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Consumer Interest in Environmentally Beneficial Chicken Feeds: Comparing High Available Phosphorus Corn and Other Varieties

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One source of phosphorous pollution in areas of high chicken production is runoff from fields using fertilizer from these operations. A potential solution is to feed chicken high available phosphorus (HAP) corn, reducing phosphorus in manure. This study examined consumer purchase likelihood of chickens fed HAP, created traditionally or through genetic modification, and other genetically modified (GM) corn including Bt and Roundup-ready. Survey results from the Delmarva Peninsula found considerable interest in non-GM HAP corn, although GM HAP corn was not typically viewed as more acceptable than other GM varieties. Overall, the marketplace appears open to products geared toward environmental benefits.

Key Words: chicken, conjoint analysis, corn, genetically modified, heteroscedastic, phosphorus pollution, Tobit

JEL Classifications: Q13, D12, C24

Phosphorus pollution is a major problem for surface water in the United States. Excess phosphorus (combined with nitrogen) can lead to heavy algal growth and eutrophication, reducing oxygen and causing fish kills. Some algal blooms such as red tides are directly toxic to fish as well as human beings. Degradation of water quality can also lead to water shortages. Among the causes of phosphorus pollution are sewage, storm water, and agricultural sources both from commercial fertilizer applications and manure.

This research focused on the chicken industry and its contribution to phosphorous concerns. In Delaware and Maryland (states with large concentrated chicken industries), at least 65% of chicken producers are considered concentrated animal feedlot operations (CAFOs), which are faced with increasing federal regulations through the Environmental Protection Agency (EPA) to control phosphorus and nitrogen runoff (National Agricultural Statistics Service, 2007a, 2007b). In the chicken industry, an animal feedlot operation is considered a CAFO if the operation houses 125,000 or more broilers or 30,000 broilers if using a liquid manure handling system (Koelsch, 2003).

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CAFOs can be a special problem because large amounts of nutrients are often created on small amounts of land as a result of the sheer volume of the operation. Although dependent on the rate of applied manure and nutrient uptake capacity, in cases where land is limited, using the manure as fertilizer in the region could lead to a situation in which agricultural fields are overfertilized, many with excess phosphorus. In such cases, much of these nutrients find their way into surface waters (Ribaudo et al., 2003).

Chicken producers in many states face increasing regulation over these issues. Delaware for instance enacted the Delaware Nutrient Management Law in 1999 (Delaware Department of Agriculture, 2007). Its neighbor Maryland enacted similar legislation (Maryland Cooperative Extension's Nutrient Management Program, 2006). These nutrient management practices include, for example, proper timing and methods of fertilizer (commercial and manure) application, planting of cover crops and vegetative buffer strips, and erosion control.

Chicken producers considered CAFOs in particular must create a Nutrient Management Plan (NMP), which contains a subset of activities found under the EPA's National Pollutant Discharge Elimination System. The NMP establishes manure application rates for each field, and producers may apply manure only if the nitrogen and phosphorus rates meet the nutrient needs of the current or proposed crops grown. Similarly, manure application may be limited or even banned from fields with a high potential for phosphorous loss.

Many farmers then have adopted a phosphorus-limiting nutrient planning program, in which the amount and frequency that phosphorus is applied to the land is greatly reduced, thus limiting the amount of phosphorus runoff. Because manure is a source of both phosphorus and nitrogen, to add the desired amount of nitrogen to the soil, farmers then use nitrogen-only sources of fertilizer such as ammonia or urea, which add no phosphorus. However, this is more costly than manure and leaves the poultry industry with the additional and substantial cost of disposing of the unused manure.

Although financial assistance for a NMP is available to producers through the USDA's Environmental Quality Incentives Program (EQIP), funding is limited to $300,000 for a 6-year period (Natural Resources Conservation Service, Environmental Quality Incentives Program, 2009). The EQIP also involves a competitive application procedure procured through each state's Natural Resources Conservation Service center. In 2005, in Delaware alone, there was a backlog of unfunded applications estimated at over $2 million (Natural Resources Conservation Service, 2005). Although NMPs can be effective, to reduce cost, producers implementing the practice often hinder its intent by substituting in more runoff-prone crops such as corn (Bonham, Bosch, and Pease, 2006). This is because such crops have a higher use of phosphorus (P), which under NMP's can allow farmers to use larger applications of manure and therefore not need to purchase as much extra supplements of nitrogen and potassium. In a similar fashion, in some areas, these producers may also increase the total number of crop acres in production, causing additional water pollution (Norwood and Chvosta, 2005).

As a result of the high costs of the current solutions, chicken producers are actively seeking ways to reduce the P content of chicken manure. A possible candidate is the corn fed to chickens. Corn is a major component of chicken feed and is a major source of P in manure. Much of the P in corn is in a form called phytic acid, which chickens are unable to digest. Hence, the undigested P ends up in chicken manure, and chicken farmers also need to supplement the diet with P that is available to the chicken. If the P in phytic acid were made more available, it would therefore reduce the P in the manure, and it would also be possible to reduce supplemental P in the diet thereby reducing costs. Currently an enzyme, phytase, is added to the diet to improve phytic acid digestion in chickens. According to Saylor (2007), phytase use has led to a 23% reduction in P in chicken manure, although Smith et al. (2004) reported a more modest 10% reduction.

