Appalachian State University

Department of Economics Working Paper

Number 11-09 | September 2011

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David M. Bruner
Appalachian State University

William L. Huth
University of West Florida

David M. McEvoy
Appalachian State University

O. Ashton Morgan
Appalachian State University

Department of Economics
Appalachian State University
Boone, NC 28608
Phone: (828) 262-6123
Fax: (828) 262-6105
www.business.appstate.edu/economics

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Abstract: Consumers' willingness-to-pay (WTP) for post-harvest processed (PHP) raw oysters – oysters without health risks – is studied in experimental *n*th-price auction markets. The experimental design decomposes the effects of taste, objective risk information, and information on four PHP technologies on consumers' valuations. Results show that relatively uninformed consumers are willing to pay equivalent amounts for PHP and traditional raw oysters. However, after a blind taste test consumers are willing to pay a significant premium for traditional raw oysters. The premium for traditional oysters persists after objective information on risk and processing technology is provided. The results are robust over PHP technologies.

JEL CODES: C9, D8, I18

KEYWORDS: experimental auction market, food safety, risk preference elicitation, consumer perceptions, oysters

Introduction

In October 2009, the Food and Drug Administration (FDA) announced a controversial policy reformulation on the use of processing technologies for raw oysters harvested from the Gulf of Mexico.[1] Unsatisfied by prior efforts to reduce the annual number of deaths associated with consuming raw oysters, the new policy, set to be effective by May 2011, banned the sale of traditional raw oysters harvested in the Gulf of Mexico during the warm-weather months. Instead, all raw oysters intended for sale in the interstate half-shell market would be required to be treated by one of four FDA-approved post-harvest processing (PHP) technologies, designed to reduce a harmful bacteria (*Vibrio vulnificus*) to non-detectable levels.[2] While the new policy would largely eliminate the risk of death to health-compromised oyster consumers, the Interstate Shellfish and Sanitation Conference (ISSC) and industry representatives expressed serious concerns regarding both the unilateral nature of the FDA's decision and the potential negative impact on the oyster industry, believing that consumers would not be willing to switch consumption from a traditional product to a processed one.[3,4,5] Based on these concerns and others, the FDA has since issued a letter postponing implementation until additional research into the consequences of such a ban can be completed.[6] The research described herein is the resulting empirical investigation of consumers' willingness-to-pay for traditional and PHP oysters, with the findings informing the ongoing policy debate regarding the economic effect of the proposed FDA mandate. The experimental design permits estimation of both the immediate and the long-term impact of such a mandate on the demand for raw Gulf oysters. Furthermore, there are a number of unique characteristics of the experiment that contribute to the growing body of literature on new food processing technologies and consumer behavior.

When evaluating the impact of new technologies in food production, it is important to recognize that there are several factors influencing consumer preference. While processing technologies can reduce the actual risks of food-borne illness, they can also potentially alter the taste, texture, smell, and aesthetics of foods. Therefore, a consumer's valuation for a new processed food product over a traditional variety is a composite measure of their valuations for actual and/or perceived differences in the individual characteristics of the food. Moreover, as consumers gain information, either through experience or from external sources, preferences and the resulting valuations are subject to change. Hence, information is likely to be an important determinant of consumers' valuation of PHP oysters, like many food products (Fox et al. 2002). It is therefore important to identify the role that different forms of information play in consumers' willingness-to-pay for improved food safety. The experimental design enables the potentially confounding effects of information regarding taste, risk, and the processing technology on consumer valuation to be identified.

As all four FDA-approved food processing technologies are not yet available in the marketplace, we examine consumers' willingness-to-pay for traditional and PHP oysters in an experimental *n*th-price auction market (see Shogren et al. 2001), in which the four processing technologies are considered individually.[7,8] For each processing technology, we conduct a separate session that consists of four rounds of bidding, in which subjects make simultaneous bids for traditional and PHP raw oysters. Hence, each session involves four simultaneous auctions for both traditional and PHP oysters.[9] The design implements multiple bidding rounds to estimate the immediate economic impact of the FDA mandate, based on oyster consumers' subjective, 'home-grown' beliefs. The design also allows us to identify the impact of information regarding various attributes of the commodity (i.e. taste, risk, and knowledge about the processing technology) on consumers' valuations as they gain familiarity with the processed product.

After each round of bidding, we systematically manipulate the information available regarding taste, risk, and the processing technology, in order to measure the impact of each on consumer valuation. In the first round of bidding, we elicit consumers' 'homegrown' willingness-to-pay for traditional and PHP oysters based only on their subjective beliefs.[10] Then, prior to the second round of bidding, each subject participates in a blind taste test. Bidding in the third round is conducted after subjects are provided with an estimate of the health risk associated with consuming a traditional raw Gulf oyster (and are informed that the PHP oyster carries no risk). Finally, before submitting bids in the fourth round, subjects are provided with a brief description of the processing technology. While the findings are specific to oyster consumer acceptance of processing technologies, disentangling the relative impacts of these information effects provides a significant contribution to the broader food-safety literature.

