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Do Handling and Cooking Practices Determine the Selection of Irradiated Beef?

Arbindra P. Rimal, Stanley M. Fletcher, and Kay H. McWatters

A censored negative binomial regression model was used to study the relationships between the selection of irradiated beef packages, the beef storage and cooking processes, and demographics. Data were collected using a supermarket simulation technique and an exit survey of a panel of Georgia consumers. The results showed that those shoppers who stored (refrigerated) ground beef packages before cooking or freezing were likely to choose more irradiated ground beef packages in a trip to supermarkets than were those who cooked or froze the products immediately. Shoppers making meat loaf and pan-frying ground beef, and grilling, roasting, and braising muscle forms (top round and rib eye steaks) were likely to choose more irradiated packages of ground and muscle forms of beef than non-irradiated packages. Female, married, educated, and employed shoppers were likely to choose more irradiated beef packages than were male, unmarried, less educated, and unemployed shoppers.

Introduction

Food irradiation provides consumers and producers with improved sanitation levels, extended food shelf life, safe transport of products, replacement of chemical fumigants, and reduction of spoilage and waste (Bruhn, Schutz, and Sommer, 1986; Misra, Fletcher, and Huang, 1991). However, opponents of irradiation technology claim that irradiation will make food radioactive and will generally increase risks to public health (Pszczola, 1990).

In December 1997, the Food and Drug Administration (FDA) approved the use of irradiation to kill harmful bacteria—such as *Escherichia coli*, commonly known as *E. coli*—in beef. The meat industry strongly supported this action; however, information about consumer response to this ruling and implementation of technology is limited. In a survey of consumer reaction to the irradiation concept published in 1984, only 23 percent of consumers had heard of the process of irradiation (Wiese Research Associates, 1984). This percentage increased to 66 percent in 1986 (Brand Group, 1986) and to 72 percent in 1995 (Resurreccion et al., 1995). With concerns about the safety of ground beef heightened nationwide, consumers who were once skeptical of irradiation might be more willing to accept irradiated products.

Previous studies on consumer acceptance of irradiated food have reported that consumer attitude toward irradiation might be improved through education and information (Bruhn, Schutz, and Sommer, 1986; Bruhn and Noell, 1987; Bord and O'Conner, 1989). The acceptance rate also depended on demographics. Educated and wealthy respondents are more likely to accept the irradiation process. While asking whether consumers would accept irradiated food, most studies have focused on consumers' general attitude about food safety and demographics.

The meat-cooking and -handling practices of households may be related to their choice of irradiated beef. Among different cuts of beef, ground beef poses the highest food safety risk because the grinding process spreads any pathogens that might be present on the surface of the meat throughout the ground product (Morrison, Buzby, and Lin, 1997). Intact muscles, such as top round or rib eye steaks, may also have surface contamination; therefore, insufficient cooking of either the interior of individual hamburger patties or the surface of intact muscles could allow a sufficient number of pathogens to survive, causing mild gastrointestinal distress or more severe conditions (hemorrhagic colitis and life-threatening hemolytic uremic syndrome) that require hospitalization. Consumers who like intact muscle prepared with minimal cooking—for example, the rare stage of doneness—might be inclined to purchase irradiated products if they perceived them to have an additional margin of safety.

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Irradiation destroys pathogenic bacteria but is also effective in reducing the spoilage of microorganisms, such as aerobic and anaerobic bacteria. In a report from an expert panel on food safety and nutrition, the following findings were summarized (Olson, 1998): (1) The shelf life of irradiated ground beef is extended by 9–10 days if stored at refrigeration temperature (4^0C), and (2) the shelf life is doubled from 4 weeks for non-irradiated vacuum-packaged sirloin cuts stored at freezing temperature (0^0C) to 10 weeks for irradiated product stored at 4^0C.

It can be argued, therefore, that consumers are likely to purchase food products consistent with their cooking and handling practices. Results of a recent consumer survey indicate that consumers rely on themselves, more than they rely on retailers, manufacturers, and the government, to ensure food safety (Sansolo, 1998). However, the same study found that the majority of consumers failed to take precautions, such as keeping food separate, washing food, refrigerating promptly, and cooking properly. An understanding of the relationships between consumers' food handling and cooking and the acceptance of irradiated beef will aid beef processors and retailers in designing appropriate and effective promotion programs. The objective of this paper is to examine the relationships between the selection of irradiated beef packages, the beef storage and cooking processes, and demographics.