Another approach is to feed the chickens a low phytate corn that they can more easily digest. This could simplify diet preparation and perhaps reduce cost by lessening the need for dietary supplements. Raboy and Gerbasi (1996) developed a low phytate, high available P (HAP) corn in the 1990s. Saylor et al. (2001) reported reductions in manure phosphorus by 16–19% when HAP corn replaced "normal" corn in broiler diets. When both technologies (phytase and HAP corn) were incorporated into diets, reductions in manure P of up to 40% were realized. Chickens fed a HAP corn diet also have less dissolved (soluble) P in their litter, and the amount of soluble P in poultry litter applied to land is the most important factor in predicting P runoff that leads to pollution (Saylor et al., 2002; Smith et al., 2004). In a study with pigs, Baxter et al. (2003) found added phytase reduced P in manure 19% and HAP corn reduced it 17%, but again the greatest benefit was in combining the programs with a reduction of 40%. However, HAP corn currently has unacceptable yield drags and does not necessarily have other traits of interest to corn farmers such as resistance to important diseases (Raboy et al., 2001). Adding desired properties may require the use of genetic modification rather than conventional breeding used for current HAP development. Efforts at developing a better HAP corn using both techniques are ongoing.

If an acceptable HAP corn is developed, it would be important to know how consumers would respond. One possibility would be that consumers would be more interested in a chicken fed HAP corn if it was promoted as environmentally beneficial. This could also depend, however, on whether the feed was created using genetic modification (GM). Although many GM crops have been grown for years, studies have shown consumer reservations exist. Summaries of these studies are available in Costa-Font, Gil, and Traill (2008) and in a meta-analysis by Lusk et al. (2005), all showing reluctance on the part of consumers and lower acceptance of GM foods.

Fewer studies have examined consumer acceptance of GM-fed animals. Lusk, Roosen, and Fox (2003) showed U.S. consumers were willing to pay significantly more for beef from cattle not fed GM products. Bernard, Pesek, and Pan (2007) found consumers were less willing to purchase GM-fed chickens. Onyango, Nayga, and Schilling (2004) gained insight on demographic differences behind acceptance of GM-fed meat products, whereas Kaneko and Chern (2005) had consumers willing to pay approximately 28% more to avoid GM-fed salmon. Other studies such as Huffman et al. (2003) and Lusk et al. (2004) have examined consumer willingness to pay for GM foods after being given positive information, including environmental benefits. Although these suggest positive environmental messages can succeed, Cox, Evans, and Lease (2007) have noted that getting consumers interested in indirect benefits of products such as those for the environment can be difficult. Lastly, however, the authors were not aware of studies that were specific on the nature of the GM feed or focused on a potential environmental benefit from feed.

The main objective of this research was thus to determine if chicken breasts from chickens fed either GM or non-GM HAP corn would be acceptable in the marketplace and if consumers may be more willing to purchase such a chicken as a result of possible environmental benefits. A conjoint analysis mail survey was conducted of consumers around the Delmarva Peninsula.[1] The conjoint task contained two attributes: feed type and price. Feed type contained both GM and non-GM HAP to account for the potential concerns expressed, whereas conventional, Bt, and Roundup-ready corn were included to capture other likely feeds.

Survey and Data

For the mail survey, a random sample of 1500 consumers, balanced by location and gender, was purchased from USAData. Location was divided into three areas. The first consisted of counties in Delaware and eastern Maryland where the chicken industry is concentrated. According to the Delmarva Poultry Industry, Inc. (2007), this area used a yearly average of 72.4 million bushels of corn between 1996 and 2005 and in 2005, it produced 571 million broilers. By comparing it with national production for 2005 (National Agricultural Statistics Service, Agricultural Statistics Board,

[1] The Delmarva Peninsula consists of those parts of Delaware, Maryland, and Virginia between the Chesapeake Bay and the Atlantic Ocean.

2007), the region accounted for approximately 6.6% of U.S. broiler production. The second area consisted of counties in Maryland and Delaware on the Delmarva Peninsula that were outside the producing area but near enough to understand its prominence to the area. The third area consisted of counties outside the peninsula in nearby Maryland, Pennsylvania, and New Jersey that should be considered well removed from the production region. These areas were chosen to see if distance from the poultry industry would have an effect on consumer attitudes toward HAP corn. Specifically, these were included to see if a greater distance from the poultry farms would lower consumer interest in HAP corn. Each area was further balanced by gender under the hypothesis that it may have a significant effect. Before sending it out, the survey was pretested on various consumers while it and the accompanying information sheet were reviewed for accuracy by an expert in poultry nutrition and an expert in the impact of P pollution.

