge of safe refrigerator temperature (open-ended response).

To collect information on knowledge of the recommended storage times for deli meats, we asked participants in the postquestionnaire to identify the recommended storage time for unopened and opened packages of vacuum-packed deli meats and freshly sliced deli meats. Participants selected the number of days from a list of responses.

2.2.2 Changes in Food Safety Practices

The pre- and postquestionnaires collected information on refrigerator thermometer ownership and the storage time for the most recently purchased package of deli meats. We also included questions in the postquestionnaire to determine the stage of change participants were in with respect to the two recommendations for listeriosis prevention. The Stages of Change Model categorizes people according to their stage of readiness with respect to the recommended behavior; the stages are precontemplation, contemplation, preparation, action, and maintenance [19].

2.2.3 Demographic and Other Questions

The postquestionnaire collected information on participants' demographics (e.g., gender, age, and education), health status, and whether a participant or household member had contracted a foodborne illness in the past year. Table 5.1 summarizes this information.

3.0 Results

3.1 Changes in Food Safety Knowledge and Attitudes

Table 5.2 summarizes participants' food safety knowledge and attitudes before and after receiving the listeriosis prevention fact sheet.

3.1.1 General Food Safety Knowledge and Attitudes

Participants considered themselves to be somewhat knowledgeable about food safety, but they doubted their knowledge after reading the listeriosis prevention fact sheet. Many participants were surprised and concerned that they were not previously aware of the information on listeriosis prevention. Comparing the pre and post data, 23 percent of participants rated themselves as less knowledgeable after receiving the listeriosis prevention fact sheet. One participant said, "I thought I was knowledgeable until I got the sheet and read about *Listeria*, which I [had] never heard of."

In the postquestionnaire, 21 percent of participants described themselves as very knowledgeable about food safety and 70 percent described themselves as somewhat knowledgeable. Most participants expressed confidence in their food safety practices. They believed they knew enough to handle and prepare food safely at home and reported the use of good hygiene practices and practices to prevent cross-contamination. However, some participants revealed they unknowingly follow some unsafe practices such as washing meats and poultry prior to cooking, which can lead to cross-contamination; mishandling leftovers; and defrosting meat and poultry at room temperature.

Participants expressed a strong interest in learning more about food safety. In the postquestionnaire, 85 percent of participants described themselves as very interested in learning more about food safety. Comparing the pre- and postquestionnaire data, 17 percent of participants rated themselves as being more interested in learning more about food safety after receiving the listeriosis prevention fact sheet. One participant said, "There's always something you can learn [about food safety]." Participants reported that they would like to know more about recommended storage times for refrigerated and frozen foods, product dating, and foodborne bacteria and illnesses.

Participants had differing levels of concern about contracting foodborne illnesses from food prepared at home. Comparing the pre and post data, 13 percent of participants rated themselves as more concerned, 17 percent rated themselves as less concerned, and 70 percent had no change in their response after receiving the listeriosis prevention fact sheet.

In the postquestionnaire, 32 percent of participants described themselves as very concerned about contracting foodborne illness from food prepared at home. Some of these participants prepare food for people who are more susceptible to foodborne illness because of other illnesses (e.g., leukemia or diabetes); thus, they are very cautious when preparing food at home. Some participants have had experience with foodborne illness (either getting sick themselves or having a family member contract foodborne illness) and want to prevent a repeated experience. Others doubted their ability to always handle and prepare food safely at home. One participant said, "I'm very concerned because I stretch the limits. I know I'm pushing it. I pray I don't get sick."

Twenty-eight percent of participants described themselves as somewhat concerned about contracting foodborne illness from food prepared at home, while 40 percent said they are not at all or not very concerned. Some participants are not very concerned because they have never had a foodborne illness and thus think it is unlikely that they will contract foodborne illness in the future. One participant stated, "I am 66 years old and it [food poisoning] hasn't happened yet." Many participants are more concerned about how food, especially meat and poultry, is handled by retailers and grocery stores before they purchase it.

3.1.2 Knowledge that Older Adults Are an At-Risk Population for Foodborne Illness

Prior to receiving the fact sheet, 41 percent of participants agreed or strongly agreed with the statement, "Because of my age, I am at an increased risk of getting food poisoning or foodborne illness from the food I eat at home." After receiving the fact sheet, 67 percent of participants agreed or strongly agreed with this statement. Comparing the pre and post data, 37 percent of participants moved from disagreeing to agreeing with this statement, suggesting the fact sheet may have educated these participants that older adults are at an increased risk for foodborne illness because of their weakened immune systems.

In the focus group discussions, most participants understood that, in general, older adults are more susceptible to contracting foodborne illness because of their weakened immune systems. They also believed, however, that older adults have safer food handling and consumption practices compared to younger adults, thus reducing their risk of contracting a foodborne illness. In addition, many participants believed that not all older adults, including themselves, are at risk for foodborne illness. They believed that older adults who have limited education or income, live alone, suffer from other illnesses, or are much older are at a greater risk for foodborne illness.

3.1.3 Knowledge of Listeria and Food Sources

Prior to receiving the fact sheet, 33 percent of participants had heard of *Listeria* but admitted in the focus groups that they had little or no knowledge about the foodborne pathogen and could not recall where they had heard about it. After receiving the fact sheet, 58 percent of participants had heard of *Listeria*—a 38 percent increase among those participants who were previously unaware.

Prior to receiving the fact sheet, no participants identified processed meats as a food source for *Listeria*. After receiving the fact sheet (which identified deli meats and other processed meat and poultry products as foods that could contain *Listeria)*, 57 percent of participants who had heard of *Listeria* correctly identified processed meats as a food source for the bacterium.

The fact sheet sparked curiosity in some participants and motivated them to want to learn more about *Listeria* and listeriosis. In four of the six groups, one or more participants said they sought out additional information after reading the fact sheet by searching the Internet, visiting USDA's Web site (the address was provided on the fact sheet), or asking a health care professional for more information.

3.1.4 Knowledge of Safe Refrigerator Temperature and Recommended Storage Time Guidelines for Deli Meats

Prior to receiving the fact sheet, 29 percent of participants knew the safe refrigerator temperature was 40°F or below. After receiving the fact sheet (which identified the safe refrigerator temperature), 58 percent knew this information—a 38 percent increase among those participants who were previously uninformed.

The fact sheet provided the recommended storage time guidelines for deli meats. On the postquestionnaire, 66 percent of participants correctly identified the recommended storage time for unopened packages of vacuum-packed deli meats (14 days or less). About half of participants correctly identified the recommended storage time for opened packages of vacuum-packed deli meats and freshly sliced deli meats (5 days or less).

3.2 Changes in Food Safety Practices

Table 5.3 summarizes participants' use of the recommended practices for listeriosis prevention after receiving the fact sheet. As described below, adoption of the recommended practices was not widespread.

3.2.1 Use of Refrigerator Thermometers

Prior to receiving the fact sheet, no participants used a refrigerator thermometer to check whether their refrigerator was at a safe temperature. After receiving the fact sheet, 42 percent of participants were in the precontemplative stage of the Stages of Change model; that is, they had not at all considered purchasing a refrigerator thermometer. Thus, the fact sheet did not motivate these participants to even consider purchasing a refrigerator thermometer.

Thirty-one percent were in the contemplative stage; that is, they had considered buying a refrigerator thermometer but had not done so yet. In addition, 15 percent were in the preparation stage; that is, they were planning to buy a refrigerator thermometer the next time they went shopping. Most participants in this stage of change agreed it was important to monitor the temperature inside their refrigerators. One participant said, "It's a good idea. It's the only way to be sure [that your refrigerator is kept at a safe temperature]," and another participant said, "Refrigerators are designed in such a way that you have no idea what temperature you're setting your refrigerator at when you turn [the thermostat] to A, B, C, D, E or 1, 2, 3, 4, 5. Those numbers are meaningless."

Six of the 48 participants (12 percent) started using a refrigerator thermometer after receiving the fact sheet (two participants purchased a new thermometer and four participants "dug one out of the drawer"). A few participants said they turned down the thermostat in their refrigerators as a safety precaution after reading the fact sheet. Several participants said they were waiting until after the focus group to decide whether to purchase a refrigerator thermometer and were glad to hear they would receive a refrigerator thermometer for participating in the focus group.

Despite the fact sheet's recommendation, some participants said they were unlikely to purchase and start using a refrigerator thermometer. Some participants considered refrigerator thermometers unnecessary because they believe their refrigerators keep food at a safe temperature. One participant said, "As long as my beer is cold, I know my refrigerator is working." Other barriers to using a refrigerator thermometer included distrust in the accuracy of refrigerator thermometers, participants' belief that they do not store refrigerated foods longer than recommended, and a general lack of concern about contracting foodborne illness.

To encourage the use of refrigerator thermometers, some participants suggested the government should educate consumers about refrigerator thermometer usage; the government should require refrigerator manufacturers to include a refrigerator thermometer as part of the product design; and refrigerator thermometers should be prominently displayed in grocery stores (e.g., in the frozen and refrigerated food sections), home improvement stores, and houseware stores.

3.2.2 Adherence to Recommended Storage Time Guidelines

Prior to receiving the fact sheet, no participants were following the recommended storage time guidelines (5 days or less) for opened packages of vacuum-packed deli meats and freshly sliced deli meats, but all participants were following the recommended guidelines (14 days or less) for unopened packages of vacuum-packed deli meats.

After receiving the fact sheet, 13 percent of participants were in the precontemplative stage of the Stages of Change model; that is, they had not at all considered following the recommended storage time guidelines for deli meats. Nineteen percent were in the contemplative stage; that is, they had considered following the guidelines but had not yet done so. Additionally, 13 percent were in the preparation stage; that is, they plan to follow the guidelines in the future. About 56 percent of participants reported they had been following the recommended guidelines all, some, or most of the time since receiving the fact sheet.

We also directly assessed participants' adherence to the guidelines by asking participants about storage time for their most recent purchase of deli meats. Nearly all participants (93 percent) stored unopened packages of vacuum-packed deli meats for the recommended time or less, although 100 percent reported following the recommended guideline prior to receiving the fact sheet. Thirty-eight percent stored opened vacuum-packed deli meats for the recommended time or less, and 59 percent stored freshly sliced deli meats for the recommended time or less.

As suggested by the fact sheet, some participants said they plan to buy smaller amounts of deli meats so they can consume the amount purchased within the recommended guidelines. Also, some participants plan to store unopened packages of deli meats in the freezer instead of the refrigerator to prolong the shelf life. In three of the six focus groups, one or more participants had already stopped or planned to stop eating deli meats because of concerns about contracting listeriosis. However, we have no way of ascertaining how long these attitudes will persist.

Despite the fact sheet's suggestion to follow the recommended storage time guidelines, some participants said they are unlikely to follow the guidelines in the future because they either store deli meat for less than 1 week, which they consider a safe amount of time, or they follow the date on the product (e.g., use-by date) for storage time guidance.

Some participants did not perceive the risk of listeriosis to be great enough to warrant special precautions even though the fact sheet included information from CDC on the morbidity and mortality rates for listeriosis. Participants' general opinion was that the number of listeriosis cases each year (2,500) is a very small percentage of the total U.S. population; thus, most participants were not very concerned about contracting listeriosis. In all six groups, however, one or more participants noted the mortality rate was quite high (one in five) and a cause for concern. One participant said, "Well, I think…the mortality rate is high. I wouldn't want to be one of those five. I have a son who has autism, and that's a very rare occurrence, and I know that these things can happen."

3.2.3 Recommendation to Reheat Deli Meats to Steaming Hot

Participants had mixed opinions on whether they would follow the recommendation to reheat deli meats to steaming hot. In the postquestionnaire, 38 percent said they would be very likely to follow the reheating recommendation because of concerns about contracting listeriosis. One participant said, “I think I would [follow the recommendation]. I have no trouble with it [deli meat] being hot, and I think I better start.” Another participant said, “I [have] never done it [reheated deli meat], but I guess I’ll try it next time … if that’s what they [USDA] say.” Several participants said they would consider following the recommendation for deli meats that are sometimes eaten hot (e.g., pastrami) but not for deli meats that are typically served cold (e.g., turkey). Prior to this study, at least one participant in two of the six groups sometimes reheated deli meats because of food safety concerns.