Materials and Methods

Experiment Design

A Simulated Supermarket (SS) test was conducted to evaluate the relationship between the consumer handling and cooking process of beef and consumer selection of irradiated beef products. Two hundred and forty participants were recruited from a database of Georgia consumers maintained in the Department of Food Science and Technology. Criteria for participation were: (1) Consumers had to be between the ages of 18 and 74; (2) they had to be the primary grocery shoppers for the household; (3) they had to consume beef at least two times per week; and (4) they had to purchase beef at least two times per month. Shoppers were asked to purchase eight packages of each of two forms of beef products in traditionally labeled packages or in packages labeled as irradiated. The two forms of beef, selected on the basis of consumer health concern and market segmentation, were ground form—including ground beef and ground chuck—and muscle form—including top round and rib eye steaks. The ground form is often associated with *E. coli* outbreaks and is often the subject of recalls. Cooking practices for the ground form of beef were generally different from those for the muscle form. In order to evaluate the effects of change in price on the demand of irradiated beef, a sufficient variation in price is required. In experimental data, such variation can be obtained through a large number of products and participants. The scope and budget of the survey did not allow for such an experimental design. Thus, price effect was removed from the package selection process by keeping the prices of both irradiated and traditionally packaged products the same. Knowledge of food safety, beef cooking and storage practices, and demographics were the topics of the exit questions. Two hundred and seven responses were complete; hence, those responses were used in the analyses.

Characteristics of Participants

The socioeconomic and demographic characteristics of participants in the simulation experiment were presented in Table 1. It was no surprise that the majority of participants were female, 81.6 percent, since primary grocery shoppers in households are typically female. The racial composition of Georgia is approximately 74 percent white as compared to the 86 percent white participant level in the experiment. More than 50 percent of the participants were less than 45 years of age, and 69.1 percent were married. Sixty percent of the participants had completed college or a vocational degree, and 67 percent were employed (full- or part-time). More than 40 percent of the households had income of more than $40,000 annually, and 90 percent of the households had four or fewer household members. Most of the households (78 percent) had either one child (33.6 percent) or more than one child (44.5 percent). Overall, the sample tended to be upscale white, with better-educated and higher-income participants slightly overrepresented in comparison with the census statistics for Georgia.

Table 1. Demographic Characteristics of Supermarket Simulation Participants (n=207).

Characteristic	Percentage of Participants	Characteristic	Percentage of Participants
Age Group:		Employment Status:	
18–24	9.7	Employed Full-Time	44.2
25–34	15.9	Employed Part-Time	22.8
35–44	27.5	Unemployed	16.0
45–54	19.8	Retired	17.0
54–64	16.9		
65–74	10.1	Education:	
		Less Than 12 Years	11.7
Gender:		Completed High School	27.8
Male	18.4	Vocational School or Some College	36.8
Female	81.6	Completed College	17.9
		Graduate or Professional School	5.7
Race:			
White	86.0		
Black	12.5		
Others	1.5	Total Number of People in Household:	
		1	9.7
Marital Status:		2	35.7
Never Married	10.6	3	23.7
Married	69.1	4	21.3
Separated/Divorced/Widowed	20.3	More Than 4	9.6
Household Income:		Total Number of Children in Household:	
Less Than $20,000	22.8	0	21.9
$20,000–$39,999	34.6	1	33.6
$40,000–$59,999	22.3	2	31.3
$60,000 or More	20.3	More Than 2	13.2

Beef Handling and Cooking Practices

The beef shopping, consumption, storage, and cooking practices of the participants in the supermarket simulation are shown in Table 2. The participants primarily shopped for groceries one time per week. Fifty eight percent bought beef at a grocery store at least one time per week. Ground beef was the form that was purchased most often (87 percent), followed by muscle forms (rib eye, T-bone, and porterhouse steaks). Two-thirds of the participants stored beef in the refrigerator (not frozen) one to two days before either cooking or freezing it.

Cooking Practices and Choice of Irradiated Packages. Grilling was common to both ground and muscle forms of beef. Four different ways of cooking muscle forms were reported while five different ways of cooking ground beef (ground beef and ground chuck) were reported (Table 2). Spaghetti sauce was the favorite way of cooking ground beef among the shoppers while the least favorite way was pan-frying. Grilling was the favorite way of cooking muscle forms of beef (top round and rib eye steaks) while frying was the least favorite way. Of those shoppers who selected all traditional or mixed packages (at least one of the selected packages was non-irradiated) of ground form, 67.98 percent grilled the meat while the rest did not. Of those who chose all irradiated packages of the ground form, 75.86 percent grilled the meat. It is likely that shoppers perceived grilling to be a relatively less safe way of cooking; thus, more of them selected irradiated beef for grilling.

Choice of Irradiated Packages and Storage (Refrigeration) Before Cooking. Most people intend to cook raw beef within 1–2 days after pur-

Table 2. Beef Shopping, Consumption, Storage, and Cooking Practices of Participants in the Simulated Supermarket (N=207).

Characteristic	Percentage of Participants	Characteristic	Percentage of Participants
Frequency of Grocery Shopping:		Favorite Ways of Cooking Ground Form:	
More than once a week	76.4	Grilling	69.1
Every two or three weeks	16.9	Sauce	78.3
Once a month or less	6.7	Chili	63.8
		Meat Loaf	52.7
Frequency of Buying Beef		Casserole	35.3
at a Grocery Store:		Pan-frying	27.5
More than once a week	58.0		
Every two weeks	25.1	Favorite ways of Cooking Muscle Form:	
Less than every two weeks	16.9	Grilling	80.7
		Roasting	59.9
Number of Days of Storage		Frying	23.7
(Refrigeration) Before Cooking:		Braising	24.6
0 days	16.9	Stir Fry	34.8
1 day	36.3		
2 days	31.9	Frequency of Eating Beef (At Home and Away From Home):	
More than 2 days	14.9	More than once a day	16.5
		Three times a week	39.1
		Twice a week	31.4
		Less than twice a week	13.0

chase; however, if circumstances changed such that people could not cook as planned, the most effective preservation practice would be freezing the raw beef. Some consumers who perceive one of the benefits of beef irradiation to be longer shelf life, not only at the supermarket level but also at the household level, are likely to refrigerate raw beef a day or two more to avoid having to eat meat that has been frozen. Therefore, the hypothesis is that households who are likely to purchase irradiated beef packages are more likely to store it for a longer period before actually cooking or freezing it. Shoppers reported the number of days that they stored (refrigerated) beef before cooking or freezing. Of those who chose all irradiated packages of the ground form of beef, 62.07 percent stored for two or more days before cooking while only 44.38 percent of those who chose all traditional and mixed packages (at least one of the selected packages was non-irradiated) stored for two or more days before cooking (Table 3). Similar results were found for the muscle form of beef packages. Of those who chose all irradiated muscle beef packages, 52.17 percent stored them for two or more days before cooking while only 46.20 percent of those who chose all traditional and mixed packages stored them for two or more days before cooking.

Count Data Model for Selection of Irradiated Beef

The SS experiment was designed to mimic a grocery-shopping trip that people make in a typical day. The shoppers were asked to select beef packages from the display cases in the simulated supermarket. Each shopper faced the decision of selecting eight packages each of two forms of either irradiated or traditional beef. The forms were ground and muscle. The discrete choice by shopper j to select or not to select an irradiated package for each individual package selection, t, is

$$\text{(1)} \qquad \text{prob}\,(T_t = 1) = f(X_j,\ \theta_t),$$

where T_t is a discrete variable that is equal to 1 if the shopper selects irradiated package t and 0 otherwise for t = 1,....,8; $f(\cdot)$ represents a function of unspecified form; X_j is the matrix representing the cooking and storage habits of shoppers and their socioeconomic characteristics; and θ_t is a vector of parameters. The outcome of eight decisions summarized in equation (1) can be expressed as

$$\text{(2)} \qquad N_{jk} = \sum_{t=1}^{8} T_t\ ,$$

Table 3. Storage (Refrigeration) and Choice of Irradiated Packages.

