Producer Welfare Changes from Meat and Poultry Recalls

Rimma Shiptsova, Michael R Thomsen, and H. L. Goodwin

The number and volume of meat and poultry recalls has increased substantially in recent years. This is likely due to regulatory emphasis on foodborne illness resulting in an increased frequency of testing for pathogens. We use an equilibrium-displacement model to examine the effects of recall costs on the beef, pork, and poultry industries. Results suggest that higher recall costs may have actually increased producer surplus to the broiler industry because of consumer substitution among products and that most losses resulting from recalls are accruing to the beef and pork industries.

Meat and poultry recalls are initiated when products already in commerce are found to pose threats to public health. Thomsen and McKenzie argue that the recall mechanism is an important policy tool and that the role of the USDA Food Safety and Inspection Service (FSIS) in requesting and supervising recalls can help to align private and social incentives with respect to levels of food safety provided by markets. As with any policy tool, changes in the way it is used or implemented are an important consideration. Using stock market data, Thomsen and McKenzie (2001) found that the equity value of firms implicated in recall situations fell. This suggests that recalls have an adverse effect on current and future profitability. In this paper we focus on profitability implications of recalls at the industry level rather than at the firm level. Our main objectives are to examine the overall magnitude of changes in recall costs and to determine the affects of these costs on the beef, pork, and poultry industries.

The number of meat and poultry recalls has increased substantially in recent years. Between 1982 and 1997 there were on average just over 27 recalls per year carried out under the oversight of the FSIS[1]. The number of recalls in 1998, 1999, and 2000 were 44, 62, and 76, respectively (USDA FSIS 2000b). The large increase in the number of recalls is likely due in part to two factors. One is the additional testing for foodborne pathogens that resulted from transition to the mandatory hazard analysis of critical control point (HACCP) inspection system. A second factor is regulatory response to highly publicized contamination incidents. We briefly discuss each of these in turn.

FSIS began to implement the HACCP inspection program in January of 1998[2] . This program was designed to improve the safety of meat and poultry products by placing more emphasis on preventing potential hazards at critical points in the production process. Along with HACCP came an increased emphasis on testing and zero-tolerance limits for *Listeria* in ready-to-eat meat and poultry products and for *E.coli O157:H7* in ground beef. This may be one factor explaining an increase in the number of recalls for contamination with these pathogens. Given the perishable nature of meat products, some companies have made the decision to ship products before test results could be obtained, which has resulted in additional recalls (Brasher 2000).

The second factor is highly publicized contamination incidents or outbreaks. One noteworthy case involved ground beef contaminated with *E. Coli O157:H7* processed at a Hudson Foods facility in Columbus, Nebraska. This recall involved 25 million pounds of product, at the time the largest recall on record. In the 12 months following this recall there were more recalls (11 events) involving *E. Coli O157:H7* than during the entire previous 10 years. The second case involved *Listeria* con-

[1] Meat and poultry recalls are voluntary actions taken by firms. In practice, many recalls are initiated at the request of FSIS. Regardless of whether the recall occurs on the firm's own initiative or at the request of the agency, FSIS supervises and monitors the recall in progress.

Rimma Shiptsova is assistant professor, Utah State University; Michael R Thomsen is assistant professor, University of Arkansas; and H. L. Goodwin is associate professor, University of Arkansas.

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[2] HACCP implementation for all meat and poultry plants employing more than 500 persons began January 26, 1998. On the same date in 1999, plants with 11 to 499 employees were added to the HACCP inspection list. Approximately 7,000 inspectors operating from 17 regional USDA-FSIS offices are currently dedicated to HACCP implementation and enforcement.

tamination at a Sara Lee plant in Zeeland, Michigan in December 1998. The incident resulted in several fatalities and numerous illnesses. Following this incident, *Listeria* recalls accounted for half of all recalls in 1999 and for 46 percent of recalls in 2000.

The purpose of this paper, though, is not to examine changes in the regulatory environment or trends in recall activity that might have led to an increase in the number and volume of meat products recalled in recent years. Rather, the study examines changes in costs due to a higher incidence of recalls and the effects of these changes on profitability and competitiveness of the beef, pork, and poultry industries. To do this, equilibrium displacement models (EDM) are employed. Within these models, a market equilibrium is characterized by functions that are linear in supply and demand elasticities. This allows an examination of changes in equilibrium outcomes due to a supply shock such as an increase in expected or actual recall costs. Such models have been used extensively in the analysis of agricultural and food policies (e.g., Summer and Wohlgenant 1985; Beghin and Chang 1992; Brown 1995; Unnevehr, Gomez, and Garcia 1998). An important aspect of the analysis is its accounting for substitution effects between poultry, pork, and beef products when examining the effects of recall costs. Unnevehr, Gomez, and Garcia (1998) demonstrated through their study on HACCP regulations that the effects of regulation on industry profitability differed considerably across industries.

Methods and Data

We begin with retail-demand equations that depend on the retail price of the product in question and the prices of substitute products. We also specify general wholesale-supply equations that depend on the wholesale price of the product in question and the costs of recalls[3]. Note that an implicit assumption is that substitution among products is not possible in supply. The equilibrium price at the retail and wholesale levels differs by a marketing margin, which is assumed to be constant. Additional assumptions made about the structural demand and supply equations are that they are continuous and differentiable. The conditions that characterize an equilibrium are

$$(1)\quad \begin{aligned} Q_i^s &= f_i^s(W_i, C_i) \\ Q_i^d &= f_i^d(P_{br}, P_p, P_b) \\ Q_i^d &= Q_i^s = Q_i \\ i &= b, br, p \end{aligned}$$

where b is beef, br is poultry, p is pork, W_i is a wholesale price for industry I, P_i is a retail price for industry I, Q_i is quantity produced by industry I, and C_i is cost per unit produced for industry i. After differentiating the supply and demand equations above and after some algebraic manipulation, the equilibrium conditions can be represented in elasticity form as

$$(2)\quad \begin{aligned} d\ln(Q_i) &= \varepsilon_i(d\ln(W_i) - c_i) \\ d\ln(Q_i) &= \sum_j \eta_{ij}\, d\ln(P_j) \\ d\ln(W_i) &= \tau_i\, d\ln(P_i) \\ i, j &= b, br, p \end{aligned}$$

where τ_i, and ε_i, are the price transmission elasticity and own price supply elasticity, for good i, respectively; c_i is a recall shock for good i; and η_{ij} is the demand elasticity for product i with respect to product j.

The shock that disrupts an equilibrium in this model is a change in the cost per unit, C_i from equation 1. The elasticity formula is derived from the differentiation of equation 1 assuming that the change in cost per-unit is due only to recall cost. For this reason, recall costs enter equation 2 in much the same manner as a tax. In equation 2, the shock c_i is recall costs as a percentage of average total production value by industry i. The intuition behind this is that in a competitive environment, a change in the cost per unit produced is equal to the change in marginal costs. Noting that average cost equals marginal cost at a long-run competitive equilibrium, it is legitimate to approximate c_i as the to-

[3] The specification of structural equations at two different levels of the vertical chain results from the specifics of the meat industry. Prices affecting suppliers are observed at the wholesale level while prices influencing consumer behavior are observed at retail.

tal costs of recalls over wholesale value of the product produced:

$$(3) \qquad c_i = \frac{C_i \overline{Q}_i}{W_i \overline{Q}_i} = \frac{C_i}{W_i}$$

where $\overline{Q}_i$ is average quantity produced by industry i.

The price transmission elasticity, τ_i, will be used to derive wholesale-price percentage change from retail-price percentage change. We use an application of Gardner's formula (1975) to calculate a synthetic value of the elasticity of price transmission between wholesale to retail prices[4]:

$$(4) \qquad \tau_i = \frac{\sigma_i + e_b}{\sigma_i + S_i e_b + (1 - S_i) e_a},$$

where σ is elasticity of substitution between meat company and marketing inputs, e_a is elasticity of supply of wholesale meat, e_b is elasticity of supply of marketing inputs, and S is meat company share of retail dollar. To implement the model we assume an elasticity of substitution of zero and an elasticity of marketing inputs of unity (Gardner 1975; Richards and Patterson 1998).

The total recall costs for an industry may be conceptualized in two ways. The first is as actual costs that occur when a product has been recalled. These actual costs incorporate the value of the product, costs of product recovery, time off the shelf, disposal, and sometimes incineration, depending on a reason for recall. The actual annual costs for each recall are estimated to be

Actual costs = 3*Retail price of a product *Pounds recalled.[5]

The second way to conceptualize recall costs is in terms of expected costs or the costs that a firm expects to incur given current information on total industry recalls. They are estimated as

$$(5) \qquad EC_i^j = 3\,\mathrm{Pr}_i^j(R) * \overline{R}_i P_i$$

where EC_i^j is expected annual costs of recall for plant j of industry I, $\mathrm{Pr}_i^j(R)$ is probability of recall for plant j of industry I, $\overline{R}_i$ is average pounds recalled for industry I, and P_i is retail price of product i. Therefore total annual recall costs for the industry are

$$(6) \qquad \begin{aligned} TC_i &= AC_i + 3\sum_j \mathrm{Pr}_i^j(R) * \overline{R}^j P_i \\ AC_i &= 3P_i \sum_j R_j^i \end{aligned}$$

where AC_i is actual annual costs of recall and R_j^i is pounds recalled for plant j of industry i.

Data required to implement the model (elasticity estimates, costs of recalls, retail and wholesale prices and quantities) were obtained as follows. Required elasticity estimates for beef, pork, and poultry products were obtained from earlier studies that have analyzed meat-demand systems (Huang 1993) or report estimated supply elasticities (Sullivan, Wainio, and Roningen 1990). We use two different estimates of demand elasticities: wholesale-demand elasticity estimates from Sullivan, Wainio, and Roningen and retail-demand elasticity estimates from Huang (1993) (Table 1).

The required information on the costs of recalls (supply shocks) was obtained from information provided by FSIS and multipliers used by the food-industry firms to estimate the direct costs of recall events. The FSIS data are available from the agency's website and cover the period from 1995 to 1999 and reflect 159 recalls of meat and poultry products (USDA FSIS 2000b). Data reflecting prices and quantities at retail and wholesale for beef, pork, and poultry were obtained from USDA/ERS *Agricultural Outlook* publications.

A probit model is utilized to estimate probability of recall $P_i^j(R)$. We use an ad hoc specification of the model with the primary aim of obtaining recall-probability estimates for use later in the EDM framework. Variables included are driven largely by data availability on FSIS inspected plants (USDA FSIS 2000a). The explanatory variables reflect location, size of the plant, and a variable to indicate whether or not the plant was under HACCP inspection.

[4] Bernard and Willet (1996) argued that elasticity of price transmission changes depending on shifts in retail food demand. This study focuses on average price-transmission elasticity; therefore, Gardner's formula is used.

[5] Industry contacts were consulted to determine that three times the retail value is a common estimate of recall costs.

Table 1. Demand and Supply Elasticity Estimates.

	Beef	Pork	Chicken
SWR[d], ε_w [a]			
Beef	0.65		
Pork		1.00	
Chicken			0.65
SWR, η_w [b]			
Beef	-0.70	0.05	0.03
Pork	0.08	-0.86	0.03
Chicken	0.09	0.06	-0.56
Huang, η_r [c]			
Beef	-0.6088	0.1214	0.0207
Pork	0.2130	-0.7162	0.0167
Chicken	0.1054	0.0484	-0.3718

[a] ε_w is wholesale elasticity of supply
[b] η_w is wholesale elasticity of demand
[b] η_r is retail elasticity of demand
[d] SWR refers to Sullivan, Wainio, and Roningen (1990)

$$Pr_i^j(R) = \alpha_0 + \alpha_1 SMALL + \alpha_2 VSMALL + \alpha_3 HACCP + \alpha_4 NORTH + \alpha_5 SOUTH + \alpha_6 SMALL*SOUTH + \alpha_7 VSMALL*SOUTH \tag{7}$$

where SMALL and VSMALL are binary variables indicating small or very small plants and NORTH and SOUTH are binary variables for location. The base category for this model was a large plant located in the West. Explanatory variables LARGE and WEST were excluded to avoid perfect multicollinearity. Likelihood-ratio specification tests supported the inclusion of the interaction terms SMALL*SOUTH and VSMALL*SOUTH. All data required to implement the probit model estimation are taken from the FSIS recall database and the FSIS data on federally inspected plants, both available through the agency's website (USDA FSIS 2000a; USDA FSIS 2000b). Each data set provides an establishment number which allowed us to match plants which experienced recall with the size and location data.

