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Public Perceptions of Food Safety: Assessing the Risks Posed by Genetic Modification, Irradiation, Pesticides, Microbiological Contamination and High Fat/High Calorie Foods

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Public Perceptions of Food Safety: Assessing the Risks Posed by Genetic Modification, Irradiation, Pesticides, Microbiological Contamination and High Fat/High Calorie Foods

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INTRODUCTION

In general, people in the developed world have access to a safe and varied supply of food.[1] Instead of systemic hunger, many developed countries have problems with obesity and other kinds of eating disorders among their citizenry.[2] It is within this context that some find public concerns about the safety of food both paradoxical and misplaced. Nevertheless, understanding how people perceive the risk associated with food is an important exercise in demonstrating accountability and in setting priorities for regulation. With the advent of technologies for producing genetically modified foods, and the development of fat blockers like Olestra,[3] the public is increasingly being asked to judge the social acceptability of various kinds of food modifications. In addition to interpreting the risks and benefits associated with these newer innovations, the public is also balancing the risks and benefits of more familiar food interventions. Not only must consumers of food assess the merits of genetic modification and food irradiation, they still must consider exposure to pesticide residues and microbiological contaminants like Salmonella, Listeria, *Escherichia coli*, and Campylobacter. Additionally, with high rates of cardiovascular disease and

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1. Serve Notermans & Martin Borgdorff, *Quantative Risk Analysis and the Production of Microbiologically Safe Food: An Introduction*, 30 Intl. J. of Food Microbiology 3 (1996); Serve Notermans & Martin Borgdorff, *A Global Perspective of Foodborne Disease*, 60 J. of Food Prod. 1395 (1997).

2. Frances Berg, *Looking at the Big Picture*, 8 Obesity and Health 15 (1993); Phillapa Hay, *The Epidemiology of Eating Disorder Behaviors: An Australian Community-Based Survey*, 23 Intl. J. of Eating Disorders 37 (1998).

3. Diane Prince & Marilyn Welschenback, *Olestra: A New Food Additive*, 98 J. of the Am. Dietetics Assn. 565 (1998).

elevated concerns about developing diseases like diabetes, many people seriously consider the fat and sugar content of the foods they consume.

This exploratory study examines how the public perceives food risks by employing a ranking exercise, a scale for assessing food safety practices, a scale for combining elements from the psychometric paradigm (e.g., voluntary exposure, perceived benefit, and perceived risk) across five potential food hazards, and demographic variables (sex, age, and level of education) most commonly linked to the perception of food risks.

LITERATURE REVIEW

In recent years, studies on food safety and public perceptions of risk have focused on the different kinds of modifications and treatments applied to food and on characteristics of food such as fat content.[4] Roughly, food safety issues divide into two broad categories similar in pattern to earlier studies of risk perception on natural versus technological hazards.[5] In a range of studies, natural hazards tended to include earthquakes, floods, hurricanes, shark attacks, and meteor impacts – to name a few. By contrast, technological hazards included nuclear power plant accidents, chemical spills, train derailments, and airline crashes. As work in the area of risk perception advanced, it became evident that this divide was imperfect. Many of the technological hazards studied had interactions with natural hazards. With respect to food safety issues, the blurring between natural and technological also exists.

For some, the development of genetically modified food represents a process that is artificial, and therefore unnatural. There is a concern that science may be crossing natural boundaries and usurping the role of the Creator.[6] Here we have a welding together of the natural and technological. A potato that is genetically modified to express a protein that acts as a pesticide illustrates this complexity. At the first order of analysis, a potato is a natural product. Excluding the consumption of green potatoes, it is widely considered a safe and wholesome food. To produce marketable potatoes in large quantities, and to satisfy export market requirements, farmers often resort to the use of pesticides and fungicides on their crops. Here at the second order of analysis, we see how the introduction of such agents repre-

4. Marc Pilisuk & Curt Acredolo, *Fear of Technological Hazards: One Concern or Many?*, 3 Soc. Behaviour 17 (1988).

5. Wibecke Brun, *Cognitive Components of Risk Perception: Natural Versus Manmade Risks*, 5 J. of Behavorial Dec. Making 117 (1992).

6. Michael Mehta, *Public Perceptions of Genetically Engineered Foods: "Playing God" or Trusting Science*, 12 Risk: Health, Safety & Environment 205 (2001).

sents a combination of natural and technological. It is the addition of a pesticide and/or fungicide that worries some about the changing nature of the potato posing new risks to human health and environment. By genetically modifying the potato to express a pesticide, a third order of analysis emerges. Instead of worrying about chemical agent residues on food, some are now concerned about changes to the very nature of food through the science of modern biotechnology.

The same kinds of concerns about the use of food irradiation exist. Food irradiation involves the use of ionizing radiation or energy to treat foods. Using a variety of sources, like radioactive isotopes of cobalt or caesium, food irradiation effectively destroys many known pathogens.[7] By treating food in this manner, food irradiation provides a number of benefits including the extension of shelf life for fruits, control of bacteria in meat, control of insects, delayed ripening, and the inhibition of premature sprouting. Many different kinds of food including poultry, ground beef, spices, seafood, and a variety of fruits and vegetables are presently treated with irradiation.

Although used in over thirty countries, food irradiation is relatively unknown by many in the public.[8] Concerns about food irradiation cover a variety of topics including beliefs about the possible toxicity of treated food and changes in nutritional composition. It is likely that negative reactions to food irradiation probably stem from a general anxiety reaction associated with exposure to radiation from anthropogenic sources like nuclear reactors, atomic weapons, and medical devices.[9] However, characterizing negative reactions to food irradiation as based simply on fear obscures some important considerations. First, negative reactions to food irradiation may represent a resistance to any additional changes that are being made to food, and perceived increases in control that big business now has over food production, processing, and distribution. Consumers now eat processed food that is likely to contain preservatives, food coloring, added salt and sugar, and flavor-enhancing ingredients like monosodium glutamate (MSG). The use of food irradiation to treat unprocessed food including fresh meat and vegetables may infringe on the rights of those who believe that they have a choice to consume "natural" food. It is this dynamic that is also probably responsible for the resistance that emerges over the use of hormones in animals in the production of meat and

7. Randall Lutter, *Food Irradiation: The Neglected Solution to Food-Borne Illness*, 286 Science 2275 (1999).

8. Susan Pickett & Tatsujiro Suzuki, *Regulation of Food Safety Risks: The Case of Food Irradiation in Japan*, 3 J. Risk Research 95 (2000).

9. Ardith Maney & Eric Plutzer, *Scientific Information, Elite Attitudes, and the Public Debate Over Food Safety*, 24 Policy Stud. Journals 42 (1996).

milk.[10] Second, intuitively there is likely to be a concern that wide-scale use of food irradiation could provide an incentive for food processors to practice less stringent quality control measures. Third, there is general distrust of the nuclear industry in the United States and Canada as indicated by the lack of support and political will to build new civilian nuclear power plants in either country.[11] Although not directly connected to nuclear energy, the food irradiation industry is probably stigmatized nonetheless. In a study of public perceptions of food irradiation and other technologies, Bord and O'Connor note that trust was the strongest predictor of support for technology.[12] In the case of irradiation and the genetic modification of food, social acceptance of these technologies involves complex ideological underpinnings and cultural contexts in which hazards are framed and debated.[13] For Von Wartburg and Liew, it is essential to understand how the public perceives technology since social acceptance is a key part of improving decision-making and for clarifying ambiguities that inherently involve values and priorities.[14]

Studies of how the public perceives the safety of food have focused on how people rank food risks,[15] differences in perception by demographic variables like sex,[16] level of education,[17] and age,[18] and the role of mass media in shaping perceptions.[19] Other studies have examined differences between consumers of organic and conventionally produced foods,[20] the role of information in changing food preparation practices,[21] and cam-

10. Doug Powell & William Leiss, *Mad Cows and Mother's Milk* (McGill-Queen's University Press 1997).

11. Michael Mehta, *The Public in Re-Licensing Nuclear Facilities in Canada*, 3 The Elec. J. of Sociology 1 <http://www.sociology.org/content/vol003.001/mehta.html> (1997).

12. Richard Bord & Robert O'Connor, *Risk Communication, Knowledge, and Attitudes: Explaining Reactions to a Technology Perceived as Risky*, 10 Risk Analysis 499 (1990).

13. Karl Dake, *Myths of Nature: Culture and the Social Construction of Risk*, 48 J. of Soc. Issues 21 (1992).

14. Walter Von Wartburg & Julian Liew, *Gene Technology and Social Acceptance* (University Press of America 1999).

15. Chris Fife-Schaw & Gene Rowe, *Public Perceptions of Everyday Food Hazards: A Psychometric Study*, 16 Risk Analysis 487 (1996); Center for Produce Quality, *Fading Scares – Future Trends: Trends in Consumer Attitudes Toward Food Safety* (1992).

16. William McIntosh, Larry Christensen & Gary Acuff, *Perceptions of Eating Undercooked Meat and Willingness to Change Cooking Practices*, 22 Appetite 83 (1994).

17. Raymond Jussaume & Lorie Higgins, *Attitudes Towards Food Safety and the Environment: A Comparison of Consumers in Japan and the U.S.*, 63 Rural Sociology 394 (1998); *see also* Pamela Williams & Jim Hammitt, *Perceived Risks of Conventional and Organic Produce: Pesticides, Pathogens, and Natural Toxins*, 21 Risk Analysis 319 (2001).

18. Williams & Hammitt, *supra* n. 17.

19. Jeffrey Johnson and David Griffith, *Pollution, Food Safety, and the Distribution Knowledge*, 24 Human Ecology 87 (1996).

20. Pamela Williams & Jim Hammitt, *A Comparison of Organic and Conventional Fresh Produce Buyers in the Boston Area*, 20 Risk Analysis 735 (2000).

21. William McIntosh et al., *Public Perceptions of Food Safety*, 31 Soc. Sci. J. 285 (1994).

paigns aimed at minimizing the risks associated with pesticide residue exposure. Although not a perfect tool for capturing the nuances of social acceptability, this kind of research provides an iterative approach for understanding public perceptions. As such, it is assumed theoretically that high assessments of risk correspond to low levels of public acceptance, and vice versa.

STUDY DESIGN

During the month of July 2000, a survey of 538 participants residing in Kingston, Ontario, was undertaken. Data from the same set of participants for Mehta are used here.[22] Participants were given a second set of questions on their perceptions of different food safety issues.

Kingston is a small city with a population of approximately 56,000 (1996) and it hosts a prestigious medium-sized Canadian institution, Queen's University. Approximately half way between Metropolitan Toronto and the Canadian capital of Ottawa, Kingston has a cosmopolitan feel and is well known as a retirement destination.

A team of three research assistants surveyed the downtown region of Kingston in randomly assigned shifts and locations. Due to the centrally planned nature of the city, many residents frequent the historically-important Princess Street. Research assistants recruited participants walking through the corridor of the city throughout the study period. Not strictly a probability sample, this technique ensures a reasonably good quota sample, and is essentially a structured kind of convenience sample.[23]

After agreeing to participate in the study, individuals were given a questionnaire assessing their perceptions of food safety and basic demographic information. The first part of the questionnaire assessed food preparation and shopping habits. Questions dealt with the washing of fruits and vegetables, peeling of fruits and vegetables, purchasing organic foods, and the consumption of a variety of fruits and vegetables.

The second part of the questionnaire asked participants to rank food safety concerns in order of personal importance from most important to least important. Five food safety concerns were provided and included

22. *See* Lutter, *supra* n. 7.

23. There are two general kinds of sampling: probability and non-probability. Probability sampling is when each person in a population has a known, non-zero probability of being selected. Probability methods include random sampling, systematic sampling, and stratified sampling. In non-probability sampling, people are selected from a population in a non-random way. These include convenience sampling, judgment sampling, quota sampling, and snowball sampling. For a more detailed discussion see <http://www.statpac.com/surveys/sampling.htm> (accessed December 2002).

excessive fat/high caloric intake, microbiological contamination, pesticide residues, food irradiation, and genetically modified foods. Before ranking these concerns, research assistants read short definitions of these terms. Excessive fat/high caloric intake was defined as food high in fat or high in calories (e.g., high sugar content). Microbiological contamination was defined as food contaminated by harmful bacteria (e.g., Salmonella). Pesticide residues were defined as pesticides (chemicals used to kill insects and other kinds of pests) applied to fruits and vegetables during pre-harvest and sometimes post-harvest. Food irradiation was defined as the use of radiation (gamma rays) to eliminate or reduce food borne pathogens (harmful bacteria) or to preserve food. It was explained to participants that irradiation is used in Canada to treat imported spices and certain kinds of sea food, and that in some countries this technique is used to kill bacteria in ground beef and chicken or to prevent premature sprouting in potatoes. Genetically modified foods were defined as foods that were developed using recombinant DNA techniques. Examples included the development of corn with a gene from a common kind of bacteria found in soil to confer insect resistance, and crops like canola that have been made tolerant to herbicides like Monsanto's Roundup.

The third part of the questionnaire explored perceptions associated with three food treatments: use of pesticides, irradiation, and genetic modification. Using a five- point Likert-type scale, participants were asked to assess the risk of each food treatment, declare how worried they would be if they consumed food treated by each method, assess the degree to which consumption is voluntary, declare the degree to which they would accept foods treated with each of these treatments if the food was made safer, and rate the degree to which each of these treatments provide important benefits.

The last part of the questionnaire gathered basic demographic information including age, sex, and level of education.

METHODS

Data were entered using Microsoft's Excel database software and analyzed with Statistical Package for the Social Sciences ("SPSS" – Version 10.0.5 for Windows 98). All data were entered with coding for missing data included and were verified for accuracy.

Data from the questions on food preparation and shopping habits were subjected to a principal components factor analysis to derive factor weights. A scale for food safety practices was created from these weights by multiplying each response by its associated weighting and summing the items.

Data on the ranking of food safety concerns were subjected to a frequency analysis to assess the relative ranking of each safety concern. Additionally, dummy variable coding for each concern was conducted so that scores on the food safety practices scale could be compared to the ranking of each food safety concern. The Pearson χ^2 statistic was used to determine if food safety practices were related to this ranking.

Data from the food treatment perception questions were subjected to a principal components factor analysis to create scales. These scales were used as independent variables in a linear regression model to predict scores on the food safety practices scale. Other independent variables included sex (dummy variable coded), level of education (dummy variable coded for college/university and below), and age.

RESULTS

A total of 538 participants residing in Kingston, Ontario, completed the survey. The mean response rate for this study across the three research assistants was approximately 60%. The age of participants ranged between 13 and 89 with a mean age of 38.62 (SD=16.67). Female participants made up 56.4% of the sample, while 43.6% of participants were male. The educational attainment of participants was high. Almost 71% of participants received some form of college or university training, while 27.5% indicated that high school was their highest level of formal education. Less than 2% of participants had a grade 9 or lower level of education. A comparison of these demographic variables with census data from Statistics Canada is available in Table 1. With respect to age and sex ratio, the sample is very close to the reported census data. However, for level of education the sample is biased towards the more highly educated.

Table 1
Comparison of demographic characteristics with census (1996) data from Statistics Canada for the City of Kingston

	Study	Census
Female	56.4%	55%
Male	43.6%	45%
Mean age	38.6	38.6
Level of education:		
Some college or university	71%	56%
High school	27.5%	42%
Grade 9 or less	1.5%	2%

FOOD SAFETY PRACTICES SCALE

The questions dealing with food preparation and shopping habits were explained best by one factor that accounted for 40.4% of the variance. Four Likert-type questions (range 1-5) were used to generate scale totals (see Table 2). Using factor weights from a principal components analysis (see Table 3), the food safety practices scale yielded scores between 2.54 and 12.72 with a mean of 8.21 (SD=1.90). In this case, higher scores represent more diligent food safety practices. Higher scoring individuals were more likely to wash fruits and vegetables, peel fruits and vegetables, purchase organic foods and eat a greater variety of fruits and vegetables.

Table 2
Questions used in Food Safety Practices Scale

Do you eat a variety of fruits and vegetables?
Do you wash your fruits and vegetables?
Do you commonly peel fruits such as apples?
Do you shop for organic food?

Table 3
Factor loadings used for construction of Food Safety Practices Scale

Variety	.66
Wash	.65
Peel	.62
Purchase organic	.62

When asked to rank a list of food safety concerns, participants revealed that excessive fat and high caloric intake were the most important concern to them personally (31.6%). Pesticide residues (28.8%), microbiological contamination (25.2%), genetically modified foods (10.2%), and irradiated foods (3.8%) represent the other first choice concerns (see Table 4).

Table 4
Frequency of ranking for food safety concerns by percent

	First (%)	**Second (%)**	**Third (%)**	**Fourth (%)**	**Fifth (%)**
High fat/high calorie	31.6	12.4	14.3	9.6	32
Microbiological contamination	25.2	27.7	21.7	18.1	7.3
Pesticide residues	28.8	35.9	22.4	8.5	4.5
Irradiation	3.8	12.3	22.9	34.4	26.7
Genetically modified	10.2	11.3	18.6	29.7	29.9

Note: Rows total to 100% with rounding errors.