Number of Days of Refrigeration Before Cooking	Package Selection: Ground Form		Package Selection: Muscle Form	
	AI[a]	TM[b]	AI	TM
Less than 2 days	11 (38%)	99 (56%)	11 (48%)	99 (54%)
More than 2 days	18 (62%)	79 (44%)	12 (52%)	85 (46%)
Total	29 (100%)	178 (100%)	23 (100%)	184 (100%)

[a]AI = All irradiated packages
[b]TM = Traditional or Mixed. At least one of the eight packages selected is non-irradiated.

where N_{jk} is the number of times that irradiated beef packages were selected by the shoppers in a day's supermarket shopping trip. Since individual selection of irradiated beef is linked to the socioeconomic attributes of shoppers and their cooking and storage practices, it is postulated that N_{jk} has an association with X_j. As discussed above, it is hypothesized that those shoppers who often employed cooking processes, which were less likely to kill bacteria, were likely to select more irradiated packages than those who used safe cooking processes. Also, those who stored (refrigerated) meat for a number of days before cooking were likely to select more irradiated packages than were those who cooked or froze the product immediately.

Variables that count the number of times that something happens are often modeled using count data models, more popularly known as Poisson regression models (Long, 1997)—for example, factors affecting how frequently a person visited the doctor (Cameron and Trivedi, 1986), how frequently members of the House of Representatives switch parties (King, 1988), and the number of police arrests in a fixed period (Land, 1992). Let N_{jk} represent the number of times that an irradiated beef package is selected by the shopper j for beef form k, where k represents two forms of beef. Four cuts of beef were divided into two forms of beef; thus, k = ground form and muscle form. The ground form included ground beef and ground chuck, and the muscle form included top round steak and rib eye steak. Shoppers were allowed to shop for four packages of each cut of beef. Thus, the maximum number of irradiated packages that a shopper could choose was eight for each form of beef, and the minimum was zero. Thus, N_{jk} takes on integer values ranging from 0 to 8 for each form of beef. The distribution of shoppers' selection of irradiated packages in a day's visit to a simulated supermarket is shown in Table 4. The variable N_{jk} is assumed to be drawn from a Poisson distribution with parameters λ_{jk}. The probability that the number of selections of irradiated packages equals n can be written as

$$(3) \quad \text{prob}(\text{Njk} = \text{n}) = e^{-\lambda_{jk}} \frac{\lambda_{jk}^{n}}{n!}, \quad n = 0,1,\ldots,8.$$

The parameter λ_{jk} is determined by a linear combination of socioeconomic characteristics and the beef storage and cooking habits of shoppers.

The Poisson regression model assumes that the conditional mean of the outcome is equal to the conditional variance. When the conditional variance of the outcome is higher than the conditional mean, as in this study, there exists the problem of overdispersion. The Poisson model will yield consistent estimates of the parameters, but standard errors are biased downward (Gourieroux, Monfort, and Trognon, 1984). This problem is very common in practice and is remedied by using a negative binomial distribution model. The negative binomial model is specified by adding a stochastic term, ε, to the expression for λ_{jk} as a function of X_j.

$$(4) \qquad \lambda_{jk} = a_0 + X_j\,\theta_k + \varepsilon\,,$$

where X_j is the set of independent variables representing shoppers' storage and cooking habits, and socioeconomic characteristics; θ_k is the vector of coefficients to be estimated for each form, k, of beef; and exp (ε) has a gamma distribution with mean 1 and variance α (Cameron and Trivedi, 1986; Greene, 1993). It is important to consider that, in real life, consumers can select more than eight packages of each form of beef product in a single shopping trip to a supermarket. That is, the sample distribution of N_{jk} was censored on the right-hand side of the equation. The estimated

Table 4. Distribution of Shoppers' Selection of Irradiated Beef Packages in Simulated Supermarket.