Endogenous variables of the EDM model (2) are the proportional changes in quantities and prices of pork, beef, and chicken. The exogenous shocks are changes in prices received by the producer due to additional costs. The change in producer surplus for commodity i is calculated as

$$\Delta PS_i = W_i Q_i (d\ln(W_i) - c_i)(1 + d\ln(Q_i)/2).[6] \tag{8}$$

Results

The results for the probability model (7) are given in Table 2 and the estimated probabilities are presented in Table 3. The results show that there has been a substantial increase in the probability of recall after HACCP implementation, especially for small plants: an average of 98- and 132-percent probability increase for large and small plants, respectively. However, these results should not be misinterpreted. As mentioned in the introduction,

[6] Consumer surplus change is not calculated because the study focuses on industry surplus changes only.

Table 2. Probit Model Parameter Estimates for Probability of Recall [equation (7)].

Parameter	Estimate	Standard Error	Chi-Square Statistics	Pr > ChiSq(1)
Intercept	-1.8957	0.1210	245.3000	<.0001
Small	-0.7722	0.1019	57.4300	<.0001
VSmall	-1.0562	0.1134	86.7600	<.0001
HACCP	0.3077	0.0722	18.1400	<.0001
North	0.1662	0.0865	3.6900	0.0549
South	-0.3757	0.1552	5.8600	0.0155
Small*South	0.5419	0.1606	11.3900	0.0007
VSmall*South	0.2612	0.2006	1.7000	0.1928

Table 3. Estimated Probabilities of Recall for U.S. Meat and Poultry Plants After HACCP Implementation.

Plant Size	South	North	West
Large plants			
Before HACCP	0.011562	0.041857	0.029001
After HACCP	0.024783	0.077536	0.056143
Probability increase (%)	114.35	85.24	93.59
Small plants			
Before HACCP	0.00618	0.006179	0.003816
After HACCP	0.014117	0.014116	0.009132
Probability increase (%)	128.43	128.45	139.31
Very small plants[a]			
Before HACCP	0.001083	0.002671	0.001579

[a] HACCP was introduced to very small plants in January of 2000; the recall data for that year were not available when this study was conducted.

HACCP may have a positive effect on recalls due to increased frequency of inspections and testing and regulations specifying zero-tolerance limits for pathogens.

The probability estimates from Table 3 were utilized to calculate expected recall costs for each plant. To do this we grouped the FSIS recalls into 12 product categories: (1) ground beef, (2) other beef products, (3) ham products, (4) other pork products, (5) chicken products, (6) turkey products, (7) luncheon meats, (8) frankfurters, (9) sausage, (10) other processed products, (11) baby foods, and (12) miscellaneous. Categories 6 through 12 do not clearly indicate meat contents of the product in terms of beef, pork, or poultry. Therefore, we calculate both an upper and a lower bound for total pounds recalled for each species. To calculate the upper bound, the sum of all categories 6 through 12 were added to the total pounds of beef, pork, and poultry products recalled.

Table 4 reports recall costs as a percentage of industry sales. While recall costs typically account for less than one percent of industry sales, this can translate into a large dollar figure. Data presented in Table 5 show recall costs reached hundreds of millions of dollars in recent years. Note that the

Table 4. Total Production, Value, and Recall Costs as a Percentage of Industry Sales.

Industry	Year	Production (mln lbs)	Industry sales (mln $)	Retail value (mln $)	% expected recall costs	
					Lower limit	Upper limit
Pork	1996	17,117	21,088.14	40,002.43	0.001	0.007
	1997	17,274	21,264.29	42,321.30	0.009	0.055
	1998	19,001	18,487.97	46,115.43	0.049	1.570
	1999	19,308	19,114.92	46,628.82	0.011	1.291
Beef	1996	25,525	40,355.03	71,521.05	0.004	0.007
	1997	25,490	40,325.18	71,244.55	0.540	0.567
	1998	25,760	39,618.88	71,380.96	0.059	0.869
	1999	26,943	46,234.19	77,541.95	0.026	0.656
Poultry	1996	31,802	19,752.44	45,336.75	0.004	0.008
	1997	32,749	19,590.33	46,826.95	0.016	0.045
	1998	33,143	20,865.90	48,107.03	0.022	0.828
	1999	34,918	20,858.23	51,045.44	0.018	0.728

Table 5. Annual Losses for the Poultry, Beef, and Pork Industries.

