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# Consumer Valuation of Food Safety: The Case of Postharvest Processed Oysters

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Consumers' willingness to pay for postharvest-processed (PHP) raw oysters—oysters without health risks—is studied in experimental auction markets. The experimental design decomposes the effects of taste, objective risk information, and information on four PHP technologies on consumer 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, and the premium persists after objective information on risk and processing technologies is provided. The results are robust across PHP technologies.

**Key Words:** consumer perceptions, experimental auction market, food safety, oysters, risk preference elicitation

In October 2009, the Food and Drug Administration (FDA), dissatisfied with the result of prior efforts to reduce the number of human deaths annually associated with consumption of raw oysters, announced a controversial policy reformulation. Effective no later than May 2011, sales of raw oysters harvested from the Gulf of Mexico<sup>1</sup> and intended for sale in the interstate half-shell market would be banned during warm-weather months. The raw oysters would also be required to be treated using one of four FDA-approved postharvest-processing (PHP) technologies designed to reduce the amount of a harmful bacterium, *Vibrio vulnificus*, present in raw oysters to nondetectable levels.<sup>2</sup> While the new policy would largely eliminate the risk of death for health-compromised oyster consumers, the Interstate Shellfish and Sanitation Conference (ISSC) and industry representatives expressed serious concerns regarding both the unilateral nature of FDA's decision and potential negative impacts on the oyster industry. They believed that consumers would not be willing to switch from a

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

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

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traditional raw product to a processed one.<sup>3</sup> Based on these and other concerns, FDA issued a letter that postponed implementation until additional research into the consequences of such a ban can be completed.<sup>4</sup> The research described herein is an empirical investigation of consumer willingness to pay (WTP) for traditional and PHP oysters; its findings inform the ongoing debate regarding the economic effects of the proposed mandate. In addition, a number of unique characteristics of the experiment contribute to a 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 several factors influence consumer preferences. While processing can reduce the actual risk of a food-borne illness, it can also potentially alter the taste, texture, smell, and aesthetics of a food. Therefore, consumers' valuations of a new processed food product relative to a traditional variety are composite measures of their valuations of actual and/or perceived differences in individual characteristics of the food. Moreover, as consumers gain information, either through experience or from external sources, their preferences and resulting valuations are subject to change. Hence, information is likely to be an important determinant of consumer valuations of PHP oysters (Fox, Hayes, and Shogren 2002). It therefore is important to identify the roles that various forms of information play in consumers' WTP for improved food safety. Our experimental design allows us to identify potentially confounding effects of information regarding taste, risk, and processing technologies on consumer valuations.

Since some of the FDA-approved food-processing technologies are not yet available in the marketplace, we examine consumers' WTP for traditional and PHP oysters in a random-price auction (described under experimental design) in which the four processing technologies are considered individually.<sup>5</sup> For each technology, we conduct a session that consists of four rounds of bidding; subjects make simultaneous bids for oysters that are traditional (raw) and oysters treated with that technology. The design implements multiple bidding rounds to estimate the immediate economic impact of the FDA mandate based on oyster consumers' subjective "homegrown" beliefs. It also allows us to identify the impact of information regarding various attributes of the commodity—taste, risk, and processing technology—on consumer valuations as they become more familiar with the processed versions. While the findings on consumers' acceptance of processing technologies are specific to oyster consumers, disentangling the relative impacts of the information effects provides a significant contribution to food safety broadly.

In response to more frequent incidents of food-borne illness, researchers have increasingly used experimental studies designed to elicit consumer WTP for technologies that improve food safety (Hayes et al. 1995, Shogren et al. 1999, Fox, Hayes, and Shogren 2002, Hayes, Fox, and Shogren 2002, Nayga, Woodward,

<sup>3</sup> The ISSC is comprised of representatives from the shellfish industry and both federal (FDA and Centers for Disease Control) and state governments and is the primary body for regulatory oversight on matters involving molluscan shellfish.

<sup>4</sup> The letter announcing postponement of the ban can be retrieved at [www.issc.org/client\\_resources/fda%201-26-2010%20letter%20to%20issc.pdf](http://www.issc.org/client_resources/fda%201-26-2010%20letter%20to%20issc.pdf).