The survey was conducted in the spring of 2005 following the Dillman (2000) method.[2] First a postcard was sent announcing the survey. A week later, the survey was sent with a cover letter, information sheet, and a dollar bill as a token of appreciation. The information sheet was deemed necessary as a result of the somewhat technical nature of the issues involved. On one side it showed a map of the Delmarva Peninsula with a circle around the major chicken production area and brief descriptions of the problems caused by P pollution and a potential solution using HAP corn. The other side described the feed types used in the conjoint study. The survey can be divided into three sections involving questions on: 1) knowledge and concern about phosphorus pollution and GM food; 2) likelihood of purchasing chicken breasts from chickens fed with five types of feed at different price levels; and 3) demographics. For the key section (2), respondents were asked to "rate the likelihood you would purchase" each chicken profile on a scale labeled from 0 ("definitely not purchase") to 10 ("definitely purchase"). A reminder postcard was sent later, and finally, if needed, a second survey package was sent to those that had not responded.

After accounting for nondeliverable addresses, the overall response rate was 40.17% (585 of 1456) and the usable response rate was 36.06% (525 of 1456). Demographic information is given in Table 1. By comparing with the census, it was found the sample is older, more educated, and less diverse than the population.[3] To correct for any possible biases from the sample, the demographics for age, gender, income, education, and race were used as variables in the following conjoint model. This procedure allows for the effects of omitted, or underrepresented, variables to be revealed and no longer be a source of bias in the results (Dumouchel and Duncan, 1983).

Conjoint Design

Conjoint studies are a common and effective way to conduct marketing studies (Green and Srinivassan, 1990; Louviere, 1988). Among the methods to conduct conjoint studies, ratings-based was selected for this study. As is typical with conjoint, this method asks consumers to consider complete products and use models to estimate the influence of each attribute studied. Recently, researchers have used the ratings-based technique to investigate interest in biotech food labels (Harrison and Mclennon, 2004), livestock price insurance (Fields and Gillespie, 2008), and functional milk desserts (Ares, Giménez, and Gámbaro, 2009) among others.

Two attributes were included in the conjoint design: price and feed type. To begin, four prices were chosen covering a moderate range of prices of boneless chicken breast around the current market price. For feed type, five varieties were selected: 1) conventional; 2) Bt; 3) Roundup-ready; 4) non-GM HAP; and 5) GM

[2] The survey and accompanying materials are available by request from the authors or can be found on the project's web site.

[3] To calculate the census numbers, county-level data were used and weighted using the respective populations.

Table 1. Comparison of the Survey Sample with the Census Data of the Counties Surveyed in this Work as Collected by the U.S. Government (U.S. Census, 2000)

Demographic	Percent (%)	Census Percent (%)
18–25 years	2.77	18.13
25–34 years	11.30	16.77
35–44 years	14.08	20.49
45–54 years	24.25	17.29
55–59 years	13.46	6.67
60–64 years	9.56	4.90
Older than 65 years	24.46	15.75
Gender		
Male	50.46	48.47
Female	49.54	51.53
Education		
Less than high school	4.96	17.48
High school graduate	24.38	31.33
Some college	23.76	18.82
Associate degree	10.43	6.34
Bachelor degree	18.69	15.82
Graduate degree	17.66	10.18
Income		
Less than $10,000	4.25	7.64
$10,000–$14,999	5.37	4.95
$15,000–$24,999	8.51	10.69
$25,000–$34,999	9.63	11.59
$35,000–$49,999	19.59	16.09
$50,000–$74,999	20.72	21.39
$75,000–$99,999	14.33	12.57
Above $100,000	17.69	15.09
Race[a]		
White	83.65	73.53
Black	12.16	19.24
Other	4.19	8.34

[a] Percentages from the U.S. Census add to more than 100 because some individuals claim more than one race.

HAP. Conventional corn was the name given to varieties that were not GM and possessed no special attributes and was used as a control category. Bt and Roundup-ready corn were chosen because they are GM varieties in widespread use and possess qualities such as requiring less pesticide use than conventional varieties consumers may find of interest. Bt corn contains genes from the soil bacterium *Bacillus thuringiensis,* which is a naturally occurring insecticide that protects the plant from feeding by corn-boring insects such as the European Corn Borer. A possible environmental benefit in the eyes of consumers would be the resulting reduction in insecticide applications (Benbrook, 2004). Roundup-ready corn is resistant to the herbicide glyphosate (sold under the brand name Roundup). The herbicides used on these crops tend to be less toxic than would have been otherwise used, suggesting an environmental benefit in the minds of some consumers (Fernando-Cornejo and McBride, 2002). Non-GM and GM HAP corn were as discussed previously and the primary focus of the study. The complete descriptions as included in the survey can be found in the Appendix.[4]

Of interest for GM HAP corn in particular, and somewhat for Bt and Roundup-ready, was the contrast of a potential environmental benefit along with the potential disadvantage in the minds of some consumers of being GM. This created the possibility of tradeoffs and perhaps interactions between the type of feed and price. Similar interactions have been found previously in Halbrendt et al. (1994) between fat content and price. Because estimating these interactions increases the number of profiles needed, it was decided to set as fixed other possible attributes of chicken. A related issue then was how many product profiles each respondent should face. Halbrendt et al. (1994) suggested that consumers would be willing to evaluate at most 10. Therefore, two blocks of 10 were created and respondents assigned at random to each block.

Given that there are different numbers of levels in each factor, it is not easy to find an orthogonal design. Furthermore, according to Kuhfeld (2009), an efficient design needs to be not only close to orthogonal, but also balanced. Therefore, it was decided to use a D-optimal design. The D-optimality criterion maximizes the determinant of $X'X$ where X is the design matrix of the model. This is equivalent to minimizing the generalized variance of the parameter estimates (Atkinson and Donev, 1992). The D-optimality criterion is the most

[4] Wording across descriptions of corn variety alternatives is not perfectly parallel, which may have influenced results but which cannot be tested. We recommend that future studies of GM products use parallel wording to describe products being evaluated.

commonly used computer search criterion (SAS Institute Inc., 2003). Computations were done using the OPTEX procedure of SAS (SAS Institute Inc., 2003). The profiles are listed in Table 2.

Model and Hypotheses

Models of conjoint analysis are derived from standard consumer demand theory and utility maximization as discussed in Halbrendt, Bacon, and Pesek (1992) and Halbrendt et al. (1994). Here, specifically, consumers' likelihood to purchase was modeled as a function of the product attributes, demographics, and the interactions between the two. The interaction effects were vital to determine the role of demographics in consumer responses to the various feed types because a key goal was to determine how various types of consumers respond to the attributes. The specific approach is discussed subsequently.

As noted earlier, for each profile, consumers' likelihood to purchase was restricted between zero and 10, where zero meant definitely not purchase and 10 meant definitely purchase.

Table 2. Profiles for Conjoint Study

Block	Profile Number	Price per Pound	Feed
1	1	\$5.99	Bt corn
1	2	\$2.99	Roundup-Ready corn
1	3	\$4.49	Non-GM HAP corn
1	4	\$5.99	Roundup-Ready corn
1	5	\$2.99	Bt corn
1	6	\$1.49	Non-GM HAP corn
1	7	\$2.99	Conventional corn
1	8	\$5.99	Conventional corn
1	9	\$4.49	GM HAP corn
1	10	\$1.49	GM HAP corn
2	1	\$2.99	Non-GM HAP corn
2	2	\$5.99	GM HAP corn
2	3	\$1.49	Roundup-Ready corn
2	4	\$2.99	GM HAP corn
2	5	\$4.49	Roundup-Ready corn
2	6	\$5.99	Non-GM HAP corn
2	7	\$4.49	Conventional corn
2	8	\$1.49	Conventional corn
2	9	\$4.49	Bt corn
2	10	\$1.49	Bt corn

GM, genetically modified; HAP, high available phosphorus.

This response is a limited-dependent variable and ordinary least squares is not a suitable method of analysis. In general, either two-limit Tobit or ordered probit is used for analysis instead. Studies have shown that both lead to consistent results (Boyle et al., 2001; Harrison and Sambidi, 2004; Harrison, Stringer, and Priyawiwatkul, 2002). Concern has been expressed, however, with using the former on ratings data because the data are ordinal (Harrison, Gillespie, and Fields, 2005). Use of ordered probit, however depends on the parallel slopes assumption (Long, 1997, p. 141). There is a score test for this assumption (Long, 1997, p. 142). For this data set, the test had a chi-square statistic of 419.2 with 189 degrees of freedom and a p value < 0.0001. Therefore, the assumption was rejected, making ordered probit inappropriate.

A larger issue was the potential for heteroscedasticity. Tobit, probit, and similar models will produce inefficient estimates when heteroscedasticity exists (Haefele and Loomis, 2001). A model was fitted that estimated the variance as a function of the attributes and demographic variables similar to Bernard, Pesek, and Pan (2007) and Bernard, Zhang, and Gifford (2006).

For the two-limit Tobit model, it is assumed there exists a latent variable y^* representing each respondent's likelihood to purchase each profile (Rosett and Nelson, 1975). For example, a profile with a highly undesirable attribute such as a high price may well be given an internal negative value, which can only be observed as a zero rating. Thus, interest lies in this latent variable. The observed profile rating, y, is related to y^* by:

$$y_i = \begin{cases} 0 & \text{if } y_i^* < 0 \\ y_i^* = x_i\beta + \varepsilon_i & \text{if } 0 \leq y_i^* \leq 10 \\ 10 & \text{if } y_i^* > 10 \end{cases}$$

(1) with

$$\varepsilon_i \sim N(0, \sigma^2 \exp(z_i\gamma))$$

In this general form, x_i represents a vector of relevant independent variables, β is a vector of coefficients, and the subscript i refers to the ith respondent and profile. The error term, ε_i, is independent and normally distributed with mean zero and variance $\sigma^2(\exp(z_i\gamma))$, where z_i represents a second vector of relevant independent variables, γ is a second vector of coefficients, and σ^2 is the variance when $z_i\gamma$ is zero. In this framework, analysis can either be made based on each respondent's observed rating or on the latent variable (Long, 1997). Here the latent variable is examined because interest is in actual consumer preferences. The model was estimated using maximum likelihood through use of the QLIM procedure in SAS (SAS Institute Inc., 2003).