Using the median score of 8.34 to dichotomize food safety practice scores, the Pearson χ^2 statistic was used to analyze dummy coded rankings for each food safety concern. The choice of excessive fat and high caloric intake as the top concern is significantly related to food safety practices (χ^2=11.71, df=1, p<.001). In this instance, participants who ranked excessive fat and high caloric intake as most important were less likely to score high on the food safety practices scale. In other words, washing and peeling fruits and vegetables, purchasing organic foods, and eating a wide variety of fruits and vegetables is of less importance to participants concerned with fat and calories. It is likely that the selection of meat, cooking methods, and amount of carbohydrate consumed is more relevant to these participants.

The choice of pesticide residues as the top concern is significantly related to food safety practices (χ^2=4.58, df=1, p=.03). In this case, participants most concerned about pesticide residues were more likely to score high on the food safety practices scale. The measures assessed by the food safety practices scale are positively associated with pesticide residues since it is commonly understood that washing and peeling of fruits and vegetables may reduce exposure to pesticides. The purchasing of organic foods is directly related since, by definition, organic foods are grown without the use of commercially produced chemical pesticides. Participants who purchase organic food are probably more concerned about the perceived risks of pesticide exposure than others, and may mistakenly believe that organic farming is pesticide-free.[24]

The choice of genetically modified foods as the top food safety concern is significantly related to food safety practices (χ^2=3.87, df=1, p=.049). Participants who selected genetically modified foods as the most important food safety issue were more likely to score high on the food safety practices scale. In this case, participants may believe that purchasing organic foods will minimize the perceived risks associated with consuming genetically modified foods.

There are no significant relationships between food safety practice scores and the first place ranking of food safety concerns for irradiated food or microbiological contamination. Perhaps participants believe that microbiological contamination, and the need for irradiation, are not problems associated with fruits and vegetables; notable public health scares for contaminated foods have focused on hamburger meat and poultry products. Even though several cases of contamination in fruits and vegetables have happened (e.g., *Escherichia coli* contamination of unpasteurized apple cider and Hepatitis A in frozen strawberries), the public perceives fruits and vegetables as relatively safe.

FOOD TREATMENT PERCEPTION SCALE

Participants were asked to assess the use of pesticides, irradiation, and genetic modification of food in greater detail. Questions dealt with the perceived risk, worry, voluntary exposure, acceptance of treated foods if deemed safer than non-treated equivalent foods, and the benefits of each food treatment (see Table 5). An exploratory factor analysis of these ques-

24. It is worth noting that organic farmers use pesticides too (e.g., Bt). To learn more about these practices visit the Canadian Organic Growers Association at <http://www.cog.ca> or the Organic Trade Association at <http://www.ota.com> (accessed December 2002).

tions yielded five factors using an Equamax rotation with convergence in seven iterations (see Table 6). These five factors accounted for 67.93% of the variance.

Table 5
Questions used in Food Treatment Perception Scale*

How risky are irradiated foods?
If you were to eat irradiated food, how worried would you be about the risk?
To what extent is eating irradiated food voluntary?
Would you choose irradiated food if it meant that your food was safer?
To what degree does irradiated food provide important benefits?

* Variations on these questions were asked for food grown with pesticides and food produced through genetic modification.

Table 6
Factor loadings for exploratory factor analysis

	Factor				
	1[a]	**2**[b]	**3**[c]	**4**[d]	**5**[e]
How risky are foods treated with pesticides?	**.66**	-.01	.36	.04	.05
How risky are irradiated foods?	**.77**	.15	.08	-.03	-.26
How risky are genetically modified foods?	.23	.03	**.83**	-.09	-.07
If you were to eat apples grown with pesticides, how worried would you be about the risk?	**.70**	.002	.21	-.01	-.03
If you were to eat irradiated wheat how worried would you be about the risk?	**.75**	.12	.19	-.03	-.22
If you were to eat tomatoes genetically modified to have a longer shelf life, how worried would you be about the risk?	.39	.03	**.78**	-.07	-.08
To what extent is exposure to eating foods treated with pesticides voluntary?	.06	**.82**	.03	.02	-.04