Following the rising incidence of food-borne illness, a growing body of experimental studies have specifically elicited consumers' willingness-to-pay for food technologies that improve food safety (Hayes et al. 1995; Shogren et al. 1999; Fox et al. 2002; Hayes et al. 2002; Nayga et al. 2006; Rousu and Shogren 2006). In addition, a number of papers have examined the roles information and understanding of food technologies play in consumers' valuations in experimental food markets (Fox et al. 2002; Hayes et al. 2002; Lusk et al. 2004b; Nayga et al. 2006; Rousu and Shogren 2006; Huffman et al. 2007; Rousu et al. 2007; Marette et al. 2009). Nonetheless, the effect of taste on willingness-to-pay measures for new food-safety technologies has largely been overlooked.[11] Particularly with fresh foods, the perceived and/or actual taste of a product is an important attribute likely to be affected by the introduction of new food-safety technologies (Melton et al.1996). While previous economic studies of new food-safety technologies have hinted at the role perceived and actual taste comparisons play in consumer valuation measures, the present experiment systematically manipulates taste perceptions in order to estimate the effect of taste information on consumers' willingness-to-pay for new food-safety technologies.[12] The study is also unique in that comparisons of consumers' willingness-to-pay across multiple food-safety technologies are conducted. As there are currently four FDA-approved technologies for processing oysters, explicitly examining each one enables an investigation of the role different technologies play in consumers' valuation for a single product. While different technologies may achieve an equivalent reduction in the risk of food-borne illness, the perceived effect on other attributes of the product may not be equivalent.

The results from the first round of bidding suggest, given their subjective beliefs regarding PHP oysters, the average consumer is willing to pay an equivalent amount for both oyster types. This result combined with questionnaire responses suggests, on average, the perceived health benefit from consuming safer PHP oysters is offset by negative perceptions of the food-safety technology. After participating in a blind taste test, difference-in-differences tests suggest that three of the four processing technologies degrade the taste of the oysters to the extent that the average subject's willingness-to-pay for PHP oysters relative to traditional oysters decreases significantly; this results in a premium for *traditional* raw oysters. We further find that disseminating information about the risk of consuming traditional raw oysters (i.e. the benefit of the PHP technology) has a slight positive effect on consumers' willingness-to-pay for PHP oysters. The premium for traditional oysters, however, remains positive and significant. Finally, information regarding the processing technology has a slight negative effect on consumers' willingness-to-pay for PHP oysters, which increases the premium for the traditional product.

While we find differences in the statistical significance of these information effects across PHP technologies, the resulting premium for traditional oysters is consistent across technologies. In short, results from the experimental market suggest naïve oyster consumers are indifferent between traditional and PHP oysters.[13] The experienced consumer, however, places a premium on the traditional product, mostly due to taste degradation caused by the processing technology.

The remainder of the article is organized as follows. In the next section, we highlight the human health risks associated with *Vibrio vulnificus* and provide more details on the FDA's proposed policy and its implications. Following that, we introduce the experimental design before presenting our results and discussing the implications of our findings.

***Vibrio vulnificus*, Human Health Risks, and PHP Regulation**

Vibrio vulnificus is a bacterium found naturally in waters along the Gulf, Atlantic, and Pacific coasts, although it is most prevalent in the warm waters of the Gulf of Mexico. The bacterium can be transmitted to humans through direct wound infection and through consumption of raw shellfish harvested from waters that contain the organism. Gulf of Mexico oysters are the primary species of shellfish associated with *Vibrio vulnificus* illness in consumers (Shapiro et al. 1998). For most healthy people the ingestion of the bacterium poses little risk of serious illness. However, for oyster consumers with weak immune systems, consuming the *Vibrio vulnificus* bacterium can be life threatening. Specifically, for oyster consumers with chronic liver disease, iron overload disease, diabetes, cancer, or HIV/AIDS, the consumption of contaminated raw oysters can lead to severe health issues, the most common being acute septicemia or blood poisoning. While the incidence of illness each year associated with oyster consumption is low, typically in the range of 25 to 30 to 35 individuals, *Vibrio vulnificus* bloodstream infections are fatal about 50% of the time, causing approximately 15 deaths per year (Shapiro et al. 1998).

While thoroughly cooking oysters removes all potentially harmful bacteria, it is a popular tradition to consume raw oysters. Traditional raw oysters are harvested, sorted and washed, boxed by a processor, shipped at approved temperatures to the retail market and then served raw. Because of the potential health risks associated with consuming raw oysters, the harvesting and shipping process is regulated by the FDA and ISSC under the National Shellfish Sanitation Program (NSSP). In 2001, a seven-year *Vibrio vulnificus* Risk Management Plan for Oysters was adopted with a specific goal to reduce the annual incidence of *Vibrio vulnificus*-related illness by 60 percent by 2008. Initial efforts primarily involved trying to educate vulnerable consumers by disseminating *Vibrio vulnificus* fact sheets and brochures that detailed the risks associated with raw oyster consumption and implementing a five-hour time limit from harvesting to refrigeration for Gulf state producers. Another component of the plan was to foster a voluntary adoption of new PHP technologies by the industry. Since this time, the frequency of reported *Vibrio vulnificus* illness across the core states (Florida, Louisiana, Texas, and California) has declined slightly with annual illness rate reductions from the 1995-1999 baseline level of between 26 to 44 percent (ISSC *Vibrio vulnificus* Illness Review Subcommittee Report 2011).

In October 2009, disappointed that the measures taken in the seven-year plan had fallen short of the desired illness rate reduction, the FDA outlined a unilateral decision to reformulate its PHP policy. The new policy mandates that all Gulf coast oysters intended for sale in the half-shell market be treated by one of four approved processing technologies during the months of April through October (when warmer Gulf temperatures increase the presence of the *Vibrio vulnificus* bacteria and cause approximately 90 percent of all illnesses). Unsurprisingly, the plan is controversial among the stakeholders in the oyster industry. On one hand, post-harvest processing reduces *Vibrio vulnificus* bacteria to non-detectable levels and as a result virtually eliminates the possibility of infection from eating raw oysters. On the other hand, harvesters and industry representatives are concerned about consumers' acceptance of processed oysters in tandem with their concerns about the associated production costs. Consumer attitudes toward PHP raw oysters are likely to be the most elusive components of the proposed policy as these attitudes can be influenced by many factors, including both subjective beliefs and objective information regarding the processed oysters. The experimental design, described in the next section, is used to elicit consumer valuations for PHP oysters. The design enables estimation of both the short- and long-term impacts of the FDA policy on the demand for raw Gulf oysters (i.e. the difference in the willingness-to-pay of naïve consumers with that of informed consumers.)