Hypotheses generated *a priori* were used to construct the initial variables of the vector *x*. The first was made with respect to the attributes. Price was expected to lower purchase likelihood for any of the chicken products. For the feed types, non-GM HAP was anticipated to be viewed the most favorably followed by conventional and GM HAP feed with the remaining feeds the least favorable. Feed type and price interactions were expected; however, likelihood ratio tests showed no evidence of these interactions and they were removed from the model.

It was hypothesized location might matter because there may be different amounts of concern depending on whether the chicken industry was located closely. Those closer may be more interested in the HAP solution to an issue in their area. From past studies, it was hypothesized that gender might have an effect. Baker and Burnham (2001) evaluated nine studies of GM acceptance and showed that women demonstrated a consistent tendency toward higher risk perception. Onyango, Nayga, and Schilling (2004) also showed that men are consistently more likely than women to accept beef from GM-fed cows. Education (high school or less vs. some college) was included because different levels of knowledge and training may affect attitudes. Kaneko and Chern (2005) reported that people with higher education had significantly lower willingness to pay for GM-fed salmon, but Baker and Burnham (2001) reviewed literature from the 1990s and found mixed effects for education level on GM food acceptance.

Higher levels of income were expected to lead to greater preferences toward more expensive but more desirable products, although mixed results are seen in past studies (Baker and Burnham, 2001). Attitudes toward new products could also be affected by age. Ethnicity such as black or other was included as a check on the diversity of the sample, although there was no expectation of differences. Location and all of the demographic variables were each also interacted with price, price squared, and feed type. To keep the model manageable, these variables and the interactions were tested for inclusion with likelihood ratio tests.[5] For the two continuous demographic variables, age and income, their square term and their interactions were also tested with likelihood ratio tests.

Lastly, previous studies generally assumed that variations did not exist across respondent demographics, and therefore the model error variance was assumed to be homoscedastic. Bernard, Zhang, and Gifford (2006) found that education and gender were sources of model heteroscedasticity. Based on Bernard, Pesek, and Pan (2007), it was expected that price would be part of the variance model in a quadratic functional form and would predict greater variability at the more extreme prices (high or low). It was hypothesized that any of the other attribute or demographic variables could influence the model error variance as could interactions between price and price squared with the demographic variables. Although it seemed likely these variables could have an effect, expected signs were uncertain. The variance part was fitted first because it could affect the means part of the model.

The final model was:

$$\begin{aligned} y_i^* = {} & \beta_0 + \beta_1 \text{Price}_i + \beta_2 \text{Bt}_i + \beta_3 \text{Roundup}_i \\ & + \beta_4 \text{NonGMHAP}_i + \beta_5 \text{GMHAP}_i \\ & + \beta_6 \text{Female}_i + \beta_7 \text{Female}_i * \text{Price}_i \\ & + \beta_8 \text{Age}_i + \beta_9 \text{Age}_i * \text{Bt}_i \\ & + \beta_{10} \text{Age}_i * \text{Roundup}_i \\ & + \beta_{11} \text{Age}_i * \text{NonGMHAP}_i \\ & + \beta_{12} \text{Age}_i * \text{GMHAP}_i + \beta_{13} \text{SomeColl}_i \\ & + \beta_{14} \text{SomeColl}_i * \text{Price}_i \\ & + \beta_{15} \text{AfricanAmer}_i \\ & + \beta_{16} \text{AfricanAmer}_i * \text{Price}_i \\ & + \beta_{17} \text{Income}_i + \beta_{18} \text{Income}_i^2 \\ & + \beta_{19} \text{ProdArea}_i + \beta_{20} \text{NearProd}_i \\ & + \beta_{21} \text{Block}_i + \varepsilon_i \end{aligned} \tag{2}$$

[5] Having children younger than 18 years was also considered because parents with children in this age group may be more concerned about what food the family consumes. However, this demographic was not significant when likelihood ratio tests were performed.