To what extent is exposure to eating irradiated foods voluntary?	-.005	**.87**	.14	.02	.03
To what degree do pesticide treated foods provide important benefits?	-.13	-.02	-.07	.07	**.78**
To what degree do irradiated foods provide important benefits?	-.18	.03	.0006	.10	**.85**
To what degree do genetically modified foods provide important benefits?	.15	.07	-.56	.09	**.63**
Would you choose foods grown using pesticides if it meant that your food was safer?	.05	.07	-.10	**.76**	.07
Would you choose irradiated foods if it meant that your food was safer?	-.05	.003	.02	**.80**	.09
Would you choose genetically modified foods if it meant that your food was safer?	-.03	.002	-.10	**.78**	.06

[a] variables in "pesticide and irradiation" index
[b] variables in "voluntary" index
[c] variables in "genetic modification" index
[d] variables in "choice" index
[e] variables in "benefit" index

The first factor is defined as a "pesticide and irradiation" factor. It includes questions dealing with the perceived risks of pesticides and irradiated foods and how worried a participant is when consuming food produced with the aid of these treatments. A reliability analysis of these questions yields a Cronbach α=0.77. The second factor is defined as a "voluntary" factor. It includes questions assessing the degree to which exposure to food treated in each of the three ways is voluntary. The reliability for these questions is α=0.80. The third factor is defined as a "genetic modification" factor. This factor includes questions dealing with the perceived risks of genetically modified foods and the degree of worry associated with consuming foods produced with this technology. These questions yield an α=0.79. The fourth factor is defined as a "choice" factor. This factor taps into questions having to do with the reduction of risks associated with each of the examined food treatments. In these cases, participants were asked to rate their willingness to consume foods grown with the use of pesticides, sterilized with irradiation, or produced through genetic modification, if the end product was safer. A reliability analysis of these questions yields an α=0.68. A fifth factor, known as a "benefit" factor, included questions addressing the benefits associated with each of these food treatments. Participants were asked to assess the degree to which each of these treatments

provides important benefits. An α=0.71 was calculated for these questions.

For each participant, five separate scales were generated using the factor weightings from the above analyses. A multiple regression analysis with food safety practice score as the dependent variable, and the five food treatment perception scores, age, sex, and level of education as independent variables was performed. This analysis shows that food safety practice scores are a positive function of older age, female gender, and higher levels of perceived risk for foods containing pesticide residues and irradiated foods, and higher levels of worry associated with their consumption ($F_{8,504}$=17.06, p<.0001). This model has an adjusted R^2=.20 (see table 7). The inclusion of other demographic variables in the study (e.g., income, socioeconomic status) and non-demographic variables (e.g., political orientation, trust in science) may have increased the ability of the model to explain food safety practice scores.

Table 7
Regression data for Food Safety Practice Scale

Covariates	**Unstandardized Coefficient and Standard Error**	**T**	**Significance**
Constant	4.62 (.60)	7.74	.0001
Age (years)	.03 (.005)	5.64	.0001
Sex (1= female, 0=male)	.52 (.16)	3.31	.001
Education (1=college or university, 0=high school or less)	.26 (.17)	1.53	.13
Pesticide and irradiation factor	.21 (.04)	6.01	.0001
Voluntary factor	-.04 (.03)	-1.29	.20

Genetic modification factor	.08 (.05)	1.53	.13
Choice factor	.02 (.04)	.60	.55
Benefit factor	-.03 (.04)	-.77	.44

DISCUSSION

Public perceptions of food safety are the result of complex sets of interactions between various factors including sex, age, perceptions of risk plus other psychometric measures, and food safety practices. The study shows that women are more likely than men to engage in food safety practices like washing and peeling fruits and vegetables, eating a wide variety of foods, and purchasing organic foods. This finding is consistent with studies that have shown women to be more concerned about risks in general,[25] and more willing to change their food preparation behaviors in accordance with new information about possible risks like microbiological contamination.[26] Women are more likely than men to evaluate the risks from pesticide residues (χ^2=19.1, df=4, p<0.001), irradiated foods (χ^2=12.2, df=4, p=0.016), and genetically modified foods (χ^2=27.6, df=4, p<0.0001) as more serious. These food treatments all involve the application of an agent or the manipulation of food at some level. In the case of pesticide residues, the addition of chemicals to fruits and vegetables has been subjected to scrutiny for decades. However, with pesticides it is likely that individuals believe that food safety practices like peeling and washing can reduce the risk. Purchasing organic foods may also provide reassurance to individuals who are interested in reducing their exposure to certain kinds of pesticides. New products like Procter and Gamble's "FIT" have capitalized on this market. It is claimed that the use of this "natural" vegetable and fruit wash can reduce the amount of wax, pesticides and chemicals on store bought food by 98%.[27]

25. Susan Cutter et al., *En-gendered Fears: Femininity and Technological Risk Perception*, 6 Indus. Crisis Q. 5 (1992).

26. *See* Williams & Hammitt, *supra* n. 17.

27. Procter and Gamble, "Fruit and vegetable wash FIT." Claim made on this product's packaging and on brochures provided with free samples of the product.

With respect to age and level of education, only age is significantly associated with food safety practices. The sample bias towards the more highly educated may have obscured a difference here. Older individuals are more likely than younger people to take measures to protect themselves from perceived risks associated with foods treated by irradiation or grown with pesticides. Older individuals may be reacting to the possible carcinogenic risks associated with foods treated in these ways, and may demonstrate a willingness to employ safeguards to reduce their risk of developing cancer. Alternately, older individuals may simply prefer variety in their foods and be better skilled in the preparation of raw foods in terms of washing and peeling than are younger individuals weaned on processed, ready-to-eat foods.

The ranking of food safety issues demonstrates that concerns about dietary fat and caloric intake prevail. In total, only 14% of participants listed either genetically modified or irradiated foods as top concerns. Perhaps consumers are drawing on an availability heuristic when assessing the risks associated with certain food interventions. There are very few cases of documented harm to human health associated with consuming genetically modified or irradiated foods. The scientific debates that predominate, especially with respect to genetically modified foods, revolve around the impacts of growing genetically modified crops on biodiversity, antibiotic resistance, and allergenicity. Recent high-profile events like the November 2000 scare associated with the release of Aventis' Starlink corn into the food supply may lead to a shift in these rankings. These results also suggest that the public understands food safety risks better than many realize. Although studies show that consumers underestimate the annual risks associated with common pathogens like Salmonella,[28] it is evident from this study that the public is not overwhelmingly against genetically modified or irradiated foods, at least not from a comparative risk perspective.

The study reveals that food safety practices are related to perceived risk, benefit, and voluntary exposure. The regression model shows that the food safety practice score varies as a function of age, sex, and score on a scale derived from factor 1 ("pesticide and irradiation"). In this instance, the risks associated with pesticides and irradiated foods interact with the degree of worry associated with consuming foods produced with these interventions to influence food safety practices. The pattern does not hold for genetically modified foods and excludes other dimensions commonly

28. Dermot Hayes et al., *Valuing Food Safety in Experimental Auction Markets*, 77 Am. J. of Agric. Econ. 40 (1995).

found in the psychometric literature on risk perception. Voluntary exposure, benefits, and the willingness to choose a food, if the intervention leads to a safer product, do not play a role in influencing food safety practices. Additionally, these dimensions play an insignificant role in influencing public perceptions about the safety of foods containing pesticides or foods having undergone irradiation, and are not significantly related to food safety practices. This pattern of results suggests that food safety practices are a valuable indicator of how people respond to the risks associated with pesticides and irradiated foods (but only in narrowly defined ways), and that age and sex play important roles. It is anticipated that as people become more aware of genetically modified foods, the fuller spectrum of psychometric dimensions found in other studies of food risks will become valuable indicators.

To conclude, studying public perceptions of food safety is an important and necessary endeavor. As new foods enter the marketplace, it is essential to ensure that the policy debates about their regulation reflect both the state of scientific knowledge and the social acceptability of these innovations. This imprecation becomes even more important due to the increased complexity of new food technologies, and the observation that complex innovations in areas like agricultural biotechnology are not being meaningfully communicated to the public and policy-makers.[29] This situation needs to change so as to prevent a continued decline in consumer confidence in government food regulatory agencies and the food industry in general, and to make decision-making more transparent and democratically accountable.[30]

29. Jeffrey Wolt & Robert Peterson, *Agricultural Biotechnology and Decision-Making: The Role of Risk Analysis*, 3 AgBioForum 291 (2000).

30. Michael Mehta, *Risk and Decision-Making: A Theoretical Approach to Public Participation in Techno-Scientific Conflict Situation*, 20 Tech. in Socy. 87 (1998).