Experimental design

Oyster consumers were recruited from the University of West Florida (UWF) to participate in the study. Upper division undergraduate and graduate students along with faculty and staff were recruited to participate in the experiments. Subjects were recruited using the UWF email and electronic announcement systems. Those interested in participating self-selected into the study via a web site where they registered for one of four sessions. Interested individuals were required to answer questions concerning their existing health conditions, and any subject that indicated they were at high risk of becoming seriously ill from eating raw oysters was precluded from participating.[14] Subjects were informed that the session would last roughly one hour and that eating raw oysters was required for participation. The UWF conference center lounge was used as a staging area for oyster preparation and a large conference room was set up for the experiment. The services of a professional oyster shucker from a local oyster restaurant were obtained so that, depending on the results of the *n*th price auction, the oysters could be delivered to the consumers in a timely manner with restaurant-quality presentation.

Four sessions were conducted; one for each PHP technology and 30 subjects participated in each session. In each session subjects made bids to consume (in sets of 3) traditional raw oysters and only one of the PHP types. A total of five different types of raw oysters were used for this study: traditional, quick-frozen, pasteurized, pressurized and irradiated. All of the oysters were harvested on September 6 and 7, 2010, from a private open water lease area in Apalachicola Bay, Florida.[15] In total, to account for all possible consumer behavior scenarios, 960 oysters were harvested for the experiment. Of this amount, 480 were traditional raw oysters and the remaining 480 oysters were separated into four groups of 120 to undergo one of the four PHP methods.[16] The oysters to be processed were transported in appropriate refrigeration to their respective treatment facilities.[17] All oysters were processed within 48 hours of harvest. The oysters were then transported to Pensacola, FL (UWF) for use in the experiment that took place on September 16, 2010.[18] In total, 120 subjects participated in the experiment with average earnings of approximately $20, including a $5 show-up fee.

Experimental protocol

The following protocols were used for each of the four experimental sessions. The 30 subjects entered the room and were seated at tables. At each seat was a brief questionnaire to collect demographic information, oyster consumption behavior, risk perceptions regarding oyster consumption, knowledge about the processing technology, and prior beliefs regarding taste differences. After completing the questionnaire, subjects then participated in a risk preference elicitation exercise. Subjects completed a menu of 10 choices over lottery pairs.[19] They were informed that only one choice would be binding at the end of the experiment.[20] After risk preferences were elicited, instructions regarding the auction mechanism were handed out and projected at the front of the room. The moderator read the instructions aloud. The instructions carefully explained the procedures of the *n*th price auction mechanism (see Shogren et al. 2001 for a detailed description of the mechanism) and included an example. The items auctioned were a set of three traditional (unprocessed) raw oysters and a set of three PHP raw oysters, on the half shell, for immediate consumption.[21] Once the moderator finished reading the instructions, subjects participated in a practice round of bidding, after which any remaining questions were answered. Subjects then participated in four sequential *n*th price auctions in which subjects made simultaneous bids for the sets of traditional oysters and PHP oysters. Subjects were not informed in advance of the number of bidding rounds, but were aware there would be more than a single round. Subjects were informed that only one round would be randomly selected and implemented as the binding round after all bidding was concluded.[22] Subjects were initially endowed with $15 for participating and had the opportunity to earn $5 from the lottery exercise.

In each of the four bidding rounds, subjects submitted separate bids for three traditional and three PHP raw oysters (bids were bounded from $0 to $5). In the first round, subjects submitted bids based solely on their subjective beliefs.[23] After the first round concluded, each subject participated in a blind taste test. Specifically, each subject was given a single raw oyster to consume, and then asked to indicate the type of oyster (traditional or processed) they believed it to be and to rate the taste of the oyster on a Likert scale (the taste test questionnaire is included in the appendix). They were then given a second (traditional or processed) oyster and asked to rate the taste of the oyster.[24] The oyster types were then revealed to subjects when they received their second round bid cards. At that point a second round of bidding occurred in which the only difference compared to the first round was that they had tasted each type of oyster. After the bid cards for the second round were collected, subjects were handed another bid card that included information regarding the illness risk associated with raw oysters. Subjects were provided with an estimate of the risk of contracting a *Vibrio vulnificus* infection from eating a traditional raw oyster and told that the treated raw oyster reduced *Vibrio vulnificus* to non-detectable levels, thereby reducing the risk of food-borne illness.

The risk estimate we presented to the subjects was calculated by pairing the results of two related studies. Hlady and Klontz (1996) report on the incidence of *Vibrio vulnificus* infection among oyster consumers in the state of Florida. They estimate an average of 10.3 adults contracting a *Vibrio vulnificus* infection for every 1,000,000 raw oyster-consuming adults. Their estimate uses reported cases of *Vibrio vulnificus* to the Department of Health and Rehabilitative Services between 1981 and 1993. Of course many cases of foodborne illness, including *Vibrio vulnificus*, do not get reported because infected persons do not always seek medical help. To account for this we rely on the adjustment factor used by Mead et al. (1999) and estimate the frequency of *Vibrio vulnificus* infection at roughly twice the reported rate.[25] Therefore, we estimate an average annual incidence of *Vibrio vulnificus* at 20 cases for every 1,000,000 (1 in 50,000) oyster-consuming adults in Florida.

In our experiments we presented the estimate regarding the illness risk from consuming raw oysters in the context of oyster meals. That is, before the third round of bidding occurred, subjects were informed that the average oyster consumer faces a risk of 1 in 50,000 of becoming ill every time he or she consumes an untreated raw oyster (this information was contained directly on their bid card). We framed the risk information in this way to make the linkage between the risk of illness and the consumption decisions made in the experiment as salient as possible. The precise language used on the bid cards was the following:

> "According to national and regional statistics, the estimated risk of food-borne illness associated with consuming an oyster meal (defined to be meals at any time in which your main course was oysters, meals in which oysters were an important ingredient in a dish, like gumbo, or meals in which you just ate an oyster appetizer) is 1 in 50,000 meals.
>
> [PHP technology] of raw oysters after harvest reduces naturally occurring harmful bacteria to non-detectable levels, thereby reducing the risk of food-borne illness."[26]

After the third round of bidding was complete, subjects received a fourth and final bid card. On this card subjects were endowed with information regarding the processing technology. The information provided subjects with a brief, one or two sentence description of the relevant process. The descriptions for each processing type were:

> **Individual quick freezing** involves rapid freezing of half shell oysters on trays, then adding a thin glaze of ice to seal in the natural juices before storing them frozen.

Low-heat pasteurization is a patented process whereby live oysters are placed in warm water for a certain time period and then immediately dipped in cold water to stop the cooking process.

High hydrostatic pressure is a patented process that subjects oysters to high pressures (35,000 to 40,000 pounds per square inch) for 3 to 5 minutes.

Irradiation involves exposing oysters, either packaged or in bulk, to high energy gamma rays. This is done in a special processing room or chamber for a specified duration.

After the fourth round of bidding concluded, one round was randomly selected using a bingo ball cage. The price for each oyster type (traditional and processed) was then randomly determined using the bingo ball cage again, with the $n - 1$ highest bidders paying the nth highest price. The bids for the selected round were displayed by a projector at the front of the room in ascending order with subject identifiers. Each subject that purchased oysters, of either type, was served a set of three freshly shucked oysters along with condiments. After all oysters were consumed, subject payments were tabulated and paid accordingly.

Results

Table 1 reports average bids for traditional and PHP raw oysters pooled across sessions in the second and third columns, respectively. The fourth column of the table reports the difference in the average bid for traditional and PHP oysters for each round. A positive difference indicates, on average, subjects were willing-to-pay more for the traditional oysters compared to the PHP oysters. Dividing these differences by 3 results in the average premium the consumer places on a single traditional oyster relative to a processed one. The difference estimate from the first round of bidding (0.05) shows that, based on home-grown values, consumers are willing to pay about the same amount for traditional oysters compared to the less-risky processed oysters.

Insert Table 1 Here

While bids for the traditional raw oysters are fairly stable across the four bidding rounds, bids for processed oysters vary substantially. Initially there is no statistical difference in the mean bids for processed and traditional oysters. After the blind taste test, however, the mean bid for PHP oysters substantially declines. This leads to a significant difference in the average bids in the second bidding round and this difference persists (at the 0.01 significance level) for the remaining rounds.

The change in the premium for traditional oysters over bidding rounds is captured in the fifth column labeled difference-in-differences. To illustrate, consider the second round of bidding that occurs after subjects taste both oyster types. After actually tasting the PHP oysters, the average premium for traditional oysters jumps from \$0.05 to \$0.62, an approximate change of \$0.58. The significance of formal difference-in-differences tests are indicated by asterisks (see Wooldridge 2002, pp.283 – 291). These tests are particularly powerful because they remove any confounding fixed-effects (e.g., subjects' understanding of the *n*th price auction, time of day, etc.). The difference-in-differences tests indicate that actually tasting the oysters significantly reduced the average subjects' willingness-to-pay for PHP oysters (i.e., information regarding taste generates a significant premium for traditional oysters). After providing subjects with information on the riskiness of consuming traditional raw oysters (i.e., the benefit of consuming

PHP oysters), the premium for the traditional product falls from \$0.62 to \$0.49 (a difference-in-differences of \$0.14). Hence, providing subjects with an estimate of the benefit of the PHP oysters significantly reduces, but does not eliminate, the premium for traditional oysters. The results from the fourth round of bidding indicate information intended to familiarize subjects with the processing technology does not significantly alter the premium for traditional oysters.

Table 2 reports average bids for traditional and PHP oysters, the difference between them, and difference-in-difference tests of information effects, for each of the four PHP technologies. Note the differences in the average bids (column four) are positive in every case except the first round of bidding for pasteurized oysters. The first round differences, however, are insignificant for all four PHP technologies. This suggests, based on their subjective, 'homegrown' beliefs, consumers are indifferent between a risky traditional oyster and a riskless, processed oyster. As with the aggregated results from Table 1, the technology specific results in Table 2 demonstrate tasting the traditional and processed oysters significantly diminishes consumer valuation for PHP oysters; information regarding taste results in a premium for traditional oysters.

The quick-frozen oysters were perhaps the closest substitutes for the traditional raw oysters. The difference-in-differences tests indicate that the information provided to subjects did not significantly affect the difference in the average bid. Hence, oyster consumers may be indifferent

Insert Table 2 Here

between consuming traditional raw oysters and safer, quick-frozen oysters. Based on the premise that consumers are more likely accustomed to freezing food products to preserve their quality (as opposed to the other three technologies), this result is consistent with Fox et al. (1994) who find that familiarity with a new technology may increase consumer acceptance. With the pressurized and pasteurized oysters, the only significant effect is from information regarding taste, which results in a premium for the traditional product. Bids in the session for irradiated oysters were the most responsive to information. While the effect of taste results in a significant premium for traditional oysters, information about the risk of illness significantly decreases, but does not eliminate, this premium. Only information describing the irradiation process significantly increases the premium for traditional oysters.

The significant effect of taste observed from the auction results is consistent with the results of the blind taste test, reported in Table 3. For all four technologies, subjects indicated that the taste of traditional raw oysters was preferred to PHP raw oysters. The first and second rows report the average Likert scale rating (1 – 10) of the traditional and processed oysters, respectively, across processing technologies. The largest difference in taste preferences occurs with the pressurized oysters while the smallest difference occurs with quick-frozen oysters.

Insert Table 3 Here

Conditional analysis

We now turn to a conditional analysis of the willingness-to-pay measures. To begin we report summary statistics on subjects' demographic information, inherent risk preferences, and subjective beliefs regarding traditional and processed oysters. The demographic information and subjective beliefs are obtained from the pre-experiment questionnaire. The measures of risk preference are obtained from the lottery exercise.

Table 4 summarizes subject responses to the questionnaire regarding socio-economic characteristics. The sample is fairly diverse when it comes to gender, age, income and ethnicity. Fifty five percent of subjects were male. Approximately 60 percent of the sample was between the ages of 18 and 24, with the remaining 40 percent being fairly uniformly distributed between the ages of 25 to 66. About 66 percent of subjects were Caucasian, 12.5 percent were Latin, eight percent were Asian, and seven percent African American.[27] Household annual income ranged from nine percent of subjects earning less than \$10k, 32 percent earning less than \$25k, 60 percent earning less than \$50k, 88 percent earning less than \$100k, and 12 percent earning more than \$100k.[28] Participants consumed oysters, on average, during 4.7 months of the year and averaged four meals per month.[29] Fifty eight percent of subjects consume both raw and cooked oysters, while 35 percent solely eat raw oysters.

Insert Table 4 Here

Table 5 characterizes the distribution of subject risk preferences. The majority of subjects were risk averse. On average, subjects made about six safe choices (i.e. the lottery with lower variance). This pattern of risk preferences is consistent with previous research (Holt and Laury 2002; Lusk, Feldkamp, and Schroeder 2004a), suggesting that oyster consumers are similar to the general population in terms of risk preferences. The fourth column reports the value of a risk preference index created by subtracting five from the number of safe choices a subject made. Hence, the index assumes a value of zero in the region of risk neutrality and incrementally increases (decreases) the more risk averse (seeking) a subject’s preferences. The risk preference index is summarized in Table 6.[30]

Insert Table 5 Here

Along with the risk preference index, other elicited beliefs are gathered. From the subject questionnaire, consumers' self-assessment of their understanding of the processing technology is reported, ranging from 0 (not informed) to 4 (well informed). Before tasting both oyster types, subjects were asked to state whether they thought that the traditional and processed oysters will taste differently. Sixty-six percent of subjects thought that the two oyster types would taste differently. Descriptive statistics for these variables are provided in Table 6.

Insert Table 6 Here

The subject-level information from the questionnaire (described in Tables 4 and 6) along with the elicited risk preferences (Table 6) is used in the regression analysis and presented in Table 7. The table reports regression results of subjects' first round bids for the PHP and traditional oysters (i.e., bid functions for both oyster types) as a function of the PHP technology, socio-economic demographics, and subjective beliefs. The regressions are used to identify the factors influencing 'home-grown' preferences. In addition to estimates using ordinary least squares, the second and fourth columns present Tobit regression results to account for censoring.[31] The more months a subject consumes oysters, the more they bid, on average, for traditional oysters.

Insert Table 7 Here

Elicited risk preferences are highly significant in both bid functions; risk aversion, on average, reduces a subject's willingness-to-pay to consume raw oysters of either type. This is consistent with previous findings regarding stated preferences for genetically modified food (Lusk, Feldkamp, and Schroeder 2004a). Finally, willingness-to-pay for raw oysters, of either type, increases with age, when controlling for income.

The final column in Table 7 reports the estimated conditional premiums for PHP oysters based solely on subjective prior beliefs. The coefficients on the dummy variables for processing technology are the premiums for that particular oyster type relative to traditional oysters, conditional on the observable characteristics of the subjects. Hence, this controls for any possible differences in subject characteristics across experimental sessions. The estimation results indicate naïve consumers place a significant premium for both pasteurized and quick-frozen raw oysters relative to the traditional product. That is, before having the opportunity to taste the processed oysters subjects are willing-to-pay more for pasteurized and quick-frozen raw oysters relative to traditional oysters. Again, this finding is consistent with previous findings that consumer acceptance of food technology increases with familiarity (Fox et al. 1994).

Conclusion/Discussion

This study is motivated by the FDA's recently proposed policy mandating that all raw oysters harvested from the Gulf of Mexico during the warmest months of the year undergo post-harvest processing before consumption. On one hand the policy would reduce *Vibrio vulnificus* bacteria to non-detectable levels and as a result virtually eliminate the possibility of infection from eating raw oysters. On the other hand, consumers may not be that accepting of post-harvest processed raw oysters. Consumer attitudes toward PHP raw oysters are likely influenced by many factors, including both subjective beliefs and objective information regarding the processed oysters. The purpose of our study is to examine the implications of the FDA's proposed policy on consumers' willingness-to-pay for both traditional raw and PHP raw oysters. While our willingness-to-pay estimates are specific to oyster consumers' acceptance of new processing technologies, the unique experimental methodology used to disentangle the various information effects (including taste) is a nice contribution to the growing experimental literature on food-safety technologies.