In the postquestionnaire, 21 percent said they would be somewhat likely and 42 percent said they would be not at all or not very likely to follow the reheating recommendation. Participants thought it would be inconvenient to reheat deli meats and were concerned that reheating deli meats would alter the taste, texture, and color of the meat. Participants did not believe this precaution was necessary because of the low mortality rate for listeriosis and doubted that many people would follow the recommendation. One participant summed up the feelings in the group by stating, “I’m willing to take the risk [by not reheating].”

Some participants were very surprised they had not previously heard of the recommendation to reheat. One participant asked, “Is it [the recommendation] being put out to the public? I haven’t heard about it. We have to know in order to make a decision.” Some participants believe that if the recommendation is important, then the government needs to educate older adults and make them aware. One participant stated, “The government is obligated to tell the public, and it is then our choice whether or not to follow.”

4.0 Discussion

This study identified the need to educate older adults about the risks of listeriosis and the recommended practices for listeriosis prevention. Before being contacted for this study, most participants had not heard of *Listeria* and listeriosis and were unaware of possible food sources and prevention practices. Similarly, a recent national survey of U.S. adults found that 44 percent had heard of *Listeria* while 94 percent had heard of *E. coli* and *Salmonella*. Furthermore, in the same survey, awareness of *Listeria* was lower among individuals 60 years of age or older [4].

After receiving information on listeriosis prevention, participants' awareness of *Listeria*, knowledge of potential food sources and recommended prevention practices, and the understanding that older adults are at greater risk for contracting listeriosis increased. Although participants received the fact sheet 4 weeks prior to the focus group discussion, 40 percent of participants could not recall or never learned the safe refrigerator temperature, and about half could not recall the recommended storage times for deli meats. Nearly all participants indicated that they read the fact sheet upon receipt, and some said they read it again prior to the focus group discussion. Therefore, although participants read the fact sheet, they did not learn or retain certain pieces of information. Typically, older adults do not remember recent experiences and information as well as younger adults because of changes in the functioning of neural systems that support these memory processes [13,28]. Thus, reading or hearing the message only once may not be sufficient for retaining the message. Therefore, there is the need to reach the target population with multiple messages on listeriosis prevention through multiple delivery mechanisms. National food safety education initiatives, such as Project CHILL, complemented by local food safety education programs, may help to increase consumer awareness and knowledge. Project CHILL is a recent campaign launched by the Food Marketing Institute (FMI) and the Partnership for Food Safety to educate consumers about the importance of using a thermometer to monitor refrigerator temperature [8]. Also, tools such as a refrigerator magnet that provides the recommended storage time guidelines and safe refrigerator temperature, may help to increase consumer knowledge and facilitate adoption of the recommended practices.

The fact sheet motivated some participants to adopt the recommended practices for listeriosis prevention; however, we do not know how long these behaviors will persist. Twelve percent of participants started using a refrigerator thermometer, about 40 percent of participants stored opened packages of vacuum-packed deli meats for the recommended time or less, and about 60 percent stored freshly sliced deli meats for the recommended time or less. More participants followed the recommended storage time guidelines for deli meats than the recommendation to use a refrigerator thermometer. Although the actual cost to purchase a refrigerator thermometer was not identified as a barrier, the time required to find and purchase one (i.e., search costs) may have been a barrier for some participants.

Some participants did not adopt the recommended practices because they were not very concerned and did not think the risk of illness warranted changes in their behavior. Because risk of listeriosis may not be a motivating factor in itself, educators may want to consider also highlighting the benefits of the recommended practices with regards to product quality. For example, these messages could include “using a refrigerator thermometer keeps foods cold so they taste good and are safe" or "storing deli meats for the recommended time provides better tasting and safer deli meats."

Knowing the stage of change for the target population enables educators to tailor the message accordingly [33]. Regarding the recommendation to use a refrigerator thermometer, 46 percent of participants were in the contemplative or preparation stage; thus, these participants were considering adopting the recommended practice but had not done so yet. Consumers may be more likely to start using a refrigerator thermometer if the search costs are reduced. For example, educators could partner with manufacturers and distribute free thermometers at events like the state fair or home shows.

Most participants were unaware of the USDA recommendation to reheat deli meats to steaming hot before eating and many participants did not react favorably to the recommendation. Participants thought the recommendation was inconvenient, did not believe this precaution was necessary, and doubted that many people would follow this recommendation. In focus group research with cancer and organ transplant patients, participants also reacted negatively to the reheating recommendation [17]. Together, these studies provide converging evidence which suggests that the "reheat or do not eat" recommendation will have limited adherence in these high-risk populations. Future research should address promoting the recommendation among target populations and identifying methods for motivating at-risk individuals to follow the recommendation.

It is important for older adults to understand why they are at risk for listeriosis and other foodborne illnesses. Two common themes emerged when discussing whether participants view older adults, including themselves, as having an increased risk for listeriosis and other foodborne illnesses. First, most participants understood that older adults are more susceptible to contracting foodborne illness because of their weakened immune systems, but they also believe that older adults have safer food handling and consumption practices compared to younger adults, thus reducing older adults' risk of contracting foodborne illness. Research studies have shown that older adults do have safer food handling practices than any other age group [1,2,3,9,11,18]. In educational materials targeted to older adults, it is important to convey that, although older adults have safer food handling practices, they are still at a greater risk for foodborne illness because of their weakened immune systems.

Second, many participants believed that not all older adults, including themselves, are at risk for foodborne illness. They believed that older adults who have limited education or income, live alone, suffer from other illnesses, and are very old (over 80 years old) are more at risk for foodborne illness. Further research is needed to examine whether there are differences in food safety knowledge, attitudes, and practices among older adults in different subgroups (e.g., education level, socioeconomic group, geographic location, age range, or culture). This information would help target educational initiatives to those subgroups that exhibit limited knowledge and/or risky behaviors.

Finally, older adults reported confidence in their ability to safely handle and prepare food when cooking at home because they have a lot of experience cooking and most have not contracted foodborne illness. However, the pathogens *L. monocytogenes*, *E. coli* O157:H7, and *Salmonella* enteritidis were not important causes of foodborne disease when older adults formed their food safety practices. Thus, it is important for older adults to understand that as pathogens evolve, so must their food safety behaviors.

Although the study provided valuable information for educators, we did not use a random sample of older adults; therefore, care should be taken in generalizing the study results to all older adults. Also, the research was limited to one geographic location. The focus group methodology employed for this study, however, is appropriate for exploratory research such as this.

In conclusion, targeted educational initiatives are needed to educate older adults about the risks of listeriosis and ways to mitigate these risks. Educators can use the findings from this and other research to develop materials on listeriosis prevention targeted to older adults. Such educational efforts are an important component of the risk management plan for *L. monocytogenes.*

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CONCLUSION

Illness continues to be of significant concern in the United States. The cost of foodborne illness is not limited to health; there are financial costs as well as interruption to the household. At the societal level, foodborne illness results in a financial burden as well as a tax on limited healthcare resources. Because of this, the government has created initiatives to reduce the level of foodborne illness. While some programs are targeted at the industry and improved legislation, an important focus is the American population. In many cases, foodborne illness can be prevented at the domestic level. The most important method that scientists and government officials have to educate the public is risk communication. Risk communications are designed to educate the public as well as motivate individuals to follow recommended food storage and handling practices. However, it is understood that risk communication is not as simple as information dissemination. Risk communication is an interdisciplinary task, borrowing approaches from risk assessors, sociologists, psychologists, and statisticians. The purpose of this dissertation has been to provide real-life situations where key techniques to creating risk communications can be developed. In the following paragraphs, each chapter of the dissertation is summarized, the focus skills are identified, and the significance of each skill is discussed.

Chapter One is a consumer-phase *Salmonella enterica* serovar *Enteritidis* risk assessment for eggs and egg-containing products. We describe a uni-dimensional probabilistic model of the role of domestic food handling behaviors on salmonellosis risk associated with the consumption of eggs and egg-containing foods. Analysis of the model indicates that at the consumer stage, adequately cooking these foods offers the best protection against salmonellosis.

Conducting a risk assessment follows prescribed steps to achieving the final risk estimate. The first step is to conduct an extensive literature review to identify possible model pathways and known parameters. Next, a mathematical model is constructed to describe how the pathogen is transferred from pre-harvest through processing, consumer storage and handling, and finally to human consumption. The levels of consumer exposure to the pathogen and the dose-response function are calculated. Next, risk is characterized as the number of illnesses per serving of food. Finally, what-if scenarios are conducted to establish which consumer behaviors result in adequate control of the pathogen of study. The usefulness of risk assessment in developing risk communications is that it provides a link between consumer behaviors and a health outcome – foodborne illness. Risk assessments identify behaviors that should be avoided and behaviors that are protective against illness. This type of information is the foundation for subsequent risk communications.

Chapter Two reports on consumer knowledge and behaviors regarding handling of deli meats and frankfurters. Proper storage and handling of refrigerated ready-to-eat foods can reduce the risk of listeriosis. A web-based survey was conducted and results were analyzed using a chi-square test to evaluate the relationship between awareness of *Listeria monocytogenes* and various socio-demographic and other variables. A binomial logistic regression model was used to identify predictors of risky storage practices. Results indicated that most households safely handle and store their deli meats/frankfurters correctly. Men, more educated individuals, and individuals living in metropolitan areas were more likely to engage in risky storage practices. The study identified the need to develop targeted educational materials on listeriosis prevention. Developing a strong statistical background is important to understanding which segments of the population are at risk and to using this information to target the message.

Chapter Three is a concept paper describing various theoretical models that may be used to guide development of food safety risk communications. Key models identified were the motivational, behavioral enaction, and stage models. Motivational models are causal models that link cognitive constructs to behavior adoption. Behavioral enaction models explore links between intentions to act and action. Stage models posit that behavioral change is a process, not an event. People move through stages toward behavioral change, and the kinds of information and interventions needed to affect behavioral change varies with the stage. In order to make consistent progress toward understanding and changing consumer food safety behaviors, it is necessary to study the problem within a theoretical framework. Established models, like those introduced in this chapter, often have significant empirical support. The model provides the framework for the message content and answers the question – what components need to be included to produce an effective message?

The objective of Chapter Four is to explore consumer expectations regarding responsibility and control of food safety in the US. Overall, there was a tendency to yield responsibility and control to manufacturers and the government and away from the consumer. In terms of food safety behavior, this perspective could be problematic, resulting in limited adherence to proper food handling and storage procedures. The concept of self-efficacy, one's belief in one's capabilities to perform a desired behavior, was introduced to interpret the results. Many respondents reported low control over food safety concerns, suggesting that these individuals may be less likely to attempt protective food safety behaviors. Further, it was suggested that the level of concern with food safety may be a predictor of the level of personal responsibility and control held by the consumer. Educational efforts should be focused on making consumers aware that food safety is a topic of personal concern, requiring their action and empowering them to make a conscious effort to maintain the safety of their food.

The objective of Chapter Five was to evaluate the effectiveness of a draft risk communication by measuring changes in participants' food safety knowledge, attitudes, and practices after receiving the fact sheet. Questionnaires were used to develop baselines and to measure changes in knowledge and behavior. Focus groups were used to gather qualitative data regarding older consumers' opinions regarding a draft of a risk communication fact sheet. Focus groups combine multiple perspectives and experiences to provide qualitative feedback on a concept or product. Results indicated that consumers considered themselves to be somewhat knowledgeable about food safety, but they doubted their knowledge after reading the fact sheet. Interestingly, after reading the fact sheet, 70% of respondents had no change in concern about contracting foodborne illness from food prepared at home. Until receiving the fact sheet, most people had little or no knowledge of listeria/listeriosis and did not use a refrigerator thermometer. In the focus group sessions, participants commented on relevancy, persuasiveness, format, and appearance, among other factors. Based on participants' comments, we selected and subsequently refined the fact sheet to optimize effectiveness. Multiple perspectives and experiences from the participants are combined to gain a holistic view. Focus groups are useful tools for refining the risk communication, evaluating and enhancing the effectiveness of the message.