Number of Irradiated Packages	Ground Form (Ground Beef and Ground Chuck)		Muscle Form (Top Round and Rib Eye Steaks)	
	Number of Participants	Percentage	Number of Participants	Percentage
0	22	10.68	14	6.80
1	12	5.83	12	5.83
2	23	11.17	36	17.48
3	29	14.08	27	13.11
4	34	16.50	33	16.02
5	31	15.05	23	11.17
6	18	8.74	22	10.68
7	8	3.88	16	7.77
8	29	14.08	23	11.17

model, therefore, is a censored negative binomial model, with a right-hand-side censor. The parameters in equation (4) were estimated with maximum likelihood using the *LIMDEP* economic software (Greene, 1995).

The descriptive statistics of the independent variables included in the model are presented in Table 5. The average number of days that shoppers stored beef was 1.5. The most popular cooking process for the muscle form was grilling, with 81 percent of shoppers employing this process, while the most popular ground form was sauce, with 78 percent employing this process. Fifty-three percent were more than 45 years old; 81 percent were female; 69 percent were married; 60 percent had a college/graduate/professional or vocational degree; 59 percent were employed (part- or full-time); 42 percent had household income of more than $40,000 annually; and 90 percent had fewer than four household members.[1]

Model Results

Based on the collinearity diagnostic tests conducted (Belsley, Kuh, and Welsch, 1980), no collinearity problems were detected in the analyses even though income and education were included in the models. The conditional indices for both models, ground and muscle form, were less than 5. The censored negative binomial regression results for the ground form and muscle form are reported in Table 6. First, the hypothesis of no overdispersion (α=0) is rejected at the 0.01 level for both forms; hence, the choice of a negative binomial over the Poisson distribution is appropriate. Also, the overall significance level for both models was at the 0.01 level. Maddala's pseudo R^2, which was expressed as a transformation of the likelihood ratio chi-square,[2] was used to evaluate the fitness of the model (Long, 1997). The values of the pseudo R^2 were 0.26 for ground form and 0.16 for the muscle form. For cross-sectional data with categorical dependent variable, the pseudo R^2 is often found to be small (Gujarati, 1995). The estimated parameters (Table 6) do not have a direct interpretation as measures of effects on *N*. For ease of

[1] In the initial run of the models, a number of dummy variables were created to account for several demographic classes. A number of estimation problems, including heteroskedasticity and collinearity, appeared due to the small size of the data set. The representation of demographic variables in the present form gives the best results.

[2] The formulae used for calculating pseudo R-squared was:

$$R^2_{ML} = 1 - \exp(-G^2/N),$$

where $G^2 = -2 \ln[L(M_\alpha)/L(M_\beta)]$, with $L(M_\alpha)$ representing likelihood function value for the restricted model and $L(M_\beta)$ representing likelihood function value for the unrestricted model.

Table 5. Description of Independent Variables Used in the Regression Models.

Variables	Distribution	Mean	Std. Deviation
Refrigeration (Number of days before cooking)	0=35; 1=75; 2=66; 3=21; 4=3; 5=7	1.53	1.13
Grill–ground beef (Yes=1; No=0)	1=143; 0=64	0.69	0.46
Grill–muscle beef(Yes=1; No=0)	1=167; 0=39	0.81	0.40
Roasting (Yes=1; No=0)	1=123; 0=83	0.60	0.49
Braising (Yes=1; No=0)	1=51; 0=155	0.25	0.43
Stir Fry (Yes=1; No=0)	1=72; 0=134	0.34	0.48
Sauce (Yes=1; No=0)	1=162; 0=45	0.78	0.41
Chili (Yes=1; No=0)	1=132; 0=75	0.64	0.48
Meat Loaf (Yes=1; No=0)	1=109; 0=98	0.53	0.48
Casserole (Yes=1; No=0)	1=73; 0=134	0.35	0.48
Pan-fry (Yes=1; No=0)	1=57; 0=150	0.28	0.44
Age (Over 45=1; Else=0)	1=110; 0=97	0.53	0.50
Sex (Female=1; Male=0)	1=168; 0=39	0.81	0.39
Marital Status (Married=1; Else=0)	1=143; 0=64	0.69	0.46
Education Level (College or Vocational Degree=1; Less than College or Vocational Degree=0)	1=125; 0=82	0.60	0.49
Employment Status (Full- or Part-time Employed=1; Else=0)	1=124; 0=83	0.59	0.49
Income Level (More than $45,000=1; Else=0)	1=86; 0=121	0.42	0.49
Household Size (More than 4=1; 4 or less=0)	1=20; 0=187	0.10	0.29

Table 6. Censored Negative Binomial Regression Model Results for Selection of Irradiated Beef Products.[a]

Ground Form			Muscle Form		
Variables	Coefficients		Variables	Coefficients	
Refrigeration (Storage)	0.0907**	(0.0473)[b]	Refrigeration (Storage)	0.0556	(0.0487)
Grilling	0.1492	(0.1392)	Grilling	0.3652***	(0.1258)
Sauce	0.0492	(0.1713)	Roasting	0.3538***	(0.1017)
Chili	0.2027	(0.1350)	Braising	0.2323**	(0.1146)
Meat Loaf	0.1986*	(0.1200)	Stir Fry	0.0236	(0.1162)
Casserole	0.1087	(0.1372)			
Pan-frying	0.4167***	(0.1487)			
Age	-0.1584	(0.1361)	Age	0.0313	(0.1136)
Sex	0.3771***	(0.1414)	Sex	0.3333***	(0.1111)
Marital Status	0.3446**	(0.1553)	Marital Status	0.2142*	(0.1233)
Education Level	0.2990**	(0.1201)	Education Level	0.3597***	(0.1099)
Employment Status	0.2644**	(0.1348)	Employment Status	0.2011*	(0.1123)
Income Level	-0.0423	(0.1507)	Income Level	-0.0754	(0.1229)
Household Size	-0.4577**	(0.2321)	Household Size	-0.2018	(0.1949)
Overdispersion Parameter (α)	0.3402***	(0.0686)	Overdispersion Parameter (α)	0.2249***	(0.0546)

[a] *Significant at .10 level; **Significant at .05 level; and ***Significant at .01 level.
[b] Numbers in parentheses are standard errors for the estimates.

presentation, the marginal effects[3] of the independent variables computed from the coefficients and evaluated at the means and their corresponding standard errors are reported in Table 7.

Storage was statistically significant and positive for the ground form of beef, which means that those who stored ground beef for several days before cooking were likely to choose irradiated packages. Every additional day of refrigeration before cooking or freezing increased the selection of irradiated ground beef by 0.25 packages during each supermarket visit (Table 7). However, storage was not a determining factor for the muscle form of beef. This result is consistent with the expectation because irradiation increases the shelf life of beef products and also because ground beef is associated more with *E. coli* and incidents of recalls due to possible contamination than is the muscle form of beef. This relationship is visually presented in Figure 1. The bottom axis shows the number of days of refrigeration, and the vertical axis shows the number of irradiated ground beef packages that were selected. This figure shows a simulated relationship between the number of days of refrigeration before cooking or freezing and the selection of ground beef packages in each trip to grocery stores.[4]

Table 7. Marginal Effects of the Independent Variables on the Selection of Irradiated Beef Packages.[a]

Ground Form			Muscle Form		
Variables	Coefficients		Variables	Coefficients	
Refrigeration (Storage)	0.2578*	(0.1476)[b]	Refrigeration (Storage)	0.1713	(0.1366)
Grilling	0.4245	(0.4077)	Grilling	1.1237***	(0.4296)
Sauce	0.1400	(0.4916)	Roasting	1.0885***	(0.3574)
Chili	0.5766	(0.4040)	Braising	0.7148**	(0.3682)
Meat Loaf	0.5643	(0.3796)	Stir Fry	0.0724	(0.3617)
Casserole	0.3091	(0.3970)			
Pan-frying	1.1846***	(0.4847)			
Age	-0.4503	(0.3958)	Age	0.0961	(0.3534)
Sex	1.072**	(0.4729)	Sex	1.025***	(0.3886)
Marital Status	0.9797**	(0.4910)	Marital Status	0.6589*	(0.3974)
Education Level	0.8501**	(0.3789)	Education Level	1.107***	(0.3733)
Employment Status	0.7516*	(0.4128)	Employment Status	0.6187*	(0.3627)
Income Level	-0.1203	(0.4333)	Income Level	-0.2318	(0.3839)
Household Size	-1.3012*	(0.7088)	Household Size	-0.6209	(0.6105)

[a] *Significant at .10 level; **Significant at .05 level; and ***Significant at .01 level.
[b] Numbers in parentheses are standard errors for the estimates.

[3] The marginal effects of change in each variable on the expected count are calculated with all other variables held at their mean using the following chain rule:

$$\frac{\partial E(Y|x)}{\partial X_k} = \frac{\partial \exp(x\beta)}{\partial x\beta} \frac{\partial x\beta}{\partial X_k} = \exp(x\beta)\beta_k.$$

[4] The simulated relationship shown in Figure 1 is calculated by keeping the remaining variables at their mean value.

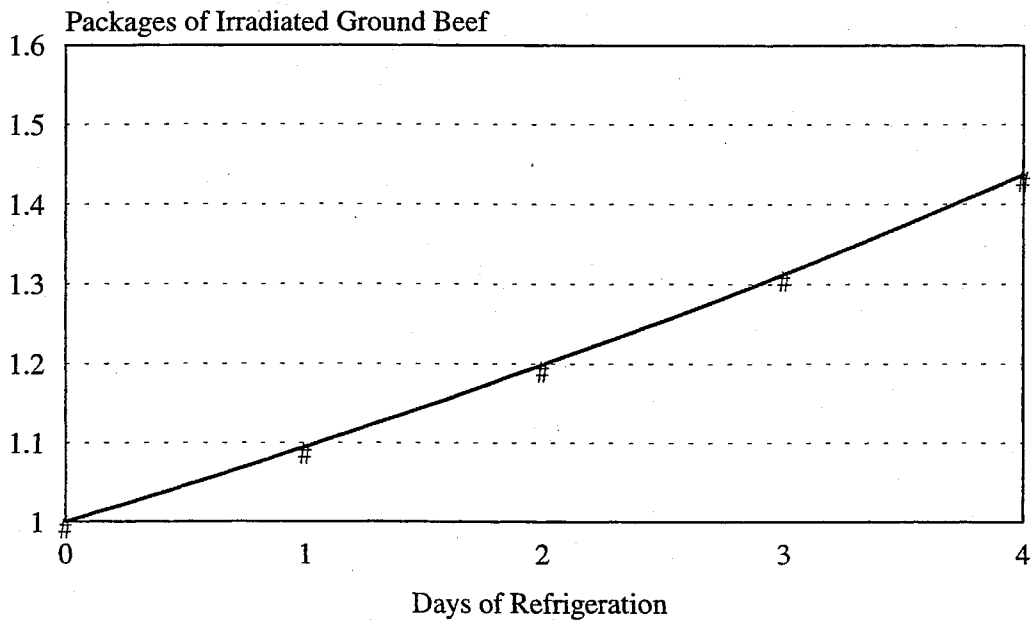

Figure 1. Simulated Relationship Between Days of Refrigeration and Selection of Irradiated Ground Beef Packages.

Only two types of cooking practices, namely meat loaf and pan-frying, were statistically significant and positive for the ground form, which means that shoppers who often made meat loaf or pan-fried ground meat were likely to choose irradiated ground beef packages. Those who pan-fried ground beef were likely to select 1.18 additional packages of irradiated ground beef during each visit to the supermarket compared to those who did not pan-fry (Table 7). In the case of the muscle form, grilling, roasting, and braising were positively related with the selection of irradiated packages (Table 6). That is, those who often chose to grill, roast, and braise top round or rib eye steaks were more likely to choose an additional irradiated muscle form package in each supermarket visit than were those who did not grill, roast, or braise the muscle form of beef (Table 7).