We hypothesize that a consumer's valuation for a new food product over a traditional variety is a composite measure of their valuations for actual and/or perceived differences in the individual characteristics of the food, and that these valuations are subject to change as consumers gain more objective information. By experimental design, we are able to isolate the effects of objective information on taste, risk, and technology type on consumers' willingness-to-pay for traditional and processed oysters.

When combining all four processing technologies, our findings from difference-in-differences tests demonstrate that, based on home-grown subjective values, there is no statistical difference between consumers' willingness-to-pay for traditional raw and processed raw oysters. We postulated that the average consumer's perceived benefit from eating less-risky oysters is offset by negative perceptions of eating processed oysters. With approximately 90% of subjects indicating that they expected the traditional oyster would taste better, it appears that the perceived taste of processed oysters is a primary component of these negative perceptions. Providing consumers with objective information treatments, our results further indicate that the processing technologies have a significant potential to degrade the taste of raw oysters to the extent that willingness-to-pay for PHP oysters declines significantly. This creates a premium such that consumers are willing to pay significantly more for traditional over PHP oysters. We also find that objective information about illness risk reduction associated with PHP oysters has a relatively small, yet significant effect on consumer valuation, reducing but not offsetting the willingness-to-pay premium for traditional oysters. Finally, providing subjects with information on the processing technology has no significant effect on the premium.

While our finding that objective information regarding the taste of the processed oysters significantly reduced consumers' willingness-to-pay may seem intuitive, this potential taste effect is largely neglected in the existing literature on food-safety experiments. Granted, this research considers the effects of new technologies on a raw food product while the existing literature examines cooked foods. It may be the case that cooked foods are not as susceptible to changes in taste caused by new technologies. Regardless, our finding suggests that future research should carefully consider the roles taste perceptions and taste information of a processed product have on consumers' valuations.

Breaking down the objective information treatment effects by PHP type, the negative taste effect on consumers' willingness-to-pay for PHP oysters is significant for three of the four PHP methods (pasteurized, pressurized, and irradiated). However, neither the taste effect nor any of the other information treatment effects are significant for oysters processed by the quick-freezing method. Further, in a conditional analysis, regressing first round bids on observable subject characteristics and treatment variables indicates that subjects are willing to pay a premium for quick-frozen and low-heat pasteurization oysters. By examining each treatment type, these findings highlight that the quick-freezing method creates the closest substitute to traditional oysters.

Finally, consumers' risk attitudes matter in forming consumer valuations for both traditional and processed oysters. As we find that more risk-averse subjects were willing to pay less for oysters of either type, future research should also consider the role of risk perceptions of the target population when examining consumer acceptance of new food processing technologies.

Footnotes

1.The announcement was made at the biennial meeting of the Interstate Shellfish and Sanitation Conference (ISSC). A presentation at the meeting from the FDA detailing the plan can be retrieved at <http://www.fda.gov/NewsEvents/Speeches/ucm187015.htm>

2. The four FDA-approved processing technologies are irradiation, individual quick-freezing, low-heat pasteurization, and high hydrostatic pressure. This policy is similar to one adopted by California in 2003.

3. The ISSC comprises representatives from the shellfish industry and both federal (FDA and Center for Disease Control) and state governments, and is the primary body for regulatory oversight on matters involving molluscan shellfish.

4. The formal response by the ISSC to the FDA can be retrieved at <http://www.issc.org/client_resources/usfda%20letter%20from%20issc%20november%202%20 2009.pdf>

5. A response from representatives of the East Coast Shellfish Growers Association, Pacific Coast Shellfish Growers Association, Gulf Oyster Industry Council is available at <http://www.ecsga.org/Pages/Issues/Human_Health/FDA_OysterBanPressRelease10-09.pdf>

6. The letter announcing the postponement of the ban can be retrieved at <http://www.issc.org/client_resources/fda%2001-26-2010%20letter%20to%20issc.pdf>

7. Laboratory auctions are an established methodology for eliciting consumers' valuation for new food technologies (Fox 1995; Fox et al. 1995; Hayes et al. 1995; Melton et al. 1996; Roosen et al. 1998; Shogren et al. 1999; Dickinson and Bailey 2002; Alfnes and Rickertsen 2003; Fox et al. 2002; Hayes et al. 2002; Huffman et al. , 2007; Lusk et al. 2004b; Lusk and Coble 2005; Rousu and Shogren 2006; Rousu et al. 2007; Bernard and Bernard 2009; Marette et al. 2009).

8. The FDA has approved the irradiation processing technology for reducing *Vibrio vulnificus* to non-detectable levels, but irradiated oysters are not yet commercially available to consumers. Individual quick-freezing, low-heat pasteurization, and high hydrostatic pressure oysters are available in the marketplace.

9. Only one of the four auctions is binding and is chosen randomly at the end of the session.

10. The recruitment procedure informed subject volunteers that they would be given the opportunity to purchase raw oysters for consumption. Hence, the vast majority of our subjects consume raw oysters on a regular basis.

11. Some studies have directly examined the effect of taste information on willingness-to-pay measures from experimental food auctions (Melton et al. 1996; Lange et al. 2002; Nalley et al. 2006; Napolitano et al. 2008; Combris et al. 2009), but not for new food technologies.

12. Fox et al. (1995) inform subjects that are bidding on pork sandwiches containing growth enhancers that " … studies have shown that there is no change in the taste, tenderness or other palatability characteristics of the meat". Shogren et al. (1999) offered free samples of both irradiated and non-irradiated chicken in a retail market experiment, apparently in an attempt to resolve differences in taste perceptions and taste experiences. Similarly, Noussiar et al. (2004) allow subjects to taste genetically modified foods before bidding on them.