Key elements in producing effective risk communications include:

1) identifying the key behavior that needs to change;

2) identifying who is at risk;

3) identifying who the message should be targeted to;

4) identifying which cognitive elements need to be included;

5) producing a draft message;

6) evaluating the effectiveness of the message; and

7) refining the message using surveys and focus groups.

These are the methods embraced in this dissertation, methods crucial for the development of effective food safety risk communications.

Table 1.1: Characterization of Food Categories Considered in the SE Model

Category	Pooling	Egg/ Ingredient	Example Foods	Consumer Survey [a]	
				% of Population Cooking Thoroughly [b]	% of Total Eggs Consumed
I	No	Egg	fried eggs	51%	31%
II	No	Egg	soft-boiled, hard-boiled, poached eggs	83%	19%
III	Yes	Egg	scrambled eggs, omelets	98%	35%
IV	Yes	Ingredient	ice cream, eggnog, Caesar salad dressing, raw cookie dough	73%	1%
V	Yes	Ingredient	custard, egg soup, soufflé, lasagna	98%	5%
VI	Yes	Ingredient	bread, cake, muffins, cookies, waffles	98%	9%

[a] Results from consumer survey (n=1,076)

[b] The % of eggs that are undercooked = 100% - % thoroughly cooked for Cat. I-III and V-VI. For Cat. IV, 26% of subjects reported using raw eggs, and the % of undercooked was 1.

Table 1.2: Input Variables and Corresponding Probability Distributions in the SE Model

Inputs	Distribution	Source
Initial contamination (Log CFU/egg)	Lognormal (2.00, 0.59)	Latimer et al., 2002
Egg shell prevalence	Pert (0.001, 0.01, 0.2)	Expert Judgment
SE from contaminated eggshell (CFU)	Uniform (0, 20)	Expert Judgment
Number of eggs mixed	Discrete (*n, p*) [a]	Consumer survey [b]
Storage temperature before cooking (^{o}C)	Pert (4, 10, 21)	Expert Judgment
Storage time before cooking (hr)	Uniform (0, 2)	Expert Judgment
Storage temperature after cooking (^{o}C)	Pert (4, 21, 35)	Expert Judgment
Storage time after cooking (hr)	Weibull (0.74, 0.70) [c]	Consumer survey
Portion of Eggs (Category I)	Discrete (*n, p*) [d]	CSFII, 1994-1996, 1998
Portion of Eggs (Categories II to VI)	Lognormal (μ, δ) [e]	CSFII, 1994-1996, 1998
Cooking reduction (thoroughly cooked)	Uniform (6, 8)	FSIS/USDA, 1998
Cooking reduction (under cooked)	Pert (α, β, γ) [f]	FSIS/USDA, 1998
Serving Size (g) (Category I)	Min{Lognormal (70.15, 42.04), 283}	CSFII, 1994-1996, 1998
Serving Size (g) (Category II)	Min{Lognormal (44.15, 77.97), 263}	CSFII, 1994-1996, 1998
Serving Size (g) (Category III)	Min{Lognormal (75.91, 62.11), 410}	CSFII, 1994-1996, 1998
Serving Size (g) (Category IV)	Min{Lognormal (16.14,12.58), 382}	CSFII, 1994-1996, 1998
Serving Size (g) (Category V)	Min{Lognormal (12.656, 4.456), 143}	CSFII, 1994-1996, 1998
Serving Size (g) (Category VI)	Min{Lognormal (10.04, 14.50), 169}	CSFII, 1994-1996, 1998

[a] One egg is used for Categories I and II
Category III: n = {1, 2, 3, 4, 5, 6, 7, 8}; p = {0.09, 0.17, 0.21, 0.20, 0.15, 0.09, 0.05, 0.02}
Categories IV to VI: n = {1, 2, 3, 4, 5, 6, 7}; p = {0.13, 0.21, 0.23, 0.19, 0.12, 0.07, 0.03}

[b] Results from a web-based consumer survey (n=1, 076)

[c] The distribution was truncated at 24hrs for foods in Category IV. For foods in other categories the distribution was truncated at 6hrs.

[d] n = {Lognormal (0.37, 0.07), Lognormal (0.95, 0.01)}; p ={0.19, 0.81} The distribution is truncated between 0 and 1.

[e] Category II: μ = 0.318, δ = 0.558; Category III: μ = 0.558, δ = 0.149; Category IV: μ = 0.329, δ = 0.733; Category V: μ = 0.117, δ = 0.125; Category VI: μ = 0.135, δ = 0.101; The distributions are truncated between 0 and 1.

[f] Category I: { α, β, γ }={0, 4, 7}; Category II: { α, β, γ }={0, 1, 7}; Categories III to VI: { α, β, γ }={0, 6, 7}

Table 1.3: Estimated Illness from Consumption of Eggs and Egg-Containing Foods (Illness/Serving)

Food Category	Mean	50th Percentile	75th Percentile	95th Percentile	99th Percentile
I	7.52×10^{-5}	0	0	5.65×10^{-5}	7.71×10^{-4}
II	7.07×10^{-5}	0	0	3.48×10^{-5}	7.14×10^{-3}
III	1.64×10^{-8}	0	0	0	0
IV	2.05×10^{-4}	0	1.78×10^{-6}	4.16×10^{-4}	2.8×10^{-3}
V	1.26×10^{-10}	0	0	0	0
VI	2.59×10^{-10}	0	0	0	0
Overall	4.87×10^{-5}	0	0	0	4.05×10^{-4}

Table 1.4: Uncertainty in the Form of 95% Probability Range of Values for Mean, 50th, 75th, 95th, and 99th Percentiles of the Probability Distribution for SE Illness

Food Categories	Mean	50^{th} Percentile	75^{th} Percentile	95^{th} Percentile	99^{th} Percentile
I	(5.4×10^{-5}, 1.6×10^{-3})	0.0	0.0	(0.0, 4.5×10^{-4})	(2.6×10^{-4}, 1.7×10^{-2})
II	(5.6×10^{-5}, 2.4×10^{-3})	0.0	0.0	(2.5×10^{-5},1.2×10^{-3})	(1.3×10^{-5},7.0×10^{-4})
III	(0.0, 9.28×10^{-7})	0.0	0.0	0.0	0.0
IV	(3.4×10^{-5}, 6×10^{-2})	0.0	(0.0, 1.9×10^{-4})	(1.2×10^{-4}, 2.1×10^{-3})	(3.4×10^{-5}, 5.0×10^{-2})
V	(0.0, 3.1×10^{-8})	0.0	0.0	0.0	0.0
VI	(0.0, 4.4×10^{-8})	0.0	0.0	0.0	0.0
Overall	(2.1×10^{-5}, 1.7×10^{-3})	0.0	0.0	(0, 3.4×10^{-5})	(2.4×10^{-4},7.5×10^{-3})

Table 2.1: Demographic Characteristics of Respondents

Characteristic	**Number of Respondents**	**Weighted (%)**[a]
Gender		
Male	609	47.9
Female	603	52.1
Age (years)		
18–29	215	21.6
30–44	341	30.5
45–59	326	26.1
≥60	330	21.8
Race/ethnicity		
White, non-Hispanic	940	73.1
Black, non-Hispanic	123	11.3
Other non-Hispanic	42	4.8
Hispanic	107	10.8
Education level		
Less than high school	135	15.1
High school graduate	398	32.7
Some college	350	27.7

Table 2.1: Demographic Characteristics of Respondents (cont.)

Bachelor's degree or higher	329	24.5
Household income		
<$15,000	139	13.3
$15,000–34,999	321	28.7
$35,000–74,999	522	42.3
>$75,000	217	14.9
No response	13	0.8
Median	1,199	$37,500
Respondent or household member in at-risk group		
60 years of age and older (i.e., senior)	401	28.6
5 years of age and younger	186	18.9
Diagnosed with diabetes or kidney disease	186	15.1
Pregnant	37	4.0
Diagnosed with condition that weakens immune system	35	2.6

[a]Analysis was conducted using individual-level weights (n = 1,212).

Table 2.2: Awareness and Knowledge of Listeria

	Weighted %[a]
Pathogen	**Aware of Pathogen**
E. coli	94.2
Salmonella	93.9
Listeria	43.8
Norwalk virus	23.9
Campylobacter	10.9
Food Source	**Identified Food as Vehicle for *Listeria*[b]**
Meat (raw)	17.4
Fruits or vegetables	5.4
Seafood	4.5
Cheese	3.8
Milk	3.6
Poultry (raw)	3.2
Processed meats (e.g., deli meats, frankfurters)	3.1
Other	3.1
Don't know/not sure/did not respond	67.4

[a]Analysis was conducted using individual-level weights (n = 1,212).

[b]Unaided response. Totals sum to more than 100 percent because respondents could enter multiple responses.

Table 2.3: Comparison of Consumers Who are Aware vs. Unaware of Listeria[a]

	Aware of *Listeria*		**Unaware of *Listeria***		
	Number of Respondents	**Weighted %**	**Number of Respondents**	**Weighted %**	**p**[b]
All respondents	553	—	634	—	
Gender of respondent					0.575
Male	275	46.1	315	48.1	
Female	278	53.9	319	51.9	
Education level of respondent					0.000
Less than high school	41	10.4	89	18.5	
High school graduate	163	28.3	225	36.3	
Some college	154	27.3	192	28.0	
Bachelor's degree or higher	195	34.0	128	17.2	
Age of respondent (years)					0.013
18–29	92	20.3	122	23.2	
30–44	163	33.7	171	27.7	
45–59	166	28.6	152	23.8	
≥60	132	17.4	189	25.3	
Race/ethnicity of respondent					0.034
White, non-Hispanic	444	76.9	482	71.5	
Black, non-Hispanic	45	7.6	74	13.9	

Table 2.3: Comparison of Consumers Who are Aware vs. Unaware of Listeria[a] (cont.)

Other non-Hispanic	23	6.0	18	3.8	
Hispanic	41	9.5	60	10.8	
Household (HH) income					0.000
<$15,000	47	10.4	87	15.5	
$15,000–34,999	114	21.3	201	35.0	
$35,000–74,999	265	49.0	258	37.8	
≥$75,000	127	19.3	88	11.7	
Level of urbanization					0.928
Metropolitan	476	79.6	532	79.9	
Nonmetropolitan	77	20.4	102	20.1	
Child ≤5 years of age in HH	102	22.0	81	16.2	0.053
Individual with weakened immune system, diabetes, or kidney disease in HH	84	14.1	114	17.6	0.169
Individual ≥ 60 years of age in HH	167	23.3	226	33.0	0.001
Pregnant woman in HH	20	4.5	17	3.8	0.652
Respondent shops for groceries	494	88.1	540	82.5	0.034
Respondent cooks meals	497	90.4	545	83.5	0.004

[a]Analysis was conducted using individual-level weights for respondents who answered the question on awareness of *Listeria* (n = 1,187).

[b]p of χ^2 test.

Table 2.4: Perceptions of Responsibility and Control for the Safety of the U.S. Food Supply[a]

In your opinion, how much responsibility does each of the following have for ensuring the safety of the U.S. food supply?

	Weighted %					
	1 None	**2**	**3**	**4**	**5 A lot**	**No Response**
U.S. government	1.1	2.2	14.5	21.5	59.8	0.9
Farmers	1.4	6.3	22.0	24.3	44.9	1.0
Food manufacturers	0.6	0.7	6.7	14.4	76.8	0.9
Supermarkets	0.8	1.3	12.2	23.5	61.5	0.7
Restaurants	0.8	1.4	7.3	14.2	75.5	0.9
Consumers	1.9	4.9	24.8	19.6	47.9	0.9

In your opinion, how much control does each of the following have for ensuring the safety of the U.S. food supply?

	Weighted %					
	1 None	**2**	**3**	**4**	**5 A lot**	**No Response**
U.S. government	1.3	5.7	18.8	25.6	47.9	0.7
Farmers	3.2	9.2	29.5	28.8	28.4	0.9
Food manufacturers	1.0	1.4	10.8	25.6	60.4	0.7
Supermarkets	1.1	4.0	23.4	34.5	36.4	0.7
Restaurants	2.0	3.3	18.3	30.2	45.5	0.7
Consumers	7.3	16.4	29.6	21.9	24.0	0.8

[a]Analysis was conducted using individual-level weights (n = 1,212).

Table 2.5: Storage and Handling Practices for Frankfurters and Deli Meats

Practice[a]	**Weighted % of Households**[b]
Frankfurters (n = 915)	
Stored unopened packages in freezer	44.2
If refrigerated, stored unopened packages for recommended time or less (≤14 days)	96.2
If opened, stored opened packages for recommended time or less (≤7 days), stored in freezer, or discarded uneaten product	86.7
Heated frankfurters before consumption	99.8
For frozen product, defrosted before heating	46.9
Deli meats (n = 903)	
Stored unopened packages of vacuum-packed deli meats for recommended time or less (≤14 days)	96.6
If opened, stored opened packages of vacuum-packed deli meats for recommended time or less (≤5 days) or discarded uneaten product	59.2
Stored freshly sliced deli meats for recommended time or less (≤5 days)	66.1

[a]The storage times are based on recommendations from USDA (*34*).

[b]Analysis was conducted using household-level weights, n = 915 for frankfurters and n = 903 for deli meats. The percentages were estimated for respondents who reported purchasing the food product.

Table 2.6: Comparison of Households Who Store Frankfurters and Deli Meats Within vs. Outside Recommended Storage Guidelines[a, b]

	Frankfurters				
	Within Guidelines		Outside Guidelines		
	Number of Respondents	Weighted %	Number of Respondents	Weighted %	p[c]
All respondents	783	—	104	—	
Gender of respondent					0.012
Male	326	38.8	57	54.7	
Female	457	61.2	47	45.3	
Education level of respondent					0.028
Less than high school	78	11.7	3	2.3	
High school graduate	271	34.7	29	29.2	
Some college	233	27.4	33	33.9	
Bachelor's degree or higher	201	26.2	39	34.6	
Age of respondent (years)					0.969
18–29	120	16.8	19	18.8	
30–44	232	35.1	30	32.8	
45–59	233	27.6	26	28.1	
≥60	198	20.5	29	20.3	
Race/ethnicity of respondent					0.315
White, non-Hispanic	622	76.6	79	70.3	

Table 2.6: Comparison of Households Who Store Frankfurters and Deli Meats Within vs. Outside Recommended Storage Guidelines[a, b] (Cont.)

Black, non-Hispanic	72	10.9	16	18.9	
Other non-Hispanic	24	3.2	2	2.8	
Hispanic	65	9.3	7	8.0	
Household (HH) size					0.329
One person	124	27.6	21	33.9	
More than one person	659	72.4	83	66.1	
HH income					0.653
<$15,000	78	14.0	8	9.2	
$15,000–34,999	210	30.1	33	35.0	
$35,000–74,999	345	41.8	42	41.9	
≥$75,000	150	14.1	21	13.9	
Level of urbanization					0.020
Metropolitan	655	79.5	99	93.0	
Nonmetropolitan	128	20.5	5	7.0	
Child ≤5 years of age in HH	132	21.7	13	14.4	0.148
Individual with weakened immune system, diabetes, or kidney disease in HH	138	14.4	15	12.0	0.544
Individual ≥60 years of age in HH	247	25.4	34	27.8	0.673
Pregnant woman in HH	24	3.4	5	4.4	0.626
Aware of *Listeria*	378	49.1	48	46.8	0.717

Table 2.6: Comparison of Households Who Store Frankfurters and Deli Meats Within vs. Outside Recommended Storage Guidelines[a, b] (Cont.)

	Deli Meats				
	Within Guidelines		**Outside Guidelines**		
	Number of Respondents	**Weighted %**	**Number of Respondents**	**Weighted %**	**p[c]**
All respondents	551	—	310	—	
Gender of respondent					0.002
Male	208	36.3	170	50.5	
Female	343	63.7	140	49.5	
Education level of respondent					0.450
Less than high school	45	10.2	19	6.7	
High school graduate	181	32.0	97	34.9	
Some college	176	28.6	88	26.1	
Bachelor's degree or higher	149	29.2	106	32.3	
Age of respondent (years)					0.009
18–29	75	12.9	59	22.2	
30–44	177	38.4	77	29.3	
45–59	156	26.7	95	30.9	
≥60	143	22.0	79	17.6	
Race/ethnicity of respondent					0.536
White, non-Hispanic	433	76.9	248	78.3	

Table 2.6: Comparison of Households Who Store Frankfurters and Deli Meats Within vs. Outside Recommended Storage Guidelines[a, b] (Cont.)

Black, non-Hispanic	53	10.3	35	12.0	
Other non-Hispanic	16	3.5	7	4.1	
Hispanic	49	9.3	20	5.6	
Household (HH) size					0.817
One person	89	28.6	56	29.6	
More than one person	462	71.4	254	70.4	
HH income					0.774
<$15,000	50	10.5	31	13.6	
$15,000–34,999	148	31.3	81	29.9	
$35,000–74,999	249	42.8	137	42.2	
≥$75,000	104	15.4	61	14.3	
Level of urbanization					0.932
Metropolitan	468	80.3	266	80.6	
Nonmetropolitan	83	19.7	44	19.4	
Child ≤5 years of age in HH	86	19.7	52	19.7	0.986
Individual with weakened immune system, diabetes, or kidney disease in HH	95	13.9	58	16.6	0.361
Individual ≥60 years of age in HH	178	26.8	98	23.8	0.412
Pregnant woman in HH	13	2.6	17	5.9	0.042
Aware of *Listeria*	260	49.0	154	51.9	0.521

Table 2.6: Comparison of Households Who Store Frankfurters and Deli Meats Within vs. Outside Recommended Storage Guidelines[a, b] (Cont.)

[a]Analysis was conducted using household-level weights for respondents who purchase the product, shop for groceries, and cook meals; n = 887 for frankfurters and n = 861 for deli meats.

[b]USDA recommends storing unopened packages of frankfurters for 14 days or less and opened packages for 7 days or less. USDA recommends storing unopened packages of deli meats for 14 days or less and opened packages for 5 days or less (*34*).

[c]p of χ^2 test.

Table 2.7: Likelihood of Households Storing Frankfurters and Deli Meats Outside Recommended Guidelines[a,b]

	Frankfurters				
	Odds Ratio	**Linearized Standard Error**	**t**	**P > | t |**	**95% Confidence Interval**
Gender of respondent (reference = female)	2.477	0.640	3.51	0.000	1.492, 4.113
Education level of respondent (reference = less than high school)					
High school graduate	3.898	2.503	2.12	0.034	1.106, 13.745
Some college	4.447	2.951	2.25	0.025	1.209, 16.360
Bachelor's degree or higher	6.129	4.131	2.69	0.007	1.633, 23.012
Age of respondent (years) (reference = ≥ 60)					
18–29	2.630	1.478	1.72	0.086	0.873, 7.923
30–44	1.281	0.760	0.42	0.677	0.400, 4.103
45–59	1.350	0.644	0.63	0.529	0.530, 3.444
Race/ethnicity of respondent (reference = white, non-Hispanic)					
Black, non-Hispanic	1.518	0.579	1.09	0.274	0.718, 3.210
Other non-Hispanic	1.254	0.834	0.34	0.734	0.340, 4.628

Table 2.7: Likelihood of Households Storing Frankfurters and Deli Meats Outside Recommended Guidelines[a,b] (Cont.)

Hispanic	1.797	0.921	1.14	0.253	0.657, 4.917
HH size (reference = more than one person)	1.312	0.426	0.84	0.403	0.694, 2.482
Household (HH) income (reference = <$15,000)					
$15,000–34,999	1.959	0.989	1.33	0.183	0.727, 5.274
$35,000–74,999	1.801	0.940	1.13	0.260	0.647, 5.014
≥$75,000	1.285	0.712	0.45	0.650	0.433, 3.812
Level of urbanization (reference = nonmetropolitan)	6.759	4.007	3.22	0.001	2.111, 21.640
Child ≤5 years of age in HH (reference = no)	0.568	0.243	-1.32	0.187	0.245, 1.316
Individual with weakened immune system, diabetes, or kidney disease in HH (reference = no)	0.813	0.277	-0.61	0.544	0.416, 1.588
Individual ≥60 years of age in HH (reference = no)	2.022	0.901	1.58	0.115	0.843, 4.851
Pregnant woman in HH (reference = no)	1.170	0.668	0.27	0.784	0.381, 3.589

Table 2.7: Likelihood of Households Storing Frankfurters and Deli Meats Outside Recommended Guidelines[a,b] (Cont.)

Aware of *Listeria* (reference = no)	0.755	0.217	-0.98	0.328	0.430, 1.326
Perceived level of responsibility for entities other than consumers (reference = not a lot)	0.747	0.184	-1.18	0.237	0.461, 1.211
Perceived level of responsibility for consumers (reference = not a lot)	1.465	0.505	1.11	0.268	0.745, 2.881
Perceived level of control for entities other than consumers (reference = not a lot)	1.198	0.311	0.69	0.488	0.719, 1.996
Perceived level of control for consumers (reference = not a lot)	0.576	0.178	-1.78	0.075	0.314, 1.057

	Deli Meats				
	Odds Ratio	**Linearized Standard Error**	**t**	**P > | t |**	**95% Confidence Interval**

Table 2.7: Likelihood of Households Storing Frankfurters and Deli Meats Outside Recommended Guidelines[a,b] (Cont.)

Gender of respondent (reference = female)	2.100	0.406	3.83	0.000	1.436, 3.070
Education level of respondent (reference = less than high school)					
High school graduate	1.668	0.668	1.28	0.202	0.760, 3.663
Some college	1.266	0.534	0.56	0.576	0.554, 2.896
Bachelor's degree or higher	1.658	0.706	1.19	0.236	0.718, 3.826
Age of respondent (years) (reference = ≥ 60)					
18–29	2.133	0.892	1.81	0.070	0.939, 4.849
30–44	1.086	0.434	0.21	0.838	0.495, 2.380
45–59	1.324	0.484	0.77	0.443	0.646, 2.714
Race/ethnicity of respondent (reference = white, non-Hispanic)					
Black, non-Hispanic	1.209	0.361	0.64	0.525	0.673, 2.174
Other non-Hispanic	0.853	0.538	-0.25	0.801	0.247, 2.942
Hispanic	0.872	0.330	-0.36	0.716	0.415, 1.831
HH size (reference = more than one person)	0.971	0.238	-0.12	0.903	0.600, 1.571

Table 2.7: Likelihood of Households Storing Frankfurters and Deli Meats Outside Recommended Guidelines[a,b] (Cont.)

Household (HH) income (reference = <$15,000)					
$15,000–34,999	0.940	0.336	-0.17	0.863	0.466, 1.897
$35,000–74,999	0.779	0.266	-0.73	0.465	0.398, 1.523
≥$75,000	0.618	0.234	-1.27	0.205	0.294, 1.301
Level of urbanization (reference = nonmetropolitan)	1.145	0.302	0.51	0.608	0.682, 1.922
Child ≤5 years of age in HH (reference = no)	1.016	0.274	0.06	0.952	0.598, 1.726
Individual with weakened immune system, diabetes, or kidney disease in HH (reference = no)	1.274	0.306	1.01	0.312	0.796, 2.041
Individual ≥60 years of age in HH (reference = no)	1.202	0.393	0.56	0.573	0.633, 2.285
Pregnant woman in HH (reference = no)	2.186	0.951	1.80	0.073	0.930, 5.134
Aware of *Listeria* (reference = no)	1.078	0.203	0.40	0.690	0.745, 1.560

Table 2.7: Likelihood of Households Storing Frankfurters and Deli Meats Outside Recommended Guidelines[a,b] (Cont.)

Perceived level of responsibility for entities other than consumers (reference = not a lot)	0.837	0.177	-0.84	0.401	0.553, 1.267
Perceived level of responsibility for consumers (reference = not a lot)	1.015	0.237	0.06	0.950	0.642, 1.605
Perceived level of control for entities other than consumers (reference = not a lot)	0.905	0.174	-0.52	0.603	0.621, 1.319
Perceived level of control for consumers (reference = not a lot)	1.001	0.195	0.01	0.994	0.683, 1.467

[a]Analysis was conducted using the individual-level weights for respondents who purchase the product, shop for groceries, cook meals, and have complete information for all variables in model (n = 834 for frankfurters and n = 813 for deli meats).

[b]*USDA recommends storing unopened packages of frankfurters for 14 days or less and opened packages for 7 days or less. USDA recommends storing unopened packages of deli meats for 14 days or less and opened packages for 5 days or less* (34).

Table 4.1 Demographic characteristics of study participants (n = 1,212)

Characteristics	**# (%)**
Gender	
Male	609 (50.2)
Female	603 (49.8)
Marriage status	
Single (never married)	232 (19.1)
Single (other)	224 (18.5)
Married	756 (62.4)
Children (<12)	
Yes	254 (21.0)
No	958 (79.0)
Ethnicity	
European-American	940 (77.6)
African-American	123 (10.1)
Hispanic-American	107 (8.8)
Other	42 (3.5)
Age Group	
<30 Years	229 (18.9)
31-40 Years	217 (17.9)

Table 4.1 Demographic characteristics of study participants (n = 1,212)(Cont.)

41-50 Years	250 (20.6)
51-60 Years	214 (17.7)
61-70	168 (13.9)
70+	134 (11.1)
Education	
<HS	135 (11.1)
HS	398 (32.8)
>HS	679 (56.0)
Income	
<$20,000	202 (16.7)
$20,000 to 29,000	177 (14.6)
$30,000 to 39,000	191 (15.8)
$40,000 to 49,000	156 (12.9)
$50,000 to 59,000	127 (10.5)
>$60,000	359 (29.6)
Region	
NE	221 (18.2)
S	425 (35.1)
MW	307 (25.3)
W	259 (21.4)

Table 4.2: Relevant Health, Behavior, and Belief Characteristics of Study Participants (n = 1,212)

Characteristics	**# (%)**
Health Status	
Excellent	171 (14.1)
Very good	447 (36.9)
Good	386 (31.8)
Fair	101 (8.3)
Poor	28 (2.3)
Belief in frequency of foodborne illness	
Not very frequent	520 (43)
Somewhat frequent	345 (29)
Very frequent	174 (14)
Cooking frequency	
Rarely (0-2 times/week)	538 (44)
Sometimes (3+ times/week)	671 (55)
Foodborne (FB) pathogen awareness	
None/few	53 (4)
Some	872 (72)
Most/all	245 (20)

Table 4.2: Relevant Health, Behavior, and Belief Characteristics of Study Participants (n = 1,212)(Cont.)

Source of food safety information	
Traditional only	37 (3)
Professional only	83 (7)
Mass media only	632 (52)
Traditional/Mass media	93 (8)
Professional/Mass media	316 (26)

Table 4.3: Significant (p<0.05) predictors of variation in ratings of responsibility/control for safety of the US food supply for three members of the farm-to-table continuum (consumer, US government, and manufacturer)

	Consumers p (eta^2)		US Government p (eta^2)		Manufacturers p (eta^2)	
	Control	Resp.	Control	Resp.	Control	Resp.
Age	.00 (.02)	.00 (.03)	.01 (.02)	.00 (.02)	.01 (.01)	.00 (.02)
Age * Cooking Frequency	.01 (.01)					
Cooking Frequency	.00 (.01)	.00 (.02)			.03 (.01)	.02 (.01)
FBI Frequency		.00 (.01)	.01 (.01)			
Gender				.00 (.01)		
Gender * Income				.03 (.01)		
Income			.01 (.01)			

Table 5.1: Participants' Demographics

	Percentage of Participants (n)
Gender	
Male	47.9 (23)
Female	52.1 (25)
Age	
60–64	29.2 (14)
65–69	31.3 (15)
70–74	29.2 (14)
75–79	6.3 (3)
80 or older	4.2 (2)
Living situation	
Living alone	31.3 (15)
Two people	52.1 (25)
More than two people	14.6 (7)
No response	2.1 (1)
Race/ethnicity	
White, non-Hispanic	64.6 (31)

Table 5.1: Participants' Demographics (Cont.)

Black, non-Hispanic	31.3 (15)
Hispanic	4.2 (2)
Education	
Less than high school degree	4.2 (2)
High school graduate or GED	12.5 (6)
Some college or 2-year college degree	35.4 (17)
4-year college degree	22.9 (11)
Postgraduate degree	25.0 (12)
Household income	
Less than $12,000	2.1 (1)
$12,000–$24,999	10.4 (5)
$25,000–$49,999	39.6 (19)
$50,000–$74,999	10.4 (5)
$75,000–$100,000	12.5 (6)
More than $100,000	8.3 (4)
No response	16.7 (8)
Perceived health status	
Excellent	10.4 (5)
Very good	52.1 (25)

Table 5.1: Participants' Demographics (Cont.)

Good	29.2 (14)
Fair	4.2 (2)
Poor	2.1 (1)
No response	2.1(1)
Participant or household member had foodborne illness in past year	16.7 (8)

Table 5.2: Changes in Food Safety Knowledge and Attitudes after Exposure to the Listeriosis Prevention Fact Sheet

	Percentage of Participants	
	Pre-questionnaire	**Post-questionnaire**
Knowledgeable about food safety		
Not at all/not very	4.3	8.5
Somewhat	57.4	70.2
Very	38.3	21.3
Interested in learning more about food safety		
Not at all/not very	4.3	0.0
Somewhat	23.4	14.9
Very	72.3	85.1
Level of concern about contracting foodborne illness from food prepared at home		
Not at all/not very	42.6	40.4
Somewhat	23.4	27.7
Very	34.0	31.9
Believe that he/she is at an increased risk for foodborne illness because of age	41.3	67.4

Table 5.2: Changes in Food Safety Knowledge and Attitudes after Exposure to the Listeriosis Prevention Fact Sheet (Cont.)

Aware of *Listeria*	33.3	58.3
[If aware of *Listeria*] Identified processed meats as food source for *Listeria*	0.0	57.1
Know safe refrigerator temperature (40°F or lower)	29.2	58.3
Know recommended storage time for unopened packages of vacuum-packed deli meats (14 days or less)	—[a]	66.1
Know recommended storage time for opened packages of vacuum-packed deli meats (5 days or less)	—[a]	51.1
Know recommended storage time for freshly sliced deli meats (5 days or less)	—[a]	55.3

[a]Question was not asked in the prequestionnaire.

Table 5.3: Food Safety Practices after Exposure to the Listeriosis Prevention Fact Sheet

	Percentage of Participants
Use of refrigerator thermometer during 4-week evaluation period	
Have not at all considered purchasing refrigerator thermometer	41.7
Have thought about purchasing refrigerator thermometer but have not done so yet	31.3
Have not purchased refrigerator thermometer but plan to buy one the next time shop at grocery or discount store	14.6
Have purchased refrigerator thermometer but have not placed it inside refrigerator yet	0.0
Have purchased refrigerator thermometer and found that refrigerator was at a safe temperature	10.4
Have purchased refrigerator thermometer and found that refrigerator was not at a safe temperature but did not adjust thermostat	0.0

Table 5.3: Food Safety Practices after Exposure to the Listeriosis Prevention Fact Sheet (Cont.)

Have purchased refrigerator thermometer and found that refrigerator was not at a safe temperature so adjusted thermostat	2.1
Use of recommended storage time guidelines for opened packages (vacuum-packed) and freshly sliced deli meats during 4-week evaluation period	
Have not at all considered following recommended guidelines	12.5
Have thought about following recommended guidelines but have not done so yet	18.8
Have not followed recommended guidelines but plan to in the future	12.5
Have followed recommended guidelines some of the time	8.3
Have followed recommended guidelines most of the time	35.4
Have followed recommended guidelines all of the time	12.5
Stored most recent purchase of deli meats for the recommended time or less (during 4-week evaluation period)	
Unopened vacuum-packed deli meats	92.9
Opened vacuum-packed deli meats	37.9

Table 5.3: Food Safety Practices after Exposure to the Listeriosis Prevention Fact Sheet (Cont.)

Freshly sliced deli meats	58.8
Likelihood of following recommendation for reheating deli meats to steaming hot before eating (or not eating if reheating is not possible)	
Not at all likely/not very likely	41.7
Somewhat likely	20.8
Very likely	37.5

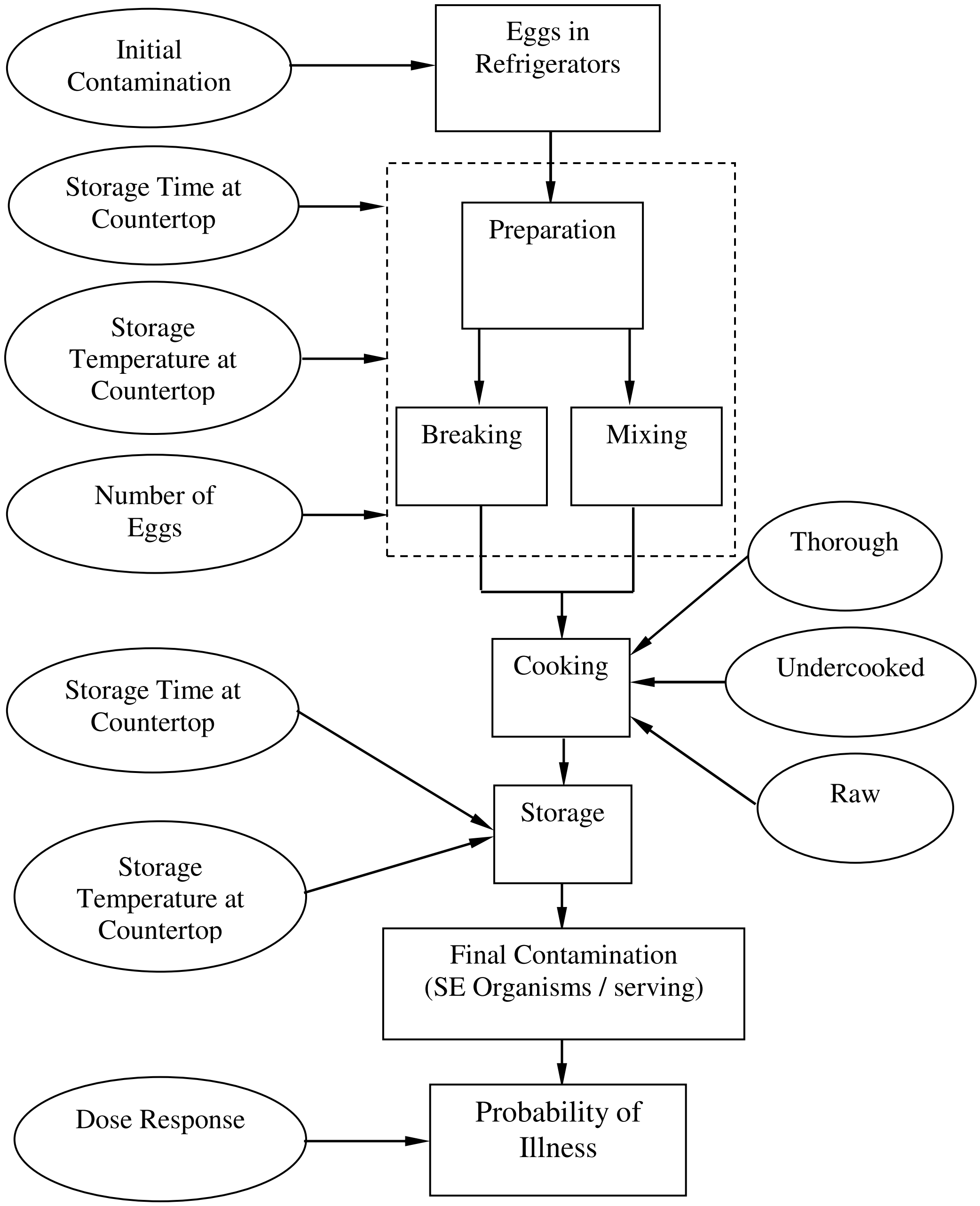

Figure1.1: Schematic diagram of the SE exposure model for domestic handling.