<sup>5</sup> Laboratory auctions are an established methodology for eliciting consumer valuations of 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, Fox, and Shogren 2002, Huffman et al. 2007, Lusk et al. 2004, Lusk and Coble 2005, Rousu and Shogren 2006, Rousu et al. 2007, Bernard and Bernard 2009, Marette et al. 2009).

and Aiew 2006, Rousu and Shogren 2006). In addition, several researchers have examined the roles that information about and comprehension of such technologies play in consumer valuations in experimental food markets (Fox, Hayes, and Shogren 2002, Hayes, Fox, and Shogren 2002, Lusk et al. 2004, Nayga, Woodward, and Aiew 2006, Rousu and Shogren 2006, Huffman et al. 2007, Rousu et al. 2007, Marette et al. 2009). However, the effect of taste on WTP measures for new food-safety technologies has largely been overlooked.<sup>6</sup> Particularly for fresh foods, the perceived and/or actual taste of a product is an important attribute that is likely to be affected by introduction of food-safety technologies (Melton et al. 1996). While previous economic studies of such technologies have hinted at the role of comparisons of perceived and actual taste, the present experiment systematically manipulates taste perceptions to estimate the effect of taste on consumers' WTP for foods treated with new food-safety technologies.<sup>7</sup>

The study is also unique in its comparisons of consumer WTP across multiple food-safety technologies. Examining each of the four FDA-approved technologies individually allows us to investigate the role of different technologies in valuations of a single product. Different technologies could achieve equivalent reductions in the risk of food-borne illness but have markedly different effects on consumers' perceptions of the products.

The results from the first round of bidding suggest that our average consumer is willing to pay an equivalent amount for traditional and PHP raw oysters based on their subjective beliefs. 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 WTP for the PHP oysters relative to traditional oysters decreases significantly; participating in the blind taste test 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 technologies) has a slight positive effect on consumers' WTP 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' WTP for PHP oysters, which increases the premium for the traditional product. While the information effect of each technology varies in terms of statistical significance, the resulting premiums for traditional oysters are consistent across technologies. In short, results from the difference-in-differences tests suggest that naive oyster consumers are indifferent between traditional and PHP oysters. More experienced consumers, however, place a premium on the traditional product, mostly due to degradation of taste caused by processing.<sup>8</sup>

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<sup>6</sup> Some studies have directly examined the effect of taste on WTP measures from experimental food auctions (Melton et al. 1996, Lange et al. 2002, Nalley, Hudson, and Parkhurst 2006, Napolitano et al. 2008, Combris et al. 2009) but not for new food technologies.

<sup>7</sup> In Fox et al. (1995), the subjects, who were bidding on sandwiches made from pork that contained growth enhancers, were informed 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 irradiated and nonirradiated chicken in a retail market experiment in an attempt to resolve differences in taste perceptions and taste experiences. Similarly, Noussair, Robin, and Ruffieux (2004) allowed subjects to taste genetically modified foods before bidding on them.

<sup>8</sup> In addition to the difference-in-differences tests, we conducted a regression analysis to examine consumers' bids and resulting premiums after controlling for oyster consumption behavior, risk attitudes, income, and subjective beliefs regarding the processing technologies

### ***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 it. Oysters from the Gulf of Mexico are the primary species of shellfish associated with *Vibrio vulnificus* illness in consumers (Shapiro et al. 1998). For most healthy people, ingestion of the bacterium poses little risk of serious illness. However, for individuals who have weak immune systems, including people who suffer from chronic liver disease, iron overload disease, diabetes, cancer, human immunodeficiency virus (HIV), and acquired immunodeficiency syndrome (AIDS), consumption of contaminated raw oysters can lead to severe, life-threatening health issues, the most common being acute septicemia (blood poisoning). The most recent data from the Centers for Disease Control (CDC) indicate that there is an average of 96 cases of food-borne illness associated with *Vibrio vulnificus* each year in the United States (Scallan 2011).

While thoroughly cooking oysters destroys 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, and shipped at approved temperatures to the retail market and then served raw. Because of the potential health risks associated with the oysters, both harvesting and shipping are regulated by the FDA and ISSC under the National Shellfish Sanitation Program. In 2001, a seven-year *Vibrio vulnificus* risk management plan for oysters was adopted with a specific goal of reducing the annual incidence of illnesses by 60 percent by 2008. The program's initial efforts primarily involved educating vulnerable consumers by way of fact sheets and brochures that detailed the risks associated with raw oyster consumption and implementing a limit of five hours between harvesting and refrigeration for Gulf-state producers. The program also fostered voluntary adoption of new PHP technologies by the industry. Since 2001, the frequency of reported *Vibrio vulnificus* illnesses in the core states of Florida, Louisiana, Texas, and California has declined by between 26 percent and 44 percent annually relative to the number of cases between 1995 and 1999 (ISSC 2011) but has fallen short of FDA's goals.

Consequently, FDA proposed the unilateral reformulation of its *Vibrio vulnificus* policy in October 2009 to require that all Gulf coast oysters intended for sale in the half-shell market between April 1 and October 31 be treated with one of the four FDA-approved processing technologies since warmer Gulf temperatures during that time increase the presence of the bacteria and cause approximately 90 percent of all illnesses. The mandate was naturally controversial among stakeholders in the oyster industry. On one hand, postharvest processing would reduce *Vibrio vulnