An Analysis of Consumer Preferences for Value-Added Seafood Products Derived from Crawfish

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Conjoint analysis is used to evaluate consumer preferences for three consumer-ready products derived from crawfish. Utility functions are estimated using two-limit tobit and ordered probit models. The results show women prefer a baked nugget or popper type product, whereas 35- to 44-year-old men prefer a microwavable nugget or patty type product. The results also show little difference between part-worth estimates or predicted rankings for the tobit and ordered probit models, implying the results are not sensitive to assumptions regarding the ordinal and cardinal nature of respondent preferences.

Key Words: conjoint analysis, consumer-ready products, crawfish, ordered probit, two-limit tobit

Mince-based foods are among the several new forms of value-added seafood available to U.S. consumers. For instance, the U.S. seafood industry produced some 18,358 metric tons of fish sticks, fish nuggets, seafood patties, and similar products in 2000. The United States also imported some 6,011 metric tons of mince-based seafood during this same year [U.S. Department of Commerce/National Oceanic and Atmospheric Administration (USDC/NOAA), 2001]. These products are manufactured using mechanical meat-shell separators to extract additional meat from the by-products of traditional processing or the further processing of undersized animals. However, despite growing consumer acceptance of mince-based products, processing of by-products and undersized animals is underutilized by many seafood industries.

The U.S. crawfish industry is one example of the underutilization problem. Most crawfish produced in the United States are harvested from rivers and natural estuaries in southern Louisiana, or they are farm-raised in shallow ponds as part of a double-crop production system with rice. After harvesting, crawfish are sorted into three or four quality grades. The larger grades are either exported to European markets, sold on local live markets, or hand peeled for their tail meat and sold on domestic markets. The smallest grades are typically not suitable for either processing or sale on live markets. These animals are by-products of the grading process and usually priced well below the current market price, or they are simply discarded by the processing plant. The smaller crawfish account for as much as 20% of total production in some years.

Crawfish production was about 18.5 million pounds during the 2000 crop year, which represents approximately $31.7 million in gross farm value (Louisiana State University Agricultural Center, 2000). Moreover, traditional processing of larger crawfish usually results in recovery of only about 15% edible tail meat, leaving some 85% of the animal's weight for further processing (Özayan, 1997).

Numerous studies have demonstrated the technical feasibility of processing by-products into edible minced meat. Lee, Meyers, and Godber (1993) showed that edible minced meat could be extracted from blue crab processing by-products using mechanical meat-shell (or meat-bone) separators. A study by Gates and Parker (1992) also reported the

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feasibility of deriving food-grade mince from blue crab processing by-products. Pigott (1994) summarized research on the further processing of fish frames into mince meat. While these studies clearly confirm the technical feasibility of minced meat seafood, little research has been conducted on the market potential for these products.

A few studies have examined the markets for traditional crawfish products. For instance, Yen, Dellenbarger, and Schupp (1995) analyzed the factors that contributed to a decline in crawfish production in 1990. Based on their conclusions, declines in production resulted from decreased demand for crawfish, which was caused by economic recession and lower priced substitute products. Their study emphasized the need to develop new markets for crawfish. Although the analysis contributed to the literature regarding identification of the factors affecting demand for traditional crawfish, most research to date has failed to examine markets for new value-added products derived from crawfish mince.

A notable exception is a study by Harrison, Özayan, and Meyers (1998), which focused on analyzing the acceptance of two value-added seafood products derived from crawfish minced meat. Conjoint analysis was used to examine the preferences of restaurant managers for two intermediate mince-based seafood products in the southern region of the United States. Soup base and crawfish stuffing products were evaluated using focus group interviews and a mail survey. Focus groups consisted of seafood processors, seafood wholesalers, distributors, seafood restaurant managers, and chefs. Product profiles consisted of three attributes: price (30%, 50%, and 70% of market tail meat price), form (fresh, frozen, and dehydrated), and flavor (mild and concentrated). A fresh product form was found to be the most important attribute among restaurant managers, followed by a discount price relative to the price of crawfish tail meat. Along with attribute optimization, a potential market was found among restaurants with annual sales between $500,000 and $2 million.

The present study builds upon the earlier work of Harrison, Özayan, and Meyers (1998), but differs in several respects. First, we analyze three previously untested consumer-ready products derived from crawfish mince, whereas Harrison, Özayan, and Meyers examined only intermediate product forms. Second, the present analysis is based on new data collected during personal interviews with consumers in the study area. Finally, the application of conjoint analysis differs significantly from the earlier study. For instance, we use individual-level preference functions to analyze three distinct market segments. Moreover, aggregate-level models are estimated using two-limit tobit and ordered probit models. These models are then used to examine how alternate assumptions regarding the ordinal and cardinal properties of consumer preferences affect part-worth estimates.

The primary objective of this study is to evaluate the market potential of three consumer-ready products derived from underutilized crawfish—nuggets, patties, and crawfish poppers. A crawfish nugget is a small finger-food, similar in shape to other popular nuggets composed of chicken or fish. The crawfish patty is a round product, approximately 1/4 inch thick, and similar to the popular crab cake. Crawfish poppers are bite-size pieces shaped to resemble crawfish tails.

Methodology

Conjoint analysis (CA) is widely used in market research because it allows the total utility of a multidimensional product to be decomposed into part-worth utilities for each attribute of the product. CA is useful because it provides a technique for measuring and evaluating the relative importance of each characteristic of a hypothetical product. It also provides a means to determine the preferred combination of product characteristics for specific market segments.

Numerous studies have used conjoint analysis to examine buyer or user preferences. As previously noted, Harrison, Özayan, and Meyers (1998) used CA to analyze crawfish base and stuffing products. Stevens, Barrett, and Willis (1997) examined the groundwater protection programs for a number of western Massachusetts towns using conjoint analysis. Conjoint analysis was employed by Huang and Fu (1995) to assess individual consumer preferences of various Chinese sausage attributes. Yoo and Ohta (1995) applied conjoint analysis to determine the optimal pricing and product planning for automobiles.

Halbrendt, Wirth, and Vaughn (1991) applied CA to determine utility values for nine different hybrid striped bass products. They also added variables for market level and attribute-market interactions to allow for inter-industry comparisons. Bacon, Halbrendt, and Toensmeyer (1991) also used CA to analyze consumer preferences for farm-raised seafood products. The conjoint approach was used by Anderson and Bettencourt (1993) to model preferences in the New England market for fresh and frozen salmon. More recently, Holland and Wessells (1998) applied CA to evaluate consumer preferences for fresh salmon in the mid-Atlantic United States.

There are three steps involved in conjoint analysis. First, relevant product attributes and their respective levels are defined in a manner consistent with the consumer's understanding of the product. Second, an appropriate experimental design and survey instrument is constructed to collect the conjoint data. At this stage, a set of hypothetical products is defined by combining product attributes at various levels. Subjects are then asked to evaluate their overall preference for selected hypothetical products. The final step of CA involves selecting the appropriate model for estimating part-worth utilities.

Selection of Product Attributes

An exploratory survey consisting of 10 local grocery stores and national supermarket chains in south Louisiana was performed to identify the most relevant attributes and levels for the crawfish prototype products. Information was collected pertaining to the characteristics of existing mince-based products similar in design to the prototype products. These characteristics included product form, product size, package type and size, number of units in the pack, recommended cooking methods, and product price.

Results of the survey revealed a wide range of breaded and battered chicken nuggets and fish sticks, shrimp poppers, and crab mince-based products. The most common forms were breaded nuggets, fish and crab patties, and shrimp poppers. Package sizes varied from 12 to 48 pieces per pack, and the reheating methods ranged from baking, microwaving, to frying. Prices were somewhat variable across stores and product forms, with an average price of 20¢ per ounce and a range from 10¢ to 50¢ per ounce. Attributes were also pre-tested with a small group of 12 subjects to determine if they were expressed in a manner consistent with the consumer's understanding of these types of products.

Based on results from the grocery store survey and the questionnaire pre-tests, the following attribute levels were selected for the conjoint design. They include three breaded product forms consisting of crawfish mince-based nuggets, patties, and poppers; three package sizes consisting of a 12-unit, a 24-unit, and a 48-unit pack; three reheating methods expressed as a baked, fried, or microwaved product; and three price levels set at 10¢, 20¢, and 50¢ per ounce.

Experimental Design and Data Collection

Four three-level attributes were selected for this study: product form, package size, reheating method, and price. A full factorial design would involve 81 ($3 \times 3 \times 3 \times 3$) hypothetical product combinations. Because subjects would have difficulty rating all 81 product profiles, a fractional factorial design was used to reduce the number of profiles to nine product combinations.

The Bretton-Clark (1988) Conjoint Designer program was used to select the experimental design. This program produces a subset of hypothetical products based on the attribute levels provided by the researcher. More specifically, the program minimizes the confounding of attribute main effects by selecting a subsample of orthogonal product combinations. The primary advantage of a fractional design is that the number of hypothetical products a subject must evaluate is greatly reduced, while enough information is retained to estimate all part-worth main effects. A disadvantage of the fractional design is that interaction part-worth effects are not usually recoverable. However, this may not be a significant restriction, as previous research has found attribute interactions to have negligible effects on total utility (Harrison, Özayan, and Meyers, 1998).

The questionnaire used to collect the conjoint data contained two sections. The first involved a series of questions pertaining to the socioeconomic and demographic makeup of the respondents, and included questions concerning age, household income, education level, and marital status. The second section of the questionnaire contained the hypothetical product profiles, which were arranged on a single page as nine distinct product profiles.

The questionnaire was administered using a personal interview method, where small groups of respondents were allowed to visually inspect the three product forms in combination with the package sizes, reheat methods, and price (as prescribed by the fractional design). After careful examination, respondents were asked to rate each profile based on an interval rating scale of 1 to 10, where 1 represents the least-preferred product and 10 represents the most-preferred product.

The survey took place over a period of four days and included three one-hour sessions per day. The sample was composed of 111 consumers participating in a food science sensory panel test of crawfish mince-based products. To avoid biasing the respondent's preference for a particular product form, the survey was conducted prior to the sensory panel tests.

Estimation of Part-Worth Utilities

The most commonly used methods for coding consumer preferences in the CA literature are rank order (RO) and interval rating (IR) scales (Harrison, Gillespie, and Fields, 2001). The primary difference between these methods is associated with the restriction each places on the metric and nonmetric properties of the subject's utility function.

The RO method requires subjects to unambiguously rank all hypothetical product choices, which provides a nonmetric ordering of respondent preferences. The IR method allows subjects to express order, indifference, and intensity across product choices, a feature allowing both metric and nonmetric properties of utility to be elicited. Since RO scaling offers no provision for subjects to express indifference or intensity across product attributes, information is lost if respondents wish to express cardinal properties in their preference ordering.

The method used to scale preferences also has implications regarding the model used to estimate part-worth values. If RO scaling is used, then the dependent variable (i.e., the RO scale) is clearly ordinal, and ordered regression models such as ordered probit or logit are best suited for estimating conjoint parameters. However, model selection becomes less clear if the IR method is used. A number of studies have used IR scaling in combination with linear regression (LR) to estimate part-worth parameters (e.g., Halbrendt, Wirth, and Vaughn, 1991; Prentice and Benell, 1992; Harrison, Özayan, and Meyers, 1998; Stevens, Barrett, and Willis, 1997; and Roe, Boyle, and Teisl, 1996). These studies implicitly assume utility is cardinal (i.e., the IR scale is continuous). Unfortunately, even if utility is cardinal, the IR scale is limited by an upper and lower bound. Therefore, LR models yield truncated residuals and asymptotically biased parameters. However, the censored nature of the scale can be accounted for with a two-limit tobit (TLT) model, which corrects for censoring and retains cardinal information between the upper and lower bounds of the scale.

Other researchers argue that ordered probit or logit (OLP) models are best suited for conjoint estimation, since IR scales are measured as discrete variables (MacKenzie, 1990, 1993; Sy et al., 1997; Holland and Wessells, 1998). However, a disadvantage of OLP models is they assume preferences are ordinal, and thus fail to account for cardinal information if respondents express intensity in their responses. Another disadvantage of OLP models is they require substantially more degrees of freedom to estimate part-worth parameters. This makes analysis of part-worth values at the individual level impossible in most cases, which may be a serious restriction if study objectives include market segmentation.

Several studies have examined the cardinal versus ordinal issue associated with eliciting consumer preferences. In separate studies, MacKenzie (1993); Roe, Boyle, and Teisl (1996); and Stevens, Barrett, and Willis (1997) analyzed the effects of treating an interval rating scale as a cardinal measure of consumer preferences. While each of these studies compare parameter estimates and the predictability of tobit with ordered probit and logit models, they have produced mixed results.

For instance, MacKenzie (1993) concluded rating scales do capture intensity (i.e., cardinality) of respondent preferences. The other two studies reported that elicitation and estimation assuming ordinal preferences is theoretically more appealing, and found empirical evidence to suggest ordered probability models are better frameworks for analysis.

More recently, Boyle et al. (2001) examined the issue of cardinality by analyzing both rating and ranking scales for independent subsamples of respondents. They observed that tobit and ordered probit models result in the same attributes being significant and having the same sign. Boyle et al. concluded that assumptions regarding ordinal/cardinal preferences were irrelevant for their sample. However, they did not examine how well the models predicted preference ordering.

In order to address these methodological issues, TLT and ordered probit (OP) models are used in this analysis. Ordered probit was selected over ordered logit because it assumes normally distributed errors, which is consistent with normality assumptions of the TLT model. Hence, a secondary objective of our study is to examine how cardinal and ordinal assumptions regarding consumer preferences affect part-worth estimates. Two-limit tobit allows for individual-level models to be estimated, and accounts for cardinal information that may be expressed in respondent preferences. The OP model requires too many degrees of freedom to estimate individual-level models, but it is consistent with ordinal properties of consumer preferences.

Model Specification

Both TLT and OP models assume a limited dependent variable framework. Moreover, in conjoint measurement, a consumer's utility is assumed to be a linear function of selected product attributes. The structural equation for both models is specified as follows:

$$(1)\quad U_i^* = \boldsymbol{\beta}\mathbf{X} + \varepsilon_i,$$

where U_i^* is a latent variable representing the *i*th individual's total utility for a particular combination of product attributes, $\boldsymbol{\beta}$ is a row vector of part-worth and marginal utility effects, $\mathbf{X}$ is a column vector of product attributes, and ε_i is the error term.

The attribute vector **X** contains a series of dummy variables defined as follows: $X_1 = 1$ and $X_2 = 0$ represent the patty form; $X_1 = 0$ and $X_2 = 1$ represent the nugget form; $X_1 = -1$ and $X_2 = -1$ represent the popper form; $X_3 = 1$ and $X_4 = 0$ represent the fried reheating method; $X_3 = 0$ and $X_4 = 1$ represent the baked reheating method; and $X_3 = -1$ and $X_4 = -1$ represent the microwave reheating method. The vector **X** also contains price and package size attributes, which are treated as continuous variables in the model.

The primary assumption of latent variable models is that IR scales provide only limited information about a consumer's true preferences (U^*). The primary difference between the TLT and OP models is related to the restriction each places on the measurement of U^*. The TLT model assumes the following relationship between the IR scale and U^*:

$$(2)\quad IR_i = \begin{cases} 1 & \text{if } U_i^* \le 1, \\ U^* & \text{if } 1 < U_i^* < 10, \\ 10 & \text{if } 10 \le U_i^*, \end{cases}$$

where IR_i is the observed value for the *i*th respondent, and U^* is as previously defined. The TLT model assumes true preferences are censored by the upper and lower values of the scale. This implies some of the respondents who chose a value of 1 or 10 when rating a product would have assigned lower or higher values to these products if allowed to do so by experimental conditions. The TLT model also assumes IR_i is continuous (i.e., cardinal) between upper and lower bounds of the scale.

The OP model likewise assumes U^* is censored, but differs from the TLT model as follows:

$$(3)\quad IR_i = \begin{cases} 1 & \text{if } U_i^* \le 1, \\ 2 & \text{if } 1 < U_i^* \le \mu_1, \\ 3 & \text{if } \mu_1 < U_i^* \le \mu_2, \\ \vdots & \\ 10 & \text{if } \mu_9 \le U_i^*, \end{cases}$$

where the μ's are unknown "thresholds" that determine the ordinal intervals of the scale, and all other variables are as previously defined. Since the μ's are unrestricted parameters, there is no significance to the unit distances associated with the discrete values of the scale (Greene, 2000). Note that since the TLT model assumes the μ's are known, the model requires fewer degrees of freedom to estimate part-worth values. The TLT model assumes ε_i is normally distributed with zero mean and variance equal to σ^2, where σ^2 is estimated along with other model parameters (Long, 1997). Ordered probit also assumes ε_i is normally distributed with zero mean, but sets σ^2 equal to one. This restriction is necessary because all values of U^* are assumed to be censored in the OP model (Long, 1997).

Analysis of Results

The analysis is divided into three stages. First, the experimental design resulted in nine observations for each subject. This provides enough degrees of freedom to estimate preference functions for each respondent in the sample (assuming the TLT specification). Once TLT part-worth values are estimated, Ward's clustering method is used to segment respondents into three distinct groups based on similarities of their preference functions. Ward's method was selected because it minimizes the sum of the squared distances between part-worth values for individuals within each segment, while simultaneously maximizing the squared distances of part-worth values between segments. Stated another way, the homogeneity of respondent preferences is maximized within a particular market segment, while the heterogeneity of respondent preferences is maximized across the three market segments. Three market segments were selected because product attributes were specified at three levels.

The second stage of the analysis involves using the OP and TLT models to estimate part-worth values for the entire sample and the three market

Table 1. Two-Limit Tobit and Ordered Probit Part-Worth Estimates for Mince-Based Crawfish Products: Total Sample

	Two-Limit Tobit		Ordered Probit		
Attribute	β	β/σ	β	μ	
Constant	6.03*	1.92*	1.84*	μ_1	0.40*
	(22.74)	(22.74)	(18.28)		(9.33)
Patty	!0.42*	!0.13*	!0.13*	μ_2	0.72*
	(!2.92)	(!2.93)	(!2.90)		(13.99)
Nugget	0.85*	0.27*	0.27*	μ_3	1.02*
	(5.95)	(5.95)	(5.53)		(18.06)
Popper	!0.43*	!0.14*	!0.14*	μ_4	1.32*
	(!3.01)	(!3.01)	(!3.05)		(21.99)
Fried Reheat	!0.38*	!0.12*	!0.12*	μ_5	1.59*
	(!2.64)	(!2.64)	(!2.65)		(25.33)
Baked Reheat	0.40*	0.13*	0.13*	μ_6	1.93*
	(2.81)	(2.81)	(2.79)		(29.13)
Micro Reheat	!0.02	!0.008	!0.01	μ_7	2.33*
	(!0.17)	(!0.18)	(!0.22)		(32.76)
Price [a]	!6.07*	!1.94*	!1.95*	μ_8	2.82*
	(!10.19)	(!10.19)	(!9.88)		(35.93)
Package Size [a]	0.01	0.003	0.003		
	(1.51)	(1.51)	(1.45)		
σ	3.13	1.0	1.0		
χ^2 LogL	142.43*		142.24*		
MSRC [b]	0.39		0.37		
WMP [c]	0.97		NA		

Notes: An asterisk (*) denotes the coefficient is different from zero at the α = 0.05 level of significance. Numbers in parentheses are the ratios of the coefficients to their standard errors.

[a] The coefficients for price and package size are expressed as marginal utilities since they are treated as quantitative variables in the model.

[b] MSRC is the median value for Spearman rank correlation coefficients. Spearman rank correlation coefficients are calculated between actual and predicted rankings for each respondent in the sample.

[c] WMP is the Wilcoxin matched pairs statistic derived from the Wilcoxin signed rank (WSR) test, which tests the null hypothesis that differences between SRC values for TLT and OP models are equal to zero. The statistic is a *Z*-value which is compared to the 1.96 critical value at the α = 0.05 level of significance.

segments. Aggregate-level TLT and OP models are evaluated by comparing consistency of parameter estimates, statistical significance of parameter estimates, and the predictive validity of choice rankings. In the third stage, predictive validity is analyzed by comparing actual ranks of hypothetical products with the predicted ranks of the two models.

Discussion of Results

Parameter estimates and diagnostic statistics for the total sample are presented in table 1. Unless otherwise noted, the significance level selected for the analysis is α = 0.05. In order to compare part-worth values across TLT and OP models, the TLT estimates are standardized by dividing through by the estimate for σ. The log-likelihood χ^2 statistics are significant for both models, indicating the part-worth estimates are jointly different from zero. All part-worth estimates for the TLT and OP models are also significant, with the exception of those associated with the microwave reheating method and the package size estimates. Moreover, the signs on all part-worth estimates are consistent across both models. The magnitudes of the standardized TLT part-worth values are also very similar to their OP counterparts. In fact, several of the standardized coefficients are nearly identical to those of the OP model. These results indicate the partial effects on the estimated utility index functions (U^*) are consistent across the TLT and OP models.

The predicted values for the two models are compared using a technique discussed by Roe, Boyle, and Teisl (1996). The technique involves using Spearman rank correlation (SRC) coefficients and Wilcoxin signed rank (WSR) tests to examine the in-sample correlation between observed and predicted values for each respondent. Spearman rank correlation coefficients are used because the OP model provides ordinal predicted values. The coefficients are constructed by assigning ranks to the predicted and observed values for each individual in the sample. Once predicted and observed values for the two models are ranked, Spearman correlation coefficients are calculated using these product rankings (Zar, 1984, p. 318).

After SRC coefficients are calculated, the Wilcoxin matched pairs (WMP) statistic is used to test the null hypothesis that SRC coefficients are statistically different across the TLT and OP models. The WSR test calculates the absolute difference between each respondent's TLT and OP Spearman coefficients, ranks the absolute values across the entire sample population, assigns the sign of the original difference to the rank, and then sums the ranks (Roe, Boyle, and Teisl, 1996, p. 156).

The median values for the SRC coefficients (MSRC), and the WMP test statistics are also reported in table 1. The median SRC values for the TLT and OP models are 0.39 and 0.37, respectively. The WMP critical value indicates the null hypothesis of equal SRC coefficients across model predictions cannot be rejected at the $\alpha = 0.05$ level of significance. Therefore, we find no significant difference between models with regard to predicting the ordinal rankings of the hypothetical products.

The signs and relative magnitudes of the part-worth estimates provide information regarding the decomposition of the average respondent's preferences for the selected product attributes. For instance, the part-worth values for the nugget product and the baked reheat method are both positive and significantly different from zero. This finding indicates that presence of both these attribute levels increases the average respondent's total utility. In contrast, the least preferred levels are the patty and popper products and the fried reheating method, as shown by negative part-worth values for these attribute levels.

As expected, price is inversely related to the average respondent's total utility, and thus higher prices decrease utility. The coefficient for the microwave method is not significant, suggesting the average respondent regards this type of reheating method as unimportant. This finding is somewhat surprising, since convenience is believed to be an important factor in the purchase decisions of U.S. consumers.

Wald tests are used to determine if part-worth estimates for product-form attribute levels and reheat-method attribute levels are statistically different from one another (refer to footnote to table 2). The Wald statistics are reported in table 2. The tests show that part-worth estimates for the nugget are statistically different from both popper and patty forms, indicating the nugget is the preferred product type. In addition, the baked and fried reheating methods are statistically different from each other, revealing respondents' preferred method for reheating is baking.

The Wald tests also show no statistical difference between the popper and patty product types, or between the fried and microwave reheating methods. Hence, the analysis failed to distinguish between these attribute levels. Wald tests are also consistent across the TLT and OP models.

Parameter estimates and diagnostic statistics for the three market segments are presented in table 3. A comparison of the parameter estimates shows that signs, significance levels, and magnitudes of the part-worth values are generally consistent across the TLT and OP models. Moreover, the log-likelihood statistics are significant, indicating part-worth estimates for both models are jointly different from zero. The MSRC and WMP statistics for segments I and III also show that predicted rankings are not significantly different across the two models. However, the WSR test shows product rankings are statistically different for segment II, with the OP model providing a slightly higher median value. Therefore, there is some evidence to suggest ordinal-based models are more appropriate for this segment.

With the exception of the package size coefficient, all part-worth estimates for market segment I are statistically different from zero. Based on our results, consumers in this segment have a preference for the nugget and popper product forms. This is shown by positive part-worth values for the two product forms, with slightly higher values corresponding to the nugget product types for both TLT and OP models (table 3). However, the Wald tests show the nugget and popper product types are not statistically different from each other (table 2). Therefore, there is no uniquely preferred product type for segment I. In contrast, the negative signs on the patty coefficients indicate consumers in this group expressed disutility associated with this product form. Moreover, the Wald tests show the patty is statistically different from both the nugget and popper products, implying the patty is the least preferred product type.

Table 2. Results of Wald Tests for Differences in Selected Part-Worth Estimates: Two-Limit Tobit and Ordered Probit Models

TWO-LIMIT TOBIT						ORDERED PROBIT					
Total Sample						**Total Sample**					
Product Form			Reheat Method			Product Form			Reheat Method		
	Patty	Nugget		Fried	Baked		Patty	Nugget		Fried	Baked
Nugget	!1.27*		Baked	!0.78*		Nugget	!0.40*		Baked	!0.25*	
	(!5.12)			(!3.14)			(!4.86)			(!3.12)	
Popper	0.01	1.28*	Micro	!0.35	0.42	Popper	0.007	0.41*	Micro	!0.11	0.14
	(0.05)	(5.18)		(!1.43)	(1.72)		(0.089)	(4.95)		(!1.44)	(1.76)
Segment I						**Segment I**					
Product Form			Reheat Method			Product Form			Reheat Method		
	Patty	Nugget		Fried	Baked		Patty	Nugget		Fried	Baked
Nugget	!3.48*		Baked	!0.48		Nugget	!1.32*		Baked	!0.18	
	(!8.60)			(!1.19)			(!7.74)			(!1.09)	
Popper	!3.36*	0.12	Micro	1.89*	2.36*	Popper	!1.27*	0.05	Micro	0.73*	0.91*
	(!8.32)	(0.29)		(4.68)	(5.88)		(!7.49)	(0.29)		(4.50)	(5.27)
Segment II						**Segment II**					
Product Form			Reheat Method			Product Form			Reheat Method		
	Patty	Nugget		Fried	Baked		Patty	Nugget		Fried	Baked
Nugget	!0.82		Baked	!0.70		Nugget	!0.29		Baked	!0.25	
	(!2.02)			(!1.73)			(!1.96)			(!1.70)	
Popper	!0.32	0.50	Micro	!0.22	0.48	Popper	!0.12	0.17	Micro	!0.08	0.17
	(!0.79)	(1.24)		(!0.54)	(1.19)		(!0.83)	(1.34)		(!0.59)	(1.14)
Segment III						**Segment III**					
Product Form			Reheat Method			Product Form			Reheat Method		
	Patty	Nugget		Fried	Baked		Patty	Nugget		Fried	Baked
Nugget	!0.10		Baked	!0.98*		Nugget	!0.03		Baked	!0.36*	
	(!0.30)			(!2.91)			(!0.27)			(!2.86)	
Popper	2.47*	2.57*	Micro	!1.88*	!0.90*	Popper	0.90*	0.93*	Micro	!0.69*	!0.32
	(7.34)	(7.66)		(!5.60)	(!2.69)		(7.00)	(6.96)		(!5.59)	(!2.42)

Notes: The Wald statistic is used to test the following null hypothesis: H_0: β_i ! β_j = 0, where β_i and β_j are selected part-worth estimates (i … j). The Wald statistic (W) is distributed as chi-squared with one degree of freedom, and is calculated as follows (Long, 1997, p. 93):

$$W \;'\; \frac{(\beta_i \,\&\, \beta_j)^2}{\mathrm{Var}(\beta_i) \,\%\, \mathrm{Var}(\beta_j) \,\&\, 2\mathrm{Cov}(\beta_i, \beta_j)} .$$

Coefficients are calculated as β_i ! β_j, where i … j. Numbers in parentheses are the Wald statistics (W). An asterisk (*) denotes the coefficient is different from zero at the α = 0.05 level of significance.

Regarding the reheating method attribute levels, both the fried and baked methods are associated with positive part-worth values. While the baked method is associated with a higher part-worth value relative to the fried product, the Wald tests show this difference is not significant. On the other hand, the microwave reheating method is significantly different from the fried and baked methods.

Results for market segment III are also presented in tables 2 and 3. All part-worth estimates are significant, with the exception of the baked reheating method and the package size coefficients (table 3). The average consumer in this group preferred the patty and nugget product forms, as reported by positive part-worth values (table 3). The magnitude of the nugget part-worth is slightly higher, but this difference is not statistically significant according to the Wald tests (table 2). Consequently, the analysis is unable to distinguish between the two preferred product forms. Hence, both patty and nugget products would be acceptable to the average consumer in this segment. A negative part-worth value for the popper product, and corresponding Wald tests showing the popper product type is not significantly different from either the patty or the nugget form, reveals the popper is the least preferred product by consumers in this group.