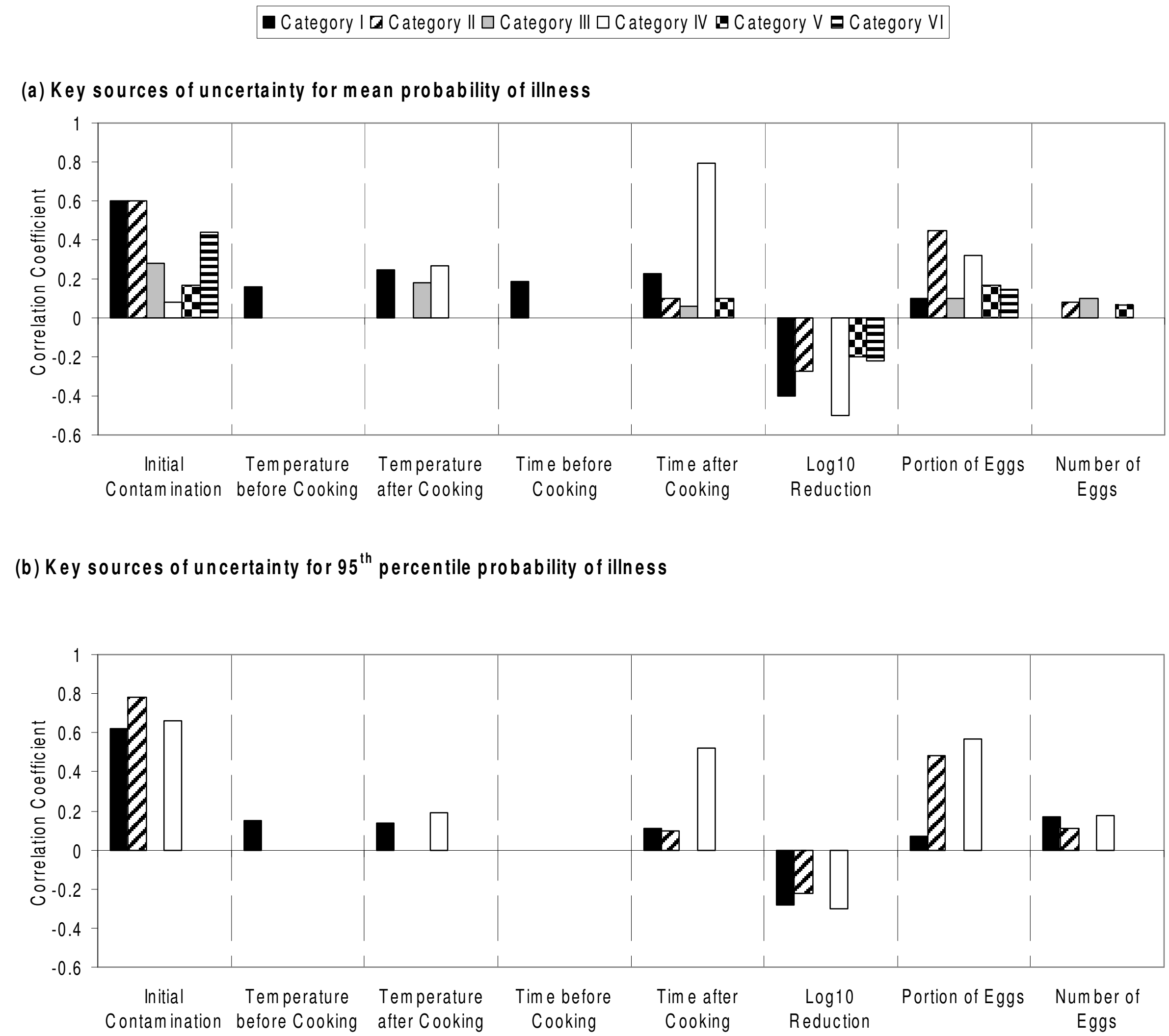

Figure 1.2: Key sources of uncertainty for: (a) mean; (b) 95th percentile; and (c) 99th percentile of the probability of SE illness in different food categories.

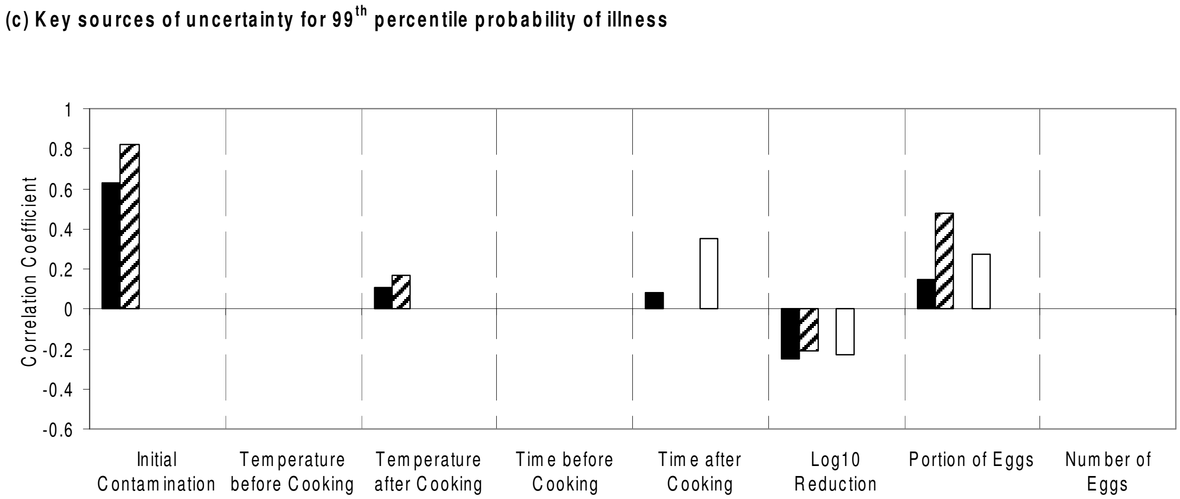

Figure 1.2: Key sources of uncertainty for: (a) mean; (b) 95th percentile; and (c) 99th percentile of the probability of SE illness in different food categories. (Cont.)

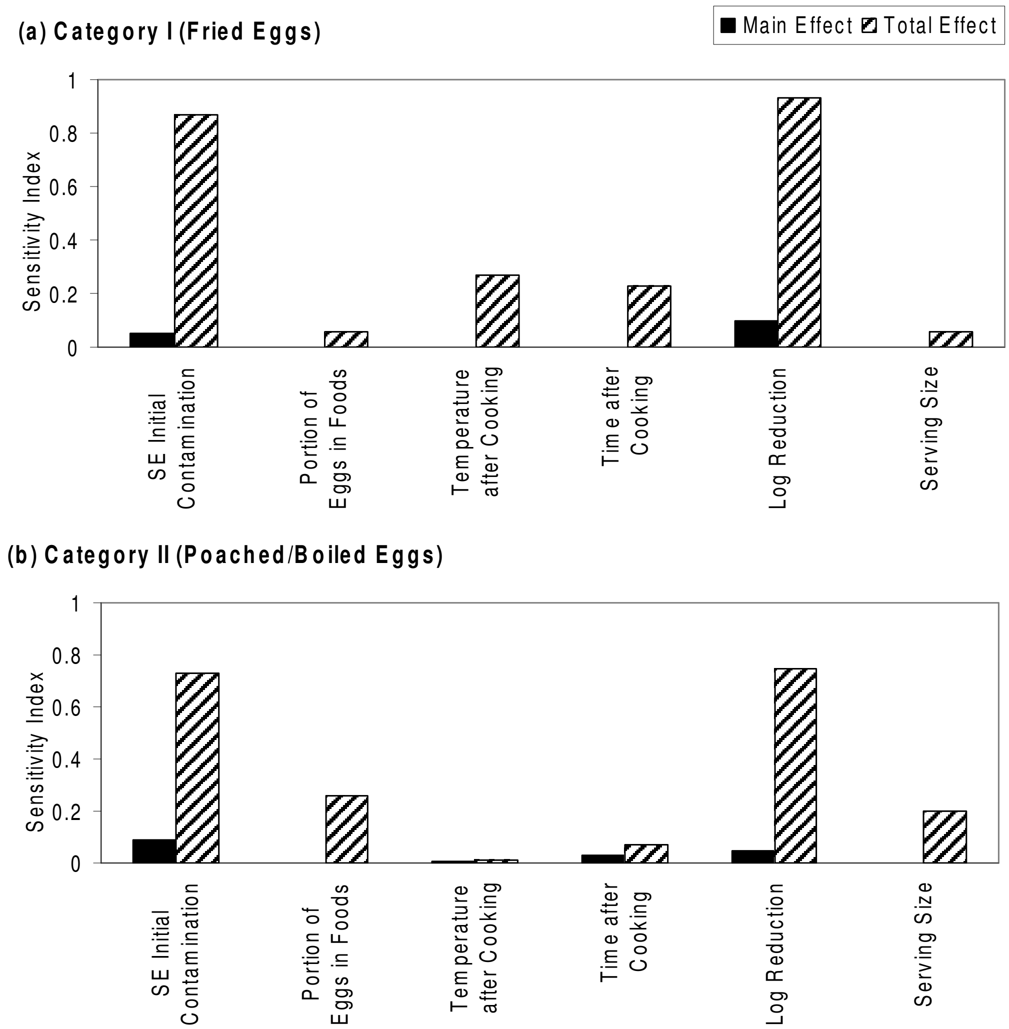

Figure 1.3: Main effect and total effect of key sources of variability based on the Sobol's methods for: (a) fried eggs (Category I); (b) poached/boiled eggs (Category II); and (c) dressing/ice cream (Category IV).

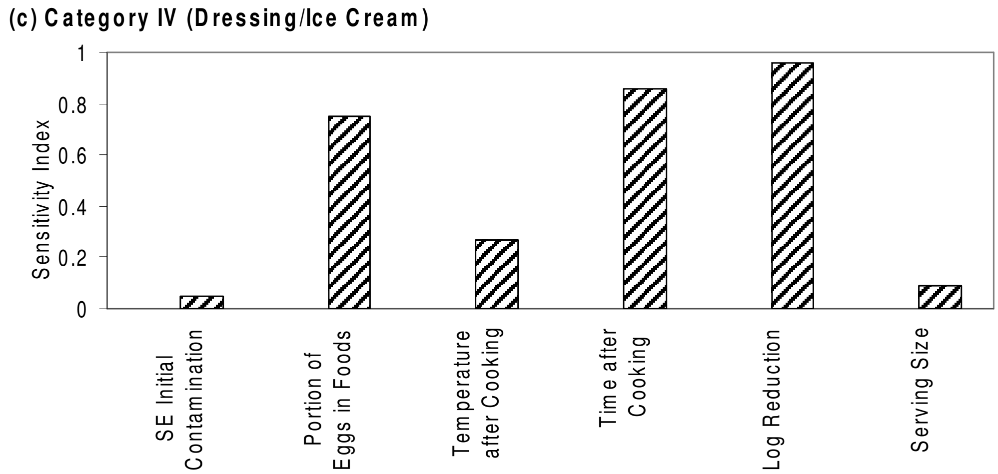

Figure 1.3: Main effect and total effect of key sources of variability based on the Sobol's methods for: (a) fried eggs (Category I); (b) poached/boiled eggs (Category II); and (c) dressing/ice cream (Category IV). (Cont.)