Table 3. Variable Names, Descriptions, and Descriptive Statistics[a]

Category/Variable Name	Definition
Rating (y)	Response variable ranging from 0 to 10 indicating willingness to purchase (mean response, 5.043; SD, 3.3008)
Price	Price per pound (mean price, \$3.74; SD, 1.6061)
Bt	1 if feed type is Bt corn and 0 otherwise (19.97% of responses)
Roundup	1 if feed type is Roundup-ready corn and 0 otherwise (19.94% of responses)
Non-GM HAP	1 if feed type is non-GM HAP corn and 0 otherwise (20.02% of responses)
GM HAP	1 if feed type is GM HAP corn and 0 otherwise (20.08% of responses)
	(Conventional is the reference level for all the feed type variables and is coded 0 for each of them [19.99% of responses])
Female[b]	1 if respondent is female and 0 if male
Age[b]	Age of respondent in years
Income[b]	Income in \$10,000s
Some college[b]	1 if respondent has some college education and 0 if they do not
AfricanAmer[b]	1 if respondent is black and 0 if they are not
ProdArea	1 if respondent lives in chicken production area and 0 otherwise (35.37% of responses)
NearProd	1 if respondent lives near chicken production area and 0 otherwise (36.70% of responses)
	(The reference level is when the respondent is not in or near the production area and is coded zero for each of the production area variables [27.93% of responses])
Block	1 if respondents completed the second block of profiles and 0 if they completed the first (49.53% of the responses are from the first block and the rest from the second)

[a] There were 3466 responses to all questions.
[b] See Table 1 for descriptive statistics.
GM, genetically modified; HAP, high available phosphorus; SD, standard deviation.

$$\text{with } \varepsilon_i \sim N\left(0,\sigma^2 \exp(z_i\gamma)\right) \text{ where}$$
$$z_i\gamma = \gamma_1 \text{Prod}_i + \gamma_2\text{NearProd}_i + \gamma_3\text{Female}_i$$

where the variables are as defined in Table 3 and ε_i is the error for the i^{th} respondent and profile.

Estimation for a heteroscedastic Tobit model is not as well behaved as for homoscedastic Tobit. In the latter, the likelihood function is uniquely maximized. For heteroscedastic Tobit, it is possible for the log likelihood function to have multiple local maxima. To help ensure that the true maximum was obtained, several convergence methods were used with the QLIM procedure of SAS (SAS Institute Inc., 2003).[6] Also for the model, it was necessary to be careful with scaling. Income was expressed in units of \$10,000 and age was expressed in units of 10. Age was converted back to years in the results.

[6] Results were also checked with LIMDEP (Greene, 2002). The two sets of results were in agreement.

Results and Discussion

Before turning to the model, some elements discovered from the first section of the survey on knowledge and opinions are worth noting. First, respondents were asked to rate their prior knowledge of GM foods, P pollution, and different types of GM feeds on a scale of 1 to 5 (1 indicating no knowledge and 5 being very familiar) with mean responses 2.02, 2.18, and 1.56, respectively. These low figures, particularly regarding GM products, show that consumers still have little understanding or awareness of this technology in the food system. Related to this, consumers were also asked to estimate the percentage of grocery items with GM ingredients on a 4-point scale by blocks of 25%. Most greatly underestimated this amount, placing the figure under 25%. This followed findings in such studies as Pew Initiative on Food and Biotechnology (2001, 2003) and Teisl et al. (2003). According to the Center for Food Safety

Table 4. Heteroscedastic Two-Limit Tobit Regression Results[a]

	Parameter	Estimate	Standard Error	p Value
Means				
	Intercept	10.4520	0.7874	< 0.0001
	Price	−0.7152	0.0842	< 0.0001
	Bt	−2.8156	0.8188	0.0006
	Roundup	−3.4447	0.8219	< 0.0001
	Non-GM HAP	−3.0901	0.8228	0.0002
	GM HAP	−4.2430	0.8202	< 0.0001
	Female	−1.0616	0.3457	0.0021
	Female*Price	0.2855	0.0842	0.0007
	Age	−0.0491	0.0101	< 0.0001
	Age*Bt	0.0491	0.0140	0.0005
	Age*Roundup	0.0537	0.0141	0.0001
	Age*Non-GM HAP	0.0702	0.0141	< 0.0001
	Age*GM HAP	0.0734	0.0141	< 0.0001
	SomeColl	1.2604	0.3816	0.0010
	SomeColl*Price	−0.4752	0.0918	< 0.0001
	AfricanAmer	−1.8642	0.5263	0.0004
	AfricanAmer*Price	0.4128	0.1276	0.0012
	Income	0.3402	0.0925	0.0002
	$Income^2$	−0.0194	0.0061	0.0013
	ProdArea	0.3246	0.1688	0.0545
	NearProd	−0.2961	0.1770	0.0944
	Block	−0.5290	0.1378	0.0001
Variance				
	Sigma	2.5741	0.0779	< 0.0001
	Female	0.4983	0.1003	< 0.0001
	ProdArea	−0.2216	0.1485	0.1356
	NearProd	0.2205	0.1266	0.0814

[a] While the individual tests for the coefficients of location are above 0.05, the omnibus test for location is significant both for means and variance.
GM, genetically modified; HAP, high available phosphorus.

(2009), it is estimated that close to 70% of processed food products in the United States contain GM ingredients. Also, despite the limited knowledge they professed, concern over P pollution rated 4.14 on a 5-point scale (5 being greatest concern). This suggested consumers should be interested in finding solutions. These factors should be kept in mind in understanding and interpreting the model results. Lastly worth examining were the statistics on the rating variable (y) itself. As seen in Table 3, the mean rating was very near the center of the 0–10 scale and the standard deviation over 3 demonstrated that responses covered a fair range of the scale. Both 0s and 10s were also observed, giving the scale full representation that should benefit the model.