13. Estimates from the conditional analysis that controls for differences in subject characteristics across sessions, indicate naïve consumers are willing-to-pay a premium for quick-frozen and pasteurized raw oysters.

14. Specifically, individuals could not participate if they had the following conditions: chronic liver disease, iron overload disease, diabetes, cancer, or HIV/AIDS.

15. Apalachicola Bay was unaffected by the British Petroleum oil spill in the Gulf of Mexico in 2010. Subjects were informed the oysters were safe for human consumption.

16. An approximate 20 percent over supply of oysters was also required for each type to account for any spoilage of the product.

17. The quick-freezing and low-heat pasteurized oysters were processed by Webb's Seafood in Youngstown, FL. The pressurized and irradiated oysters were processed by Motivatit Seafood in Houma, LA, and by FTS, Inc. in Mulberry, FL, respectively.

18. It was necessary to conduct all the sessions on the same day to ensure the same level of freshness across oyster types.

19. Each decision involves a choice between two binary lotteries, which pay either \$5 or \$3 with probability p and \$0 or \$2, respectively, with probability $1 - p$. The probability of winning is increased from 10% to 100% in 10% increments in each successive decision so as to induce the subject to switch from choosing the safe lottery to choosing the risky lottery. The point at which the subject switches provides an interval estimate of the subjects' underlying risk preference, which can be characterized by an index normalized to zero if the less risky lottery (i.e. the lottery that pays either \$3 or \$2) is chosen five times. Choosing the safer lottery less than five times indicates the subject has a preference for risk and more than five safe choices indicates the subject is risk averse.

20. Subjects were informed a bingo cage would select the decision (1 – 10) that would be binding. The bingo cage was used a second time to determine the outcome of their chosen lottery for the selected decision. The bingo cage spins were conducted at the end of the experiment after oysters had been purchased and consumed.

21. Subjects were informed in advance that they would be provided saltine crackers, hot sauce, cocktail sauce, and fresh sliced lemons to eat with any raw oysters they purchased. In addition, each subject was provided with a bottle of water.

22. A bingo cage was also used to select the binding bidding round. We discuss the procedure in detail later in this section.

23. The questionnaire informed subjects there were traditional and PHP oysters available. The questionnaire told subjects the processing technology was intended to reduce the risk of illness from raw oyster consumption, but no other information was given.

24. The order of the oyster types was alternated between sessions.

25. To account for the total number of food-borne illnesses, Mead et al. (1999) attach multipliers to the reported cases. The multipliers they use range from 38 to 2 and they attach low multipliers to pathogens that cause serious illness. Their reasoning is that if the health impacts from a food-borne illness are severe, infected persons will likely seek medical help and those cases will be documented. We take a conservative estimate and use the lowest of the multipliers to estimate cases of *Vibrio vulnificus*.

26. Each sessions bid cards replaced [PHP technology] with the one of the four processes.

27. The remainder indicated they were of another ethnicity.

28. Except for the final category, cumulative frequencies are reported.

29. Hence, the average subject consumes oysters about 18.8 times per year. This is consistent with surveys of oyster consumer behavior (Morgan, Martin, and Huth 2009).

30. Previous studies (e.g., Lusk, Feldkamp, and Schroeder 2004a) have used the midpoint of the range of risk parameter values.

31. Bids were restricted to be between \$0 and \$5 for a set of 3 oysters of each type. To the extent that individuals' willingness-to-pay was greater than \$5 or negative, the data are censored. There are 10 lower censored observations and 4 upper censored observations for both bid distributions. It was possible for the differences in bids to be censored as well. However, we do not observe any differences of $\pm$ \$5. Harrison and Ruström (2004) discuss the possibility of bids being censored by the retail market price. The local retail price of raw oysters on the half shell was approximately \$5 per half dozen (or \$2.50 for a set of 3). The bid distributions do not suggest this was an issue.

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Table 1. Average Bids for Three Traditional and Processed Oysters

Bidding Round	Traditional	Post-harvest Processed (PHP)	Difference	Difference-in-Differences
1	1.55	1.51	0.05	---
	(1.17)	(1.14)	(0.58)	
2	1.50	0.88	0.62***	0.58***
	(1.17)	(0.95)	(1.20)	(0.12)
3	1.41	0.93	0.49***	-0.14**
	(1.22)	(1.02)	(1.23)	(0.06)
4	1.44	0.87	0.57***	0.08
	(1.28)	(0.99)	(1.21)	(0.05)

Notes: Standard errors are in parentheses. Asterisks used to indicate significance levels (*: 10%,**: 5%, ***: 1%). All values are in U.S. dollars.

Table 2. Average Bids for Three Traditional and Treated Oysters by PHP Technology

Bidding Round	Traditional	Post-Harvest Processed	Difference	Difference-in-Differences
Quick-Frozen				
1	1.54	1.45	0.09	---
	(1.04)	(0.94)	(0.47)	
2	1.19	0.91	0.27*	0.19
	(1.03)	(0.85)	(0.84)	(0.14)
3	1.12	0.97	0.15	-0.13
	(1.04)	(1.05)	(0.81)	(0.11)
4	1.07	0.89	0.18	0.03
	(1.05)	(1.00)	(0.93)	(0.08)
Pressurized				
1	1.97	1.91	0.06	---
	(1.38)	(1.30)	(0.62)	
2	1.86	0.72	1.14***	1.08***
	(1.29)	(0.87)	(1.65)	(0.30)
3	1.79	0.69	1.10***	-0.04
	(1.37)	(0.85)	(1.62)	(0.12)
4	1.73	0.63	1.10***	0.00
	(1.42)	(0.87)	(1.72)	(0.14)
Pasteurized				
1	1.69	1.77	-0.08	---
	(1.13)	(1.20)	(0.56)	
2	1.81	1.29	0.52**	0.59**
	(1.32)	(1.04)	(1.15)	(0.22)
3	1.73	1.41	0.32	-0.20
	(1.40)	(1.10)	(1.23)	(0.14)
4	1.81	1.32	0.49**	0.18
	(1.51)	(1.05)	(1.01)	(0.12)
Irradiated				
1	1.02	0.90	0.13	---
	(0.92)	(0.81)	(0.67)	
2	1.16	0.59	0.57***	0.45*
	(0.86)	(0.91)	(0.84)	(0.23)
3	1.02	0.64	0.38**	-0.19**
	(0.83)	(0.93)	(0.92)	(0.08)
4	1.16	0.66	0.50**	0.12**
	(0.92)	(0.91)	(0.86)	(0.06)