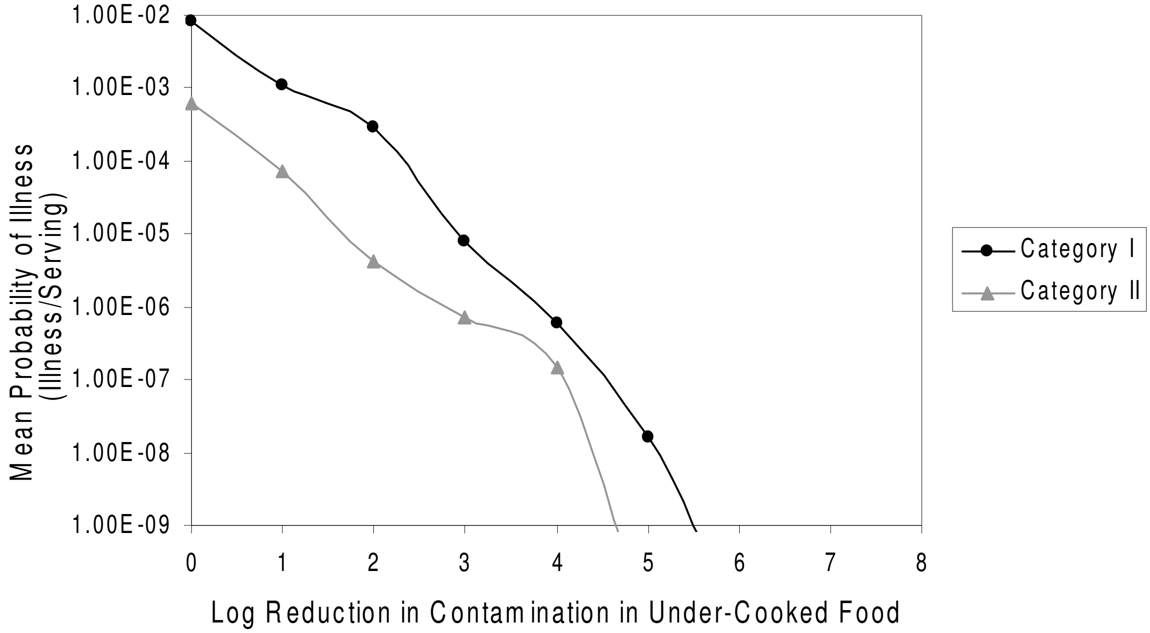

Figure 1.4: Variation of mean probability of SE illness with respect to the log reduction in under-cooked foods for foods in Categories I and II.

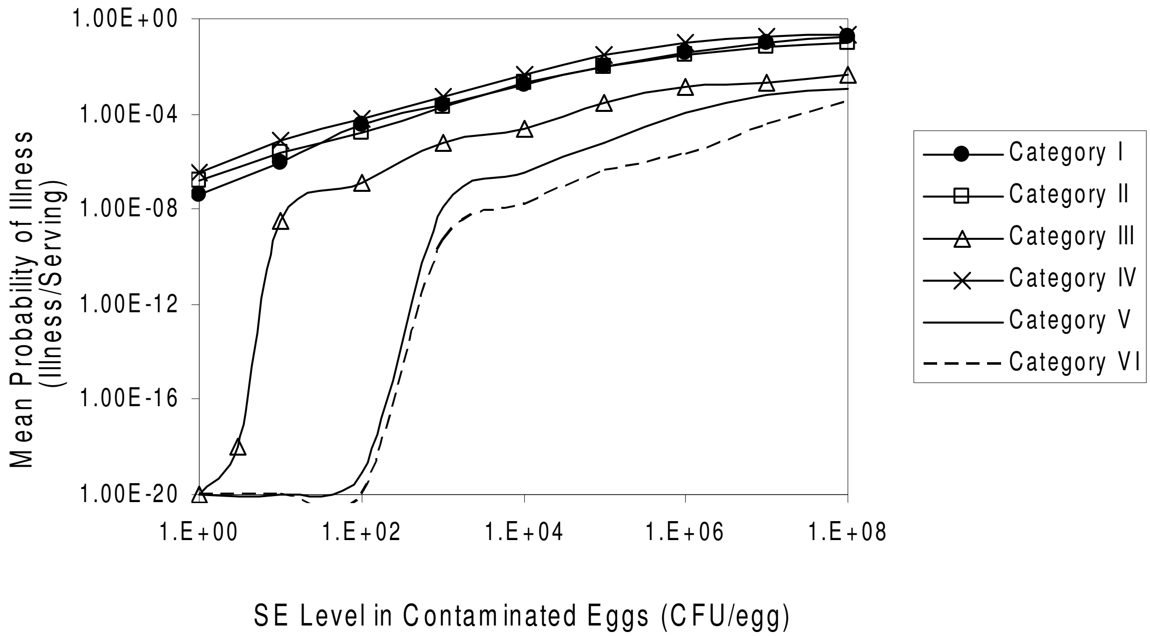

Figure 1.5: Variation of mean probability of SE illness with respect to the SE level in contaminated eggs for the six food categories.

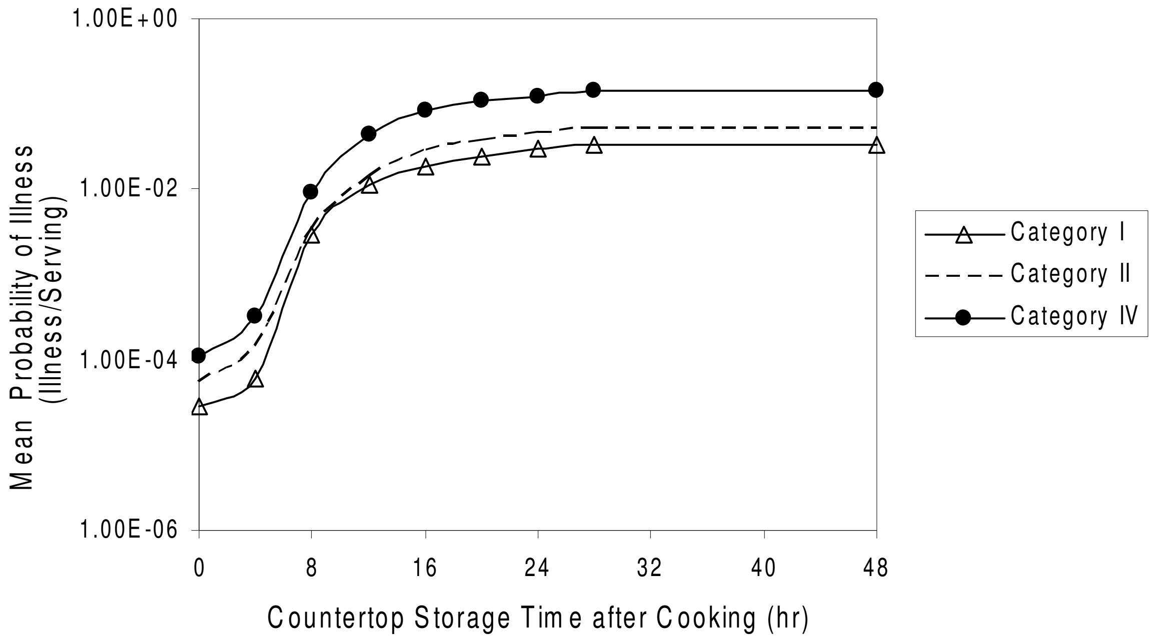

Figure 1.6: Variation of mean probability of SE illness with respect to the countertop storage time after cooking.