Results of the model are reported in Table 4. The main focus of the results was on the likelihood to purchase chicken fed the different feed types. Note that because interactions with each feed type and age were significant, they need to be taken into account when interpreting the results for the feed types. Therefore, the best way to understand the relationships in purchase likelihood between the feed types was graphically, as displayed in Figure 1.[7]

Of most interest from the figure, given the objectives, were the two possible versions of

[7] The figure was created by holding the values of the other variables fixed. Changing the values of the fixed variables would raise or lower the lines but not alter the pattern of interaction.

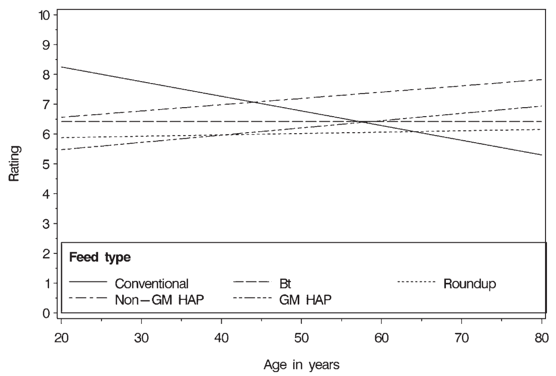

Figure 1. Age by Feed Type Interaction

HAP corn. Two things were immediately evident. One was that the likelihood to purchase rose steadily with age so that both were the most preferred options after age 60 years. Even more encouraging for the technology, non-GM HAP corn was the most preferred option for everyone older than age 45 years. This clear preference suggested that many consumers would be willing to purchase chicken fed such corn and aid against P pollution. It was, however, somewhat surprising given the potential benefits that non-GM HAP was not preferred by all groups. Non-GM HAP corn may not have been chosen by some because of uncertainty resulting from its still being in the research and development stage. Non-GM HAP corn might be more preferred in a study in which consumers are directly asked about the acceptability of this product without consideration of its stage of development. The other evident element was the constant advantage of a nearly 1-rating point for non-GM HAP corn over its GM complement. Except for older individuals, GM HAP was not even seen as a superior option to either of the other GM feeds. The discrepancy relative to non-GM HAP follows previous studies in which consumers have consistently noted they would avoid GM if given the option. Although this distinction might not be relevant unless labeling was required for the GM version, it should be something for seed developers to consider.

As just noted, the two other GM feeds, Roundup-ready and Bt, were preferred over GM HAP with younger consumers. Part of this may stem from these versions having already been well established in the marketplace as opposed to the novel aspect of GM HAP corn. For both, age was not an overly important factor with purchase likelihood fairly level. Bt corn, however, was noticeably preferred over Roundup-ready. This could reflect a perceived greater environmental benefit from Bt, which eliminates use of some pesticides, whereas Roundup-ready corn simply replaces them with less toxic versions. Especially when considered relative to the possible environmental benefits of the HAP corn varieties, Roundup-ready could understandably be viewed as the least obviously beneficial from a consumer perspective.

Conventional feed exhibited a much different pattern than the other feed types. Conventional feed was the most highly rated for young respondents but had the lowest likelihood to purchase among older respondents and was the least preferred option by those older than 65 years. Although this result seemed counterintuitive, it conformed with Onyango, Nayga, and Schilling (2004) who reported that people older than 55 years were significantly more willing to consume meat products from animals fed GM corn or soybeans. It may simply be that younger consumers, typically viewed as proponents of new technologies, prefer to keep technology out of food and relate more with current trends such as natural and organic. Further investigation of this age relationship may be warranted.

In terms of other findings from the model, price interacted with the demographic variables gender, race, and education. For gender, females were less price-sensitive than males following Bernard, Pesek, and Pan (2007). For race, a similar pattern was seen. Blacks were less sensitive to price increases. For education, it was seen that those with some college were more price-sensitive than those with a high school education or less. Although these demographics did not influence acceptance of feed types, the differing price sensitivities mean that the price adjustments mentioned depend on these demographic variables. Income exerted a modest positive effect on likelihood to purchase leveling off around an income of $100,000. This could be attributed to the fact that food is a smaller part of the budget as income increases so people can afford what they want. It could also be that increasing income is correlated somewhat with increasing concern for health and boneless chicken breast may be regarded as a healthier way to consume meat.

Next, the two location variables in the model were significant. Consumers in production areas had higher acceptance of the chicken products than those far from production, as would be anticipated. However, this accompanying closeness to potential P pollution issues did not lead to any extra interest in either version of HAP corn as might have been expected. It may be that water quality was an issue equally shared by respondents across the survey locations. Also unexpected was the lower acceptance of consumers near production areas relative to those further away. It could be that those near production, but less dependent on it, have some negative impressions and were exercising their right to choose alternatives and be contrary to the emphasis on chicken around them. Such an effect would dissipate with distance.