Notes: See Table 1 notes.

Table 3. Summary Statistics from Blind Taste Test

	Quick-Frozen	Pressurized	Pasteurized	Irradiated
Traditional Rating	6.93	7.33	7.87	6.2
Processed Rating	5.93	5	6.73	4.87

Table 4. Descriptive Statistics of Subject Demographics

Variable	Description	Mean	S.D	Min	Max
Gender	1 if male	0.55	0.50	0	1
Age	Age of participant	27.67	10.34	18	66
Caucasian	1 if Caucasian	0.66	0.48	0	1
Income	Family income (1 = <$ 10k to 5 >$100K)	3.11	1.16	1	5
Oyster Months	Number of months per year eats oysters	4.70	3.26	0	12
Oyster Meals	Number of oyster meals per month	4.22	4.80	0	25
Raw	Method of Consumption (1 = if raw; 2 if cooked; 3 if both)	2.23	0.94	1	3

Table 5. Distribution of Elicited Risk Preferences

Number of Safe Choices	CRRA Parameter	Classification	Index	Number of Subjects
2 or less	$-0.222 > r > -0.398$	very risk loving	-3 or less	5
3	$-0.097 > r > -0.222$	risk loving	-2	7
4	$0.000 > r > -0.097$	slightly risk loving	-1	14
5	$0.079 > r > 0.000$	slightly risk averse	0	25
6	$0.146 > r > 0.079$	risk averse	1	30
7	$0.204 > r > 0.146$	very risk averse	2	17
8 or more	$r > 0.204$	extremely risk averse	3 or more	22

Notes: Category frequencies are reported assuming subject responses were consistent. 25 percent of subjects had inconsistent responses.

Table 6. Descriptive Statistics of Elicited Beliefs

Variable	Description	Mean	S.D	Min	Max
PHP Knowledge	Knowledge of treatment process (1 = Nothing to 4 = Well informed)	1.49	0.651	1	4
Taste Difference	1 if believes traditional and treated taste different	0.66	0.47	0	1
Risk Preference Index	< 0 = loving; 0 = neutral; > 0 = averse	0.91	2.22	-5	5

Table 7. Regression Analysis of First Round Bids

	Traditional		Processed		Difference
Variable	OLS	Tobit	OLS	Tobit	OLS
Frozen	0.239	0.052	0.668	0.526	0.429*
	(0.486)	(0.512)	(0.487)	(0.513)	(0.252)
Pressurized	0.432	0.264	0.866*	0.692	0.434
	(0.518)	(0.548)	(0.519)	(0.549)	(0.269)
Pasteurized	0.393	0.257	0.949*	0.801	0.556**
	(0.500)	(0.526)	(0.501)	(0.528)	(0.259)
Irradiated	-0.412	-0.725	-0.035	-0.370	0.377
	(0.457)	(0.485)	(0.458)	(0.488)	(0.237)
Oyster Months	0.096***	0.111***	0.037	0.049	-0.058***
	(0.034)	(0.036)	(0.034)	(0.036)	(0.018)
Oyster Meals	-0.006	-0.007	-0.002	0.002	0.004
	(0.022)	(0.023)	(0.022)	(0.023)	(0.011)
Risk Difference	-0.065	-0.070	-0.032	-0.021	0.033
	(0.060)	(0.063)	(0.060)	(0.063)	(0.031)
PHP Knowledge	-0.015	-0.045	-0.036	-0.017	-0.021
	(0.212)	(0.224)	(0.213)	(0.225)	(0.110)
Taste Difference	-0.128	-0.145	-0.318	-0.381	-0.190
	(0.228)	(0.242)	(0.229)	(0.244)	(0.118)
Risk Preference	-0.094*	-0.098*	-0.096**	-0.101**	-0.002
	(0.048)	(0.050)	(0.048)	(0.051)	(0.025)
Age	0.024**	0.027**	0.025**	0.030**	0.002
	(0.011)	(0.011)	(0.011)	(0.011)	(0.006)
Male	0.250	0.267	0.050	0.060	-0.200*
	(0.206)	(0.217)	(0.206)	(0.218)	(0.107)
Caucasian	0.009	0.000	-0.167	-0.132	-0.176
	(0.219)	(0.231)	(0.219)	(0.231)	(0.113)
Income	0.134	0.144	0.146	0.138	0.012
	(0.090)	(0.095)	(0.090)	(0.095)	(0.047)
Obs	115	115	115	115	115
R^2	0.704		0.683		0.137

Table Notes: Standard errors are reported in parentheses. Asterisks used to indicate significance levels (*: 10%, **: 5%, ***: 1%). Censored data models assume lower censoring at \$0 and upper censoring at \$5. There are 10 lower censored observations and 4 upper censored observations for both bid distributions.