Other contrasts between consumers in the first and third segments can be traced to the reheating method. For instance, individuals in the first segment prefer

Table 3. Two-Limit Tobit and Ordered Probit Part-Worth Estimates for Mince-Based Crawfish Products: Three Market Segments

	Segment I					Segment II					Segment III				
	Two-Limit Tobit		Ordered Probit			Two-Limit Tobit		Ordered Probit			Two-Limit Tobit		Ordered Probit		
Attribute	β	β/σ	β		μ	β	β/σ	β		μ	β	β/σ	β		μ
Constant	5.30*	2.00*	1.89*	μ_1	0.39*	7.66*	2.68*	2.75*	μ_1	0.59*	5.20*	1.89*	1.72*	μ_1	0.38*
	(12.24)	(12.24)	(9.20)		(4.45)	(19.94)	(17.63)	(14.20)		(6.28)	(14.46)	(14.46)	(11.09)		(5.46)
Patty	!2.28*	!0.86*	!0.87*	μ_2	0.78*	!0.38	!0.13	!0.13	μ_2	0.99*	0.79*	0.29*	0.29*	μ_2	0.72*
	(!9.73)	(!9.73)	(!8.68)		(7.08)	(!1.62)	(!1.62)	(!1.65)		(9.16)	(4.08)	(4.08)	(3.92)		(8.33)
Nugget	1.20*	0.45*	0.46*	μ_3	1.15*	0.44	0.15	0.15	μ_3	1.36*	0.89*	0.32*	0.32*	μ_3	1.04*
	(5.17)	(5.17)	(4.77)		(9.20)	(1.89)	(1.69)	(1.76)		(11.60)	(4.61)	(4.61)	(4.20)		(10.80)
Popper	1.08*	0.41*	0.41*	μ_4	1.57*	!0.06	!0.02	!0.02	μ_4	1.68*	!1.68*	!0.61*	!0.61*	μ_4	1.38*
	(4.61)	(4.67)	(4.14)		(11.80)	(!0.03)	(!0.26)	(!0.23)		(13.70)	(!8.68)	(!8.65)	(!7.92)		(13.40)
Fried Reheat	0.47*	0.18*	0.18*	μ_5	1.92*	!0.31	!0.11	!0.11	μ_5	1.97*	!0.95*	!0.35*	!0.35*	μ_5	1.70*
	(2.02)	(2.02)	(1.98)		(13.50)	(!1.31)	(!1.31)	(!1.33)		(15.30)	(!4.91)	(!4.91)	(!4.98)		(15.50)
Baked Reheat	0.95*	0.36*	0.36*	μ_6	2.32*	0.39*	0.14	0.14	μ_6	2.31*	0.03	0.01	0.01	μ_6	2.11*
	(4.08)	(4.08)	(3.68)		(15.10)	(1.68)	(1.68)	(1.63)		(17.10)	(0.13)	(0.13)	(0.17)		(18.20)
Micro Reheat	!1.42*	!0.54*	!0.54*	μ_7	2.73*	!0.09	!0.03	!0.03	μ_7	2.68*	0.93*	0.34*	0.34*	μ_7	2.61*
	(!6.09)	(!6.10)	(!6.00)		(17.10)	(!0.37)	(!0.37)	(!0.34)		(19.20)	(4.78)	(4.79)	(4.42)		(20.60)
Price [a]	!2.55*	!0.97*	!0.98*	μ_8	3.28*	!12.46*	!4.36*	!4.41*	μ_8	3.12*	!3.30*	!1.20*	!1.22*	μ_8	3.19*
	(!2.65)	(!2.65)	(!2.53)		(18.40)	(!12.60)	(!12.60)	(!11.20)		(20.50)	(!4.08)	(!4.08)	(!3.91)		(23.70)
Package Size [a]	0.002	0.0009	0.0003			0.009	0.003	0.003			0.002	0.006	0.005		
	(0.208)	(0.208)	(0.16)			(0.86)	(0.86)	(0.79)			(1.72)	(1.72)	(1.49)		
σ	2.64	1.0	1.0			2.86	1.0	1.0			2.74	1.0	1.0		
χ^2 LogL	115.64*		115.18*			140.16*		140.58*			111.42*		109.68*		
MSRC [b]	0.60		0.58			0.60		0.64			0.55		0.54		
WMP [c]	!0.40		NA			2.56*		NA			0.03		NA		

Notes: An asterisk (*) denotes the coefficient is different from zero at the $\alpha = 0.05$ level of significance. Numbers in parentheses are the ratios of the coefficients to their standard errors.

[a] The coefficients for price and package size are expressed as marginal utilities since they are treated as quantitative variables in the model.

[b] MSRC is the median value for Spearman rank correlation coefficients. Spearman rank correlation coefficients are calculated between actual and predicted rankings for each respondent in the sample.

[c] WMP is the Wilcoxin matched pairs statistic derived from the Wilcoxin signed rank (WSR) test, which tests the null hypothesis that differences between SRC values for TLT and OP models are equal to zero. The statistic is a *Z*-value which is compared to the 1.96 critical value at the $\alpha = 0.05$ level of significance.

baking and frying methods, as reflected by positive coefficients for the fried and baked part-worth values (table 3). Negative signs on the part-worth values for the microwave reheating method, however, show consumers in segment I expressed disutility for this product attribute.

Conversely, the average consumer in segment III expressed disutility for the fried product, while preferring the microwave reheating method. This finding is confirmed by negative part-worth values for the fried product and positive part-worth values for the microwavable product (table 3). Moreover, the Wald tests for segment III (table 2) show all three attribute levels associated with the reheating methods are significantly different from one another.

The results from the second market segment model are less revealing than models for segments I and III. None of the part-worth values are significant, except for the price coefficient, which is negative and relatively large in magnitude (table 3). Consequently, the Wald tests indicate that neither product form nor reheat method attribute levels are significantly different from one another. Thus the average consumer in segment II found none of the attributes to be important except price.

Analysis of Product Rankings

As noted earlier, there are 81 possible attribute combinations in the study. The model estimates discussed in the previous section are used to simulate the total utility for these 81 hypothetical products. The utility values for the TLT model are calculated as follows:

$$(4)\quad U^k_{abcd} = \beta^k_0 + \sum \beta^k_{abcd},$$

where U^k_{abcd} is the simulated total utility for a particular hypothetical product, which is defined by the attribute-level combination given by the subscripts *abcd*. The superscript *k* designates the model estimates used in the simulations. The subscripts *abcd* refer to the previously defined levels for product form, reheating method, price, and package size, respectively. The intercept term (β^k_0) is the estimated mean preference rating for the *k*th model, and $\sum \beta^k_{abcd}$ is the summation of the *k*th model's part-worth estimates for hypothetical products defined by the attribute level combination *abcd*.

The utility values for the OP model are simulated by calculating the probability of occurrence for each value of the interval rating (IR) scale given each of the 81 possible attribute-level combinations. The simulated utility is equal to the scale value associated with the highest probability of occurrence. The top five products and simulated utility values for the TLT and OP models are presented in table 4.

Relative importance (RI) weights for each product attribute are calculated using the method described in Halbrendt, Wirth, and Vaughn (1991). First, the highest and the lowest part-worth utilities are determined for each attribute. The difference between the highest and lowest part-worth establishes the utility range for the *i*th attribute. Once a range for each attribute has been determined, the relative importance of the *i*th attribute is specified as follows:

$$(5)\quad RI_i = \frac{\textit{Utility Range}_i}{\sum \textit{Utility Ranges} \ \forall \ \textit{Attributes}} \times 100,$$

where RI_i is defined as the relative importance measure for the *i*th attribute. The RI weights are also reported in table 4.

The simulations reveal both models are identical with regard to the composition of the top-ranked products. However, examination of the utility values demonstrates how the models differ with regard to cardinal and ordinal assumptions of the IR scale. The TLT model provides a unique ordering of the top five products, whereas the OP model does not. The OP model does not distinguish among the top five products for the total sample, or any of the three market segments. Yet, this finding does not imply the TLT model is superior.

Indeed, the attribute levels delineating the top-ranked products in the TLT model are either not statistically different from zero, or they are not significantly different from one another. For instance, the top-ranked product for the total sample is a nugget, formulated for baking, priced at 10¢ per ounce, and offered in a 48-piece package. The only attribute that delineates this product from the second- and third-ranked products is package size, which is not statistically different from zero in either the TLT or OP models (tables 1 and 4).

Additionally, the only difference between the first- and fourth-ranked products is the baked reheat method (which appears in the former) and the microwave reheat method (which appears in the latter). However, the two attribute levels are not statistically different from each other in either the TLT or OP models (see table 3, total sample). The OP model reflects indifference between these attribute levels, and therefore ranks these products equivalently. Similarly, the product forms distinguishing

Table 4. Simulated Total Utilities and Top Five Rankings of Crawfish Value-Added Products

	Product Form			Reheating Method			Product Price (cents/ounce)			Package Size (pieces/pack)			Simulated Utility [c]	
Sample/Rank	Patty	Nugget	Popper	Fried	Baked	Micro	10¢	20¢	50¢	12	24	48	TLT	OP
Total Sample:		(26, 27) [a]			(16, 16)			(50, 50)			(8, 7)			
1		X [b]			X		X					X	7.16	9.00
2		X			X		X				X		6.92	9.00
3		X			X		X			X			6.80	9.00
4		X				X	X					X	6.73	9.00
5		X			X			X				X	6.55	9.00
Segment I:		(49, 51)			(35, 34)			(15, 15)			(1, 0.4)			
1		X			X		X					X	7.29	9.00
2		X			X		X				X		7.24	9.00
3		X			X		X			X			7.22	9.00
4			X		X		X					X	7.17	9.00
5			X		X		X				X		7.12	9.00
Segment II:		(12, 12)			(10, 10)			(73, 73)			(5, 5)			
1		X			X		X					X	7.68	9.00
2		X			X		X				X		7.46	9.00
3		X			X		X			X			7.35	9.00
4		X				X	X					X	7.24	9.00
5			X		X		X					X	7.18	9.00
Segment III:		(44, 42)			(32, 28)			(23, 22)			(1, 8)			
1		X				X	X					X	6.78	9.00
2		X				X	X				X		6.73	9.00
3		X				X	X			X			6.70	9.00
4	X					X	X					X	6.68	9.00
5	X					X	X				X		6.63	9.00

[a] The relative importance (RI) values are given in parentheses for each attribute; the two-limit tobit (TLT) values are reported first, followed by the ordered probit (OP) values.
[b] A particular combination of X's defines a hypothetical product.
[c] The simulated total utility for the hypothetical product.

the top-ranked products in the TLT models are not significantly different from one another. Consequently, it is not possible to determine an "optimal product" for either the TLT or OP models.

On the other hand, the results do suggest differences between market segments I and III with respect to the reheating methods. For example, the average consumer in segment I prefers the baked reheating method over the microwave method. This can be observed by noting that all top-ranked products in segment I are associated with the baked reheating method. In contrast, consumers in segment III prefer the microwave reheating method over frying or baking (table 2).

The relative importance (RI) weights also show few differences between the TLT and OP models (table 4). The most important attributes for the total sample are price and product form, which accounted for 50% and 26%, respectively, of the total range in utility for the TLT model. Similarly, the OP model yielded 50% and 27% RI values for price and product form, respectively.