Industry	Year	Actual Losses		Actual and Expected Losses	
		Lower limit	Upper limit	Lower limit	Upper limit
Pounds					
Pork	1996	41,765	200,615	45,042	203,892
	1997	33,000	1,351,026	273,342	1,591,368
	1998	491,512	39,119,626	1,234,880	39,862,994
	1999	140,587	33,887,056	302,999	34,049,468
Beef	1996	168,374	327,224	171,651	330,501
	1997	25,709,958	27,027,984	25,950,300	27,268,326
	1998	2,050,410	40,678,524	2,793,778	41,421,892
	1999	1,241,602	34,988,071	1,404,014	35,150,483
Poultry	1996	190,320	349,170	193,597	352,447
	1997	474,702	1,792,728	715,044	2,033,070
	1998	305,892	38,934,006	1,049,260	39,677,374
	1999	713,242	34,459,711	875,654	34,622,123
Millions of $					
Pork	1996	0.293	1.407	0.316	1.429
	1997	0.081	9.930	2.009	11.697
	1998	1.193	284.830	8.991	290.242
	1999	0.340	245.512	2.195	246.688
Beef	1996	0.472	2.751	1.443	2.778
	1997	215.578	226.630	217.593	228.645
	1998	5.682	338.161	23.225	344.340
	1999	3.573	302.087	12.122	303.489
Poultry	1996	0.814	1.493	0.828	1.507
	1997	2.036	7.690	3.067	8.721
	1998	1.332	169.536	4.569	172.773
	1999	3.128	151.128	3.840	151.840

large divergence in the upper and lower bounds for pounds and recall costs in 1998 and 1999 is primarily due to large recalls for *Listeria* that affected luncheon meats and frankfurters. Because of an inability to trace back to a given species, both of these recalls are included only in the upper-bound estimates.

The results for producer welfare change come from the different elasticity estimates employed in the analysis. Price-transmission elasticities of 1, 1.17 and 1.25 for the pork, beef, and poultry industries, respectively, were estimated by utilizing Gardner's formula (4), assuming plausible values for the elasticity of supply of marketing services (1.00) and the elasticity of substitution between farm and marketing inputs (0.0) (Gardner 1975; Richards and Patterson 1998).

The results for producer welfare changes are presented in Table 6. Estimates are reported both with and without substitution effects. By comparing the two sets of estimates one can observe the importance of consumer behavior on the impact of recalls to the various meat industries. Without substitution effects, higher own-price elasticities cor-

Table 6. Estimated Producer Welfare Losses with Expected Costs (in Million Dollars).

Industry	Year	Industry surplus change without substitution effects (lower limit)	Industry surplus change without substitution effects (upper limit)	Industry surplus change with substitution effects (lower limit)	Industry surplus change with substitution effects (upper limit)
Sullivan, Wainio, and Roningen					
Pork	1996	-0.15	-0.66	-0.16	-0.56
	1997	-0.93	-5.41	2.85	-1.29
	1998	-4.16	-133.71	-3.69	-125.91
	1999	-1.01	-113.72	-0.85	-107.28
Beef	1996	-0.75	-1.44	-0.20	-0.56
	1997	-112.72	-118.44	-55.53	-57.89
	1998	-12.04	-178.29	-5.29	-69.40
	1999	-6.29	-157.19	-2.93	-59.38
Poultry	1996	-0.38	-0.70	-0.12	-0.08
	1997	-1.42	-4.04	5.60	5.21
	1998	-2.11	-79.86	0.22	-10.04
	1999	-1.78	-70.20	-0.36	-10.63
Huang					
Pork	1996	-0.13	-0.60	-0.001	-0.443
	1997	-0.84	-4.88	-0.001	-0.447
	1998	-3.75	-120.73	-2.681	-102.599
	1999	-0.92	-102.67	-0.363	-88.088
Beef	1996	-0.70	-1.34	-0.162	-0.146
	1997	-105.15	-110.48	-0.162	-0.146
	1998	-11.23	-166.31	-1.704	-1.109
	1999	-5.86	-146.63	-1.202	0.472
Poultry	1996	-0.30	-0.55	0.121	0.261
	1997	-1.12	-3.17	0.120	0.259
	1998	-1.66	-62.81	1.690	37.207
	1999	-1.40	-55.20	0.791	31.148