Several demographic variables were statistically significant for both forms of beef. Female shoppers were more likely to choose irradiated beef compared to male shoppers. This finding is rather different from the findings of a number of previous studies, which indicated that female shoppers were more concerned about the safety of irradiated foods, and thus, were more unlikely to select foods subjected to this process (Sapp, Harrod, and Zhao, 1995; Malone, 1990; Schutz, Bruhn, and Diaz-Knauf, 1989). The estimated marginal impact on package selection (Table 7) showed that a female shopper is likely to select 1.07 more irradiated ground beef packages than a male shopper. Married shoppers were more likely to choose irradiated beef than were unmarried shoppers. Those shoppers who had a college or vocational degree were more likely to choose irradiated beef than were those with less education. Previous research (Terry and Tabor, 1990; and Nayga, 1996) found a positive relationship between education and irradiated food. Resurreccion et al. (1995); Schutz, Bruhn, and Diaz-Knauf (1989); and Lusk, Fox, and Mcilvain (1999) found that people with less formal education were more concerned with perceived problems associated with irradiation and, hence, were unlikely to choose irradiated foods. Those who were employed (full- or part-time) were more likely to choose irradiated beef than were those who were not employed. Household size was negatively related with the selection of the ground form of irradiated beef packages. Households with four or more members were likely to choose 1.30 less packages of irradiated ground beef than were those households with fewer than four members. This result is consistent with the expectation because large households have income constraints and are more likely to emphasize price differentials between irradiated and traditional packages than they are to emphasize the safety factor. Household size, however, was not important with the selection

of the muscle form. Top round and rib eye steaks are often targeted toward high-income households. Family size is unlikely to impose a constraint on their budget; thus, these shoppers are likely to choose safe beef, irrespective of family size.

Conclusions, Limitation, and Implications

This research evaluated the hypothesis that consumers who expect safe food from their own handling and cooking practices are more likely to demand safe food from markets. The relationships between beef storage and cooking processes and consumer acceptance of irradiated beef were empirically estimated using the data from a simulated supermarket setting.

Censored negative binomial models for the selection of ground and muscle forms of beef packages revealed that those shoppers who stored (refrigerated) ground beef for several days before freezing or cooking were likely to select more irradiated ground beef packages than were those who cooked or froze them immediately. A similar relationship was found to be statistically insignificant for the muscle form of beef package selection. The difference in consumer attitude toward the storage of ground beef compared to muscle beef is consistent with the fact that ground beef is often associated with incidents of *E. coli* and meat recalls.

Cooking methods also determined the selection of packages. Consumers who employed less safe ways of cooking beef—for example, grilling the muscle form of beef—selected more packages of irradiated beef than did those who employed a safer way of cooking. Demographic characteristics determined the selection of irradiated packages; however, there was no important distinction between the ground form and the muscle form of beef. It is interesting to note that income level had no effect on the selection of irradiated packages while education and employment had a significant effect. In this study, income variable was represented as a dummy variable, with a single threshold of income level.

The results of this study indicate that the target consumers for irradiated beef are females, married, educated with a college or vocational degree, and employed. An efficient promotion campaign to inform and persuade potential consumers to purchase irradiated ground beef must highlight the storage benefits of meat irradiation through labels and promotion materials, such as in-store posters; however, consumer education should emphasize that, despite irradiation, meat products are still perishable and must be handled carefully to protect them from recontamination.

Consumers who like the muscle form of beef cooked minimally might be inclined to purchase irradiated beef if they perceived it to have an additional margin of safety. A promotion campaign for irradiated beef might emphasize such culinary benefits of irradiated beef to attract buyers. Also, irradiated beef packages might be promoted more intensively during annual cookout occasions—for example, the July 4th weekend.

Market data for the actual purchase of irradiated beef is not available because irradiated beef products are not sold in the market. Before market data becomes available, researchers must rely on experimental data, such as simulated supermarket and survey data in which respondents are offered a hypothetical situation. It is important to evaluate the results of this study within the limitation set forth by the data set. The results from this study should be used along with the results from other studies before generalizing for all U.S. consumers. The results of this study also suggest the need for future research that addresses issues in food handling and cooking at the household level. For example, do consumers know how to safely store and handle food? What are the most effective means of educating consumers about the safe handling of food? What are the long-term physiological effects of consuming irradiated foods?

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