The most important attributes for market segment I are product form with RI values of 49% for TLT and 51% for OP, and reheating method with RI values of 35% for TLT and 34% for OP. For market segment II, the most important product attribute is price, which accounts for 73% of the total range in utility for both TLT and OP models. This represents a notable difference compared to segments I and III, where price placed third in terms of relative importance. As is the case for segment I, product form and reheating method are the most important attributes for market segment III.

Analysis of Market Demographics

Consumer preferences can be analyzed further by examining the demographic information from the survey. Table 5 shows the median age, gender, marital status, education, and income level for the total sample and the three market segments. Pearson chi-squared tests were used to determine if the three segments differed according to socioeconomic

Table 5. Median Values of Socioeconomic Variables for the Total Sample and Each Market Segment for Crawfish Value-Added Products

Socioeconomic Variable (degrees of freedom)[a]	Total Sample (N = 111)	Segment I (n = 30)	Segment II (n = 35)	Segment III (n = 46)
Age (df = 5)	25 to 34 years	25 to 34 years (7.62)	18 to 24 years (4.49)	35 to 44 years** (10.91)
Gender (df = 1)	male	female** (3.27)	male (1.56)	male* (2.79)
Marital Status (df = 3)	married	married (2.46)	single** (10.01)	married** (8.05)
Education (df = 3)	4-yr. college graduate	4-yr. college graduate (0.49)	graduate school* (6.28)	< 4 years college (3.78)
Income (df = 7)	$30,000 to $39,000	$30,000 to $39,000 (7.88)	$20,000 to $29,000* (12.11)	$40,000 to $49,000 (9.17)

Notes: Asterisks (* and **) denote that the Pearson chi-squared test rejected the null hypothesis of equality of socioeconomic frequencies across market segments at the $\alpha = 0.10$ and $\alpha = 0.05$ levels of significance, respectively. Critical values differ across variables because degrees of freedom differ. Numbers in parentheses are Pearson χ^2 statistics.

[a] Degrees of freedom differ according to the number of categories for each variable.

characteristics. Frequency tables were constructed to compare cell frequencies of socioeconomic variables in one segment with cell frequencies for all other respondents (Baker and Crosbie, 1993). Pearson chi-squared statistics test the null hypothesis that cell frequencies are equal across segments. Several of the chi-squared tests are significant at either the $\alpha = 0.05$ or $\alpha = 0.10$ level of significance, denoting that differences in preference functions across segments correspond to differences in consumer profiles.

Combining results of table 5 with those from table 4 reveals market segment I is primarily composed of women, and the highest rated products in this segment are the baked nugget and popper products in combination with the lowest price. Respondents in market segment III, which is composed of 35- to 44-year-old married men, prefer a nugget or patty product in combination with the microwavable reheating method at the lowest possible price. Consumers in segment II are primarily conscious of price, and this segment is largely composed of single, relatively lower income students (tables 4 and 5).

Conclusions

The primary objective of this study was to analyze the attributes necessary for consumer acceptance of new consumer-ready products derived from the further processing of crawfish. A conjoint survey was used as the basis for the analysis. Two-limit tobit (TLT) and ordered probit (OP) models were developed to estimate aggregate utility models for the total sample of respondents, and for respondents assigned to three market segments based on differences in their individual preference functions. A secondary objective of the analysis was to examine the effects of alternate assumptions regarding cardinal and ordinal properties of the interval rating scale on part-worth estimates.

Results from the study suggest consumers in the total sample preferred the nugget product form in combination with the baked reheating method at the lowest possible price. Moreover, based on results from the market segmentation, some of the respondents in the first market segment would also find the popper type product acceptable. Similarly, the patty product was found to be attractive to consumers in segment III. Additionally, the average consumer in segment I preferred baking or frying as the reheating method, whereas the average consumer in segment III preferred microwaving the product.

Results from market segmentation provide several implications for guiding food science research and commercial development of these types of products. First, women prefer the baked nugget or popper products to the microwavable patty product. Therefore, crawfish processors wishing to target this market should develop both baked nugget and popper type products. Crawfish patties and microwavable products are not expected to succeed in this segment. Second, crawfish processors wishing to target segment III, which is primarily composed of 35- to 44-year-old married men, should develop both microwavable nugget and patty type products. The popper product in combination with a fried reheating method would not be expected to succeed in this segment.

Another important finding of the study is that there appears to be little difference between the TLT and OP models with respect to part-worth estimates and predictive validity. The signs, relative magnitudes, and statistical significance of all part-worth estimates were consistent across the two models. Moreover, there were no statistical differences found for individual-level Spearman rank correlation coefficients between predicted and observed values for the two models. This was true for the total sample as well as for two of the three market segments.

If the OP model estimates had been found to be inconsistent with the TLT model, or superior in terms of predictive ranks, then it might be concluded that preferences expressed by the interval rating scale are ordinal. However, except for the higher predictive validity of the OP model for segment II, results from this study suggest alternative assumptions regarding the cardinal/ordinal nature of consumer preferences had little effect on the analysis. These findings are consistent with those of Boyle et al. (2001), who also found consistency of parameter estimates across tobit and probit models.

Nevertheless, caution should be exercised in interpreting these findings as a general result. The OP model did outperform the TLT for segment II. In addition, Roe, Boyle, and Teisl (1996) found an ordered logit specification to be superior to the two-limit tobit model. Hence, results are mixed, suggesting model selection is closely tied to the construction of the dependent variable, the particular method of utility elicitation, and the respective consumer sample. Further research is needed to determine the sensitivity of part-worth estimates and predictive validity given alternative constructions of the utility scales and experimental conditions.

A limitation of this study is that only the market potential of these type products was examined. Further development of products with characteristics desired by the market may be challenging from the perspective of technical and economic efficiency. It may also be challenging to produce crawfish mince-based products which retain consistent quality characteristics using different reheating methods. However, given the commercial success of multiple reheating methods for similar seafood products, one would expect this could also be achieved with a crawfish formulation. Further research is needed to determine if these types of products can be produced in a commercial setting given seafood HACCP regulations and other industry standards, accompanied by a cost analysis to determine financial feasibility.

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