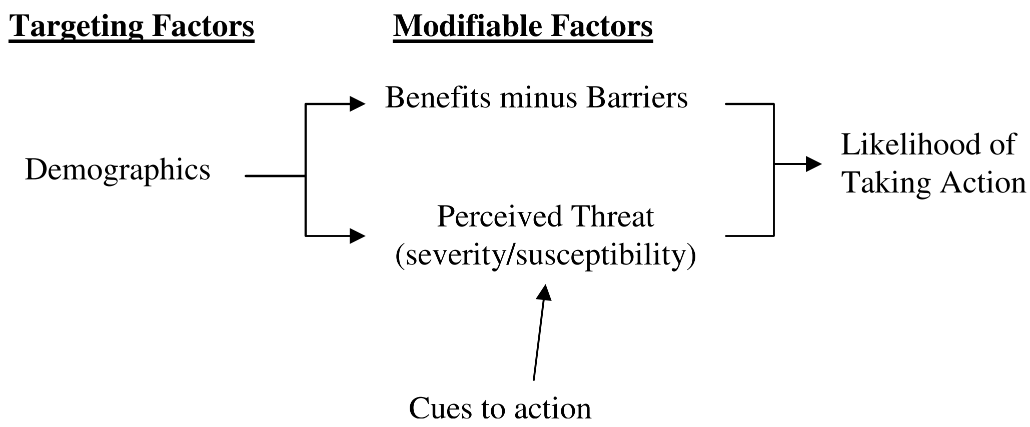

Figure 2.1: The Health Belief Model

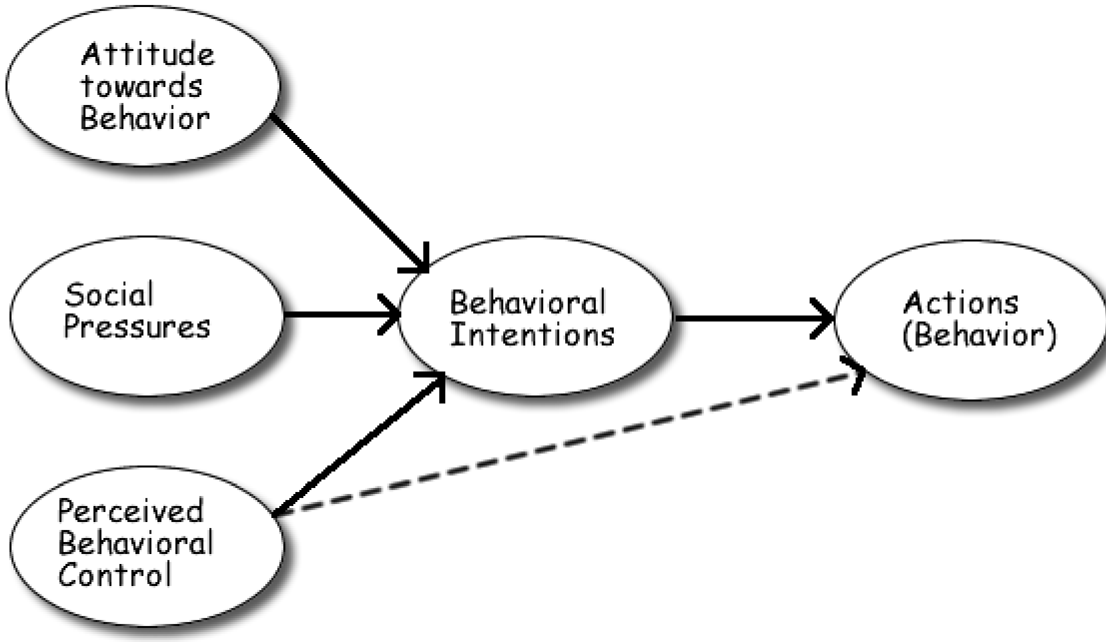

Figure 2.2: The Theory of Planned Behavior

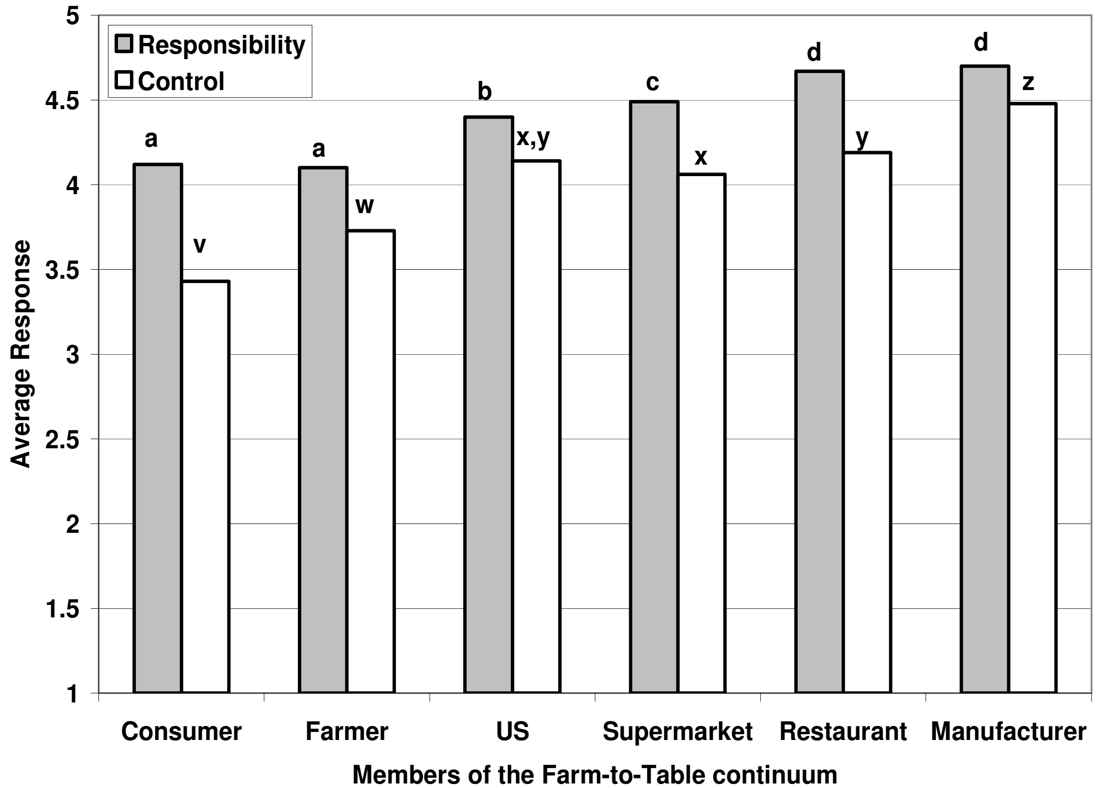

Figure 3.1: Consumer Ratings of Responsibility and Control across the Food Chain

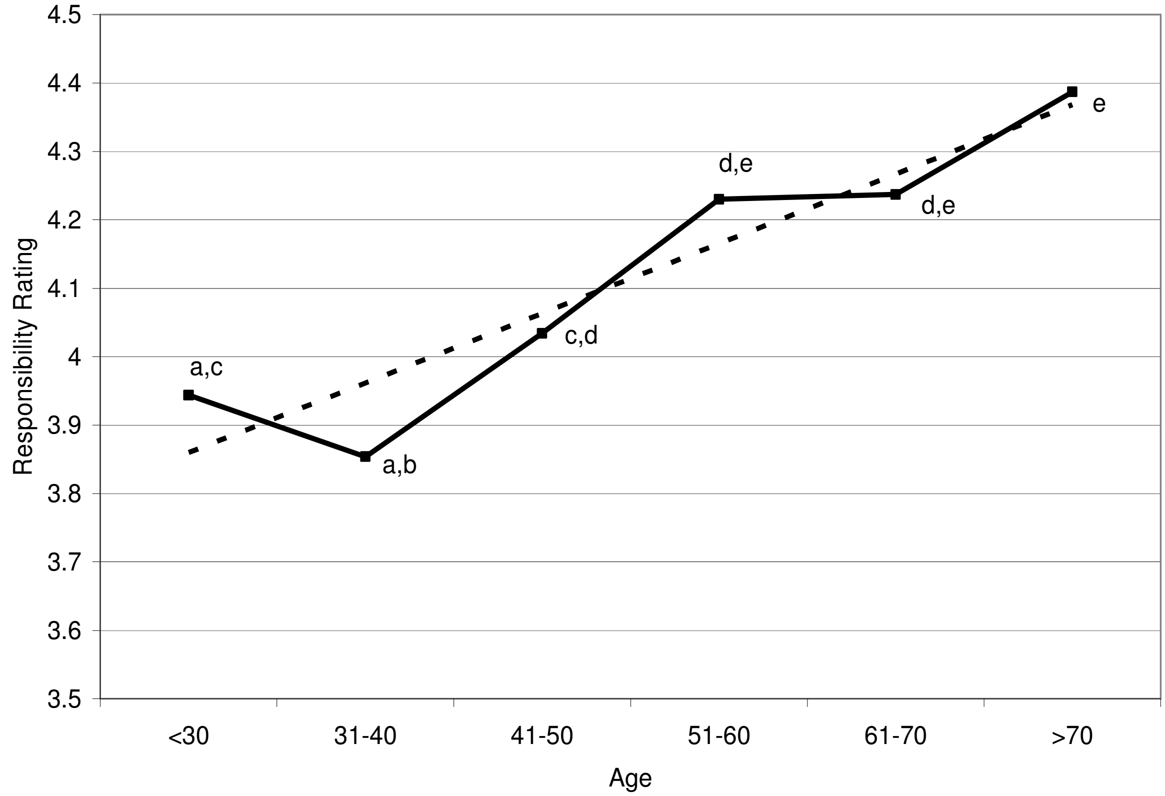

Figure 3.2: Consumer Responsibility Ratings by Age

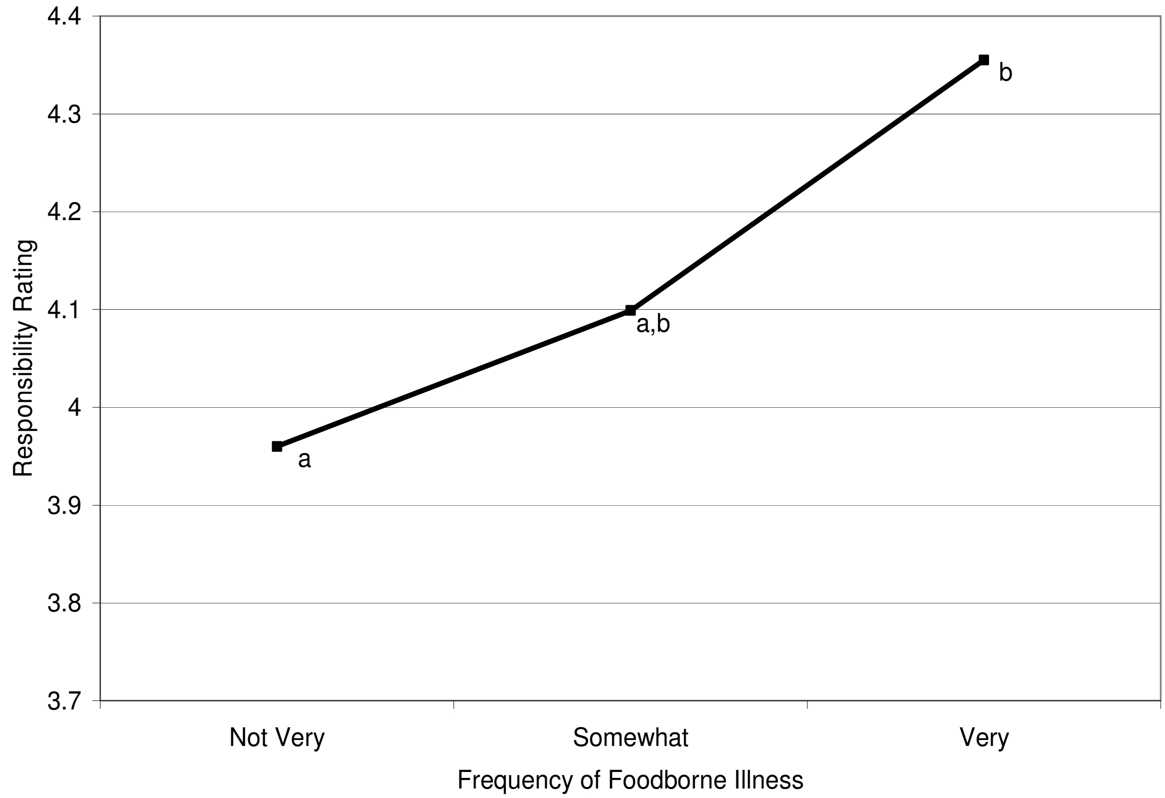

Figure 3.3: Consumer Responsibility Ratings by Belief in the Frequency of FBI

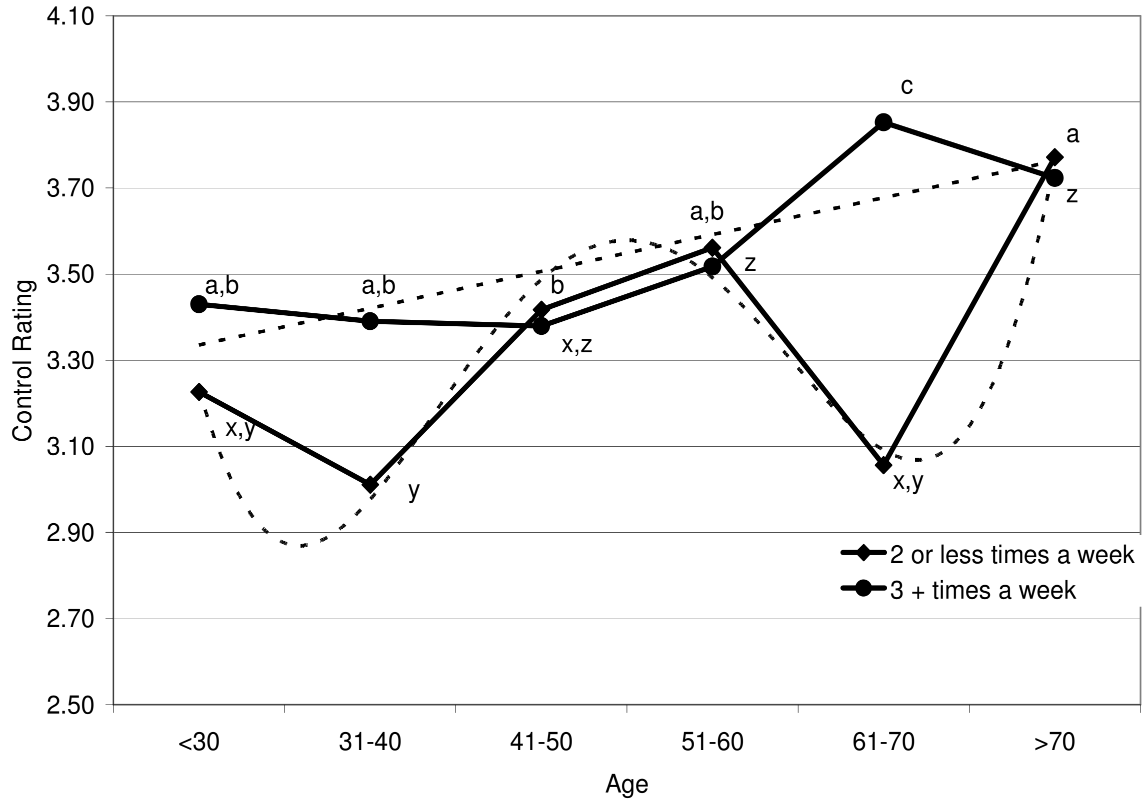

Figure 3.4: Consumer Control Ratings for Age x Cooking Frequency