Finally, for the mean results, a significant block effect was found. This was difficult to understand because respondents were randomly assigned to blocks. To assess the impact of block, the model was rerun without it. Except for the intercept, none of the coefficients were substantially changed. Given this, the block effect was not viewed as detrimental to the results and interpretations.

Only two factors were relevant in the variance portion of the model: gender and location. It was found that females had more variability in purchase likelihood than males. For location, the near production area was more variable than the production area. This may be the result of varying attitudes toward the chicken industry in this area just next to it. Unlike Bernard, Pesek, and Pan (2007), price was not significant in this portion of the model.

Conclusion

As one source of P pollution, the chicken industry and other CAFOs face increasing regulation and scrutiny of their nutrient management. Because current practices to reduce the problem are expensive for all involved, the search for a better solution is ongoing. HAP corn, which has P in a form more digestible by chickens, could be a partial remedy. Development efforts include work using both traditional plant breeding and genetic modification techniques. Even with a viable product, however, the key to success will be consumer willingness to purchase chickens that have been fed this novel feed.

Overall, consumers appeared to support HAP corn, although purchase likelihood did vary significantly dependent on age. Older consumers had the highest preference for HAP corn and were more likely to purchase chicken fed it than those given any other feed covered in the study. The technology behind HAP corn did matter, however. HAP corn developed through traditional methods was preferred by a consistent and considerable margin over its GM counterpart. Younger consumers preferred non-GM HAP over any of the other feed types except for conventional. This suggested that such consumers were most interested in food technologies with strong potential environmental benefits.

Although the two other GM feed types examined, Roundup-ready and Bt corn, may also have some environmental benefits, they have not traditionally been promoted that way. Findings here suggest that may not be easy to do or necessary. Although only Bt corn came close to the purchase likelihood of non-GM HAP, and that was only for the youngest consumers, acceptance of these two feed types did not lag substantially behind the others. This could be viewed as good news for the industry because these feed types are commonly used. These results suggest that in the arguably unlikely event that labeling of GM feed was introduced, consumers would continue to be likely to purchase such chickens.

Although other demographics were investigated, no others were found to influence the purchase likelihood for the different feed types. Gender, race, and education level were found to interact with price, with females, blacks, and those with a high school education or less being less sensitive to price changes. This suggested consumer purchasing decisions adjust with price changes in a similar fashion for each feed type. Location was important but also failed to be a relevant factor with respect to feed type. Future research in other areas of the country, however, may be useful.

The primary benefit of this study was in demonstrating that HAP corn could be successful in terms of consumer acceptance. For specific recommendations, seed developers would be best served if they were able to produce a non-GM version of HAP corn. Of the nonconventional corn varieties, this had the highest purchase likelihood across all demographics. Greater effort would be required, however, to convince younger consumers to move away from chickens fed conventional corn. If developers can only manage a well-performing GM version of HAP corn, this could still be successful but more effort would be required in promotion.

Another benefit to the study was in realizing that consumers have concerns about P pollution and interest in assisting with a solution. Discovery of this interest in aiding the environment through their chicken purchases will assist marketers and food companies. Given the level of purchase likelihood expressed, producers may wish to consider labeling chicken fed HAP corn as a marketing tool, again, especially a non-GM version. A potential premium could offset a small yield drag if problems developing HAP corn were to persist. Finally, policymakers should consider these results as evidence of how solutions to environmental problems may be aided by involving the consumer in the process. If successful in this case with the support of consumers, waterways could be improved.

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Appendix. Description and Explanation of Feed Types Accompanying Survey

Term	Definition/Explanation
GM feeds	Genetic modification is the process where living organisms (plants, animals, bacteria) have had genes altered or inserted from other species. In this survey, we study chickens fed with a variety of GM corn. The three varieties of GM corn feed considered in this survey are:
1) GM HAP corn	A genetically modified corn with increased availability of phosphorous. It benefits the environment by reducing phosphorous in poultry manure, which is expected to improve water quality. This variety of corn is still in the research and development stage.
2) Roundup-ready corn	Roundup-ready corn is genetically modified to be tolerant to the herbicide Roundup. This corn provides flexibility for farmers. It reduces the use of more toxic pesticides and also minimizes tillage use, reducing soil erosion.
3) Bt corn	Bt corn is genetically modified by inserting a specific gene to produce a protein that protects the plant from feeding by corn boring insects. It also requires less pesticide use.
Nongenetically modified (GM)feeds	Non-GM feed does not contain any DNA insertion or manipulation, and is not produced using any GM ingredients. The two varieties of non-GM corn feed considered in this survey are:
1) Conventional corn	Conventional corn is not genetically modified and is typically grown using synthetic chemicals and fertilizers to increase crop yields and herbicides and pesticides to protect it from weeds and insects.
2) Non-GM HAP corn	A non-GM corn with increased availability of phosphorous. It benefits the environment by reducing phosphorous in poultry manure, which is expected to improve water quality. This variety of corn is still in the research and development stage.

HAP, high available phosphorus.