respond to higher producer welfare losses. When demand is inelastic, small decreases in quantity lead to the large increases in price, thereby offsetting a large part of producer losses. The results indicate that producer surplus change is always negative (net loss) when there is no substitution effect on the demand side (cross-price elasticities are set to zero). Without substitution effects, producer welfare losses range from approximately $0.3 million to $134 million for the pork industry, $1 million to $178 million for the beef industry, and $0.4 million to $80 million for the poultry for both the Sullivan, Wainio, and Roningen (1990) and Huang (1993) elasticities of demand. Note that price-transmission elasticities are used only with the Huang elasticities because these are at the retail level, while the Sullivan, Wainio, and Roningen (1990) demand elasticities are at the wholesale level. The retail-level elasticities are slightly lower in magnitude for the own-price elasticities (see Table 1).

When industry losses are computed with substitution effects, the distribution of losses among the industries changes substantially and recall costs can sometimes translate into welfare gains. Most notably, depending on which elasticity estimates are used, the poultry industry appears to have been a net beneficiary as consumers substitute poultry for beef and pork. When no substitution occurs, the total adjustment to shifts in supply is reflected by movement along the demand curve. When the substitution effect occurs, producer losses also depend on the direction and magnitude of the demand shift. The poultry and pork industries benefited from the substitution effects. The gains for the poultry industry were as much as $37 million in 1998, compared to a loss of $63 million during the same year when substitution effects are not considered. These magnitudinal differences in losses with and without substitutability again emphasize the importance of consumer behavior on producer welfare losses.

Policy Implications

The major contribution of the paper is a better understanding of how the use of recalls as a policy tool can impact competitiveness among meat and poultry industries. Results show that after HACCP implementation the probability of a product recall has significantly increased for the pork, beef, and poultry industries. This is most likely due to an increase in the rigor of testing for pathogens. The higher incidence of recalls, however, appears to have the largest impact in terms of producer welfare loss on the beef industry. Given most of the estimates of welfare change reported in this paper, it appears that larger numbers of recalls have actually benefited the broiler industry.

The importance of consumer behavior on producer welfare changes as a result of recalls is also demonstrated. A primary reason why the effects of recalls are not constant across industries is that consumers shift among the three commodities in reaction to a price change. This can be advantageous to some industries. Unfortunately, the elasticity estimates are assumed constant and also do not capture consumer responses to a product recall. A better understanding of consumer behavior would allow for more accurate estimation of producer welfare changes.

Concluding Comments

Actual consumer-health benefits are difficult to assess. Only in recent years has a large increase in

Table 7. Rate[a] of Selected Pathogens Detected by FoodNet[b] at the Five Original Sites, by Year and Pathogen, 1996-2000.

Pathogen	1996	1997	1998	1999	2000
Campylobacter	23.5	25.2	21.4	17.5	18.1
E.coli O157	2.7	2.3	2.8	2.1	2.0
Salmonella	14.5	13.6	12.3	14.8	14.1
Salmonella Enteritidis	2.5	2.3	1.4	1.3	1.2

[a] Per 100,000 population
[b] Source: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5115a3.htm

the number and volume of meat and poultry recalls occurred, and sufficient statistics have not been accumulated to test whether a statistically significant decrease in foodborne illness has occured. The FoodNet of the Centers for Disease Control and Prevention collected data for selected counties in 5 states in 1996 and in 1997, and in 7 states in 1998 and 1999. Therefore, any difference in the results might occur as a result of different samples. Despite this limitation, these data indicate that there were no substantial overall changes in human health in 1998 (see Table 7). *Salmonella Enteritidis* decreased and rates of occurrence of *Campylobacter* declined slightly in 1998/99. However it is difficult to attribute these declines to an increase in recalls. The increase in recalls has mostly reflected problems with *E. Coli* and *Listeria* rather than with *Salmonella* or *Campylobacter*. In the case of *Salmonella*, the decline likely has more to do with egg-quality-assurance programs than with pathogens on meat. However, incidences of human illness might be negatively correlated with recalls because they increase consumer awareness of hazards in the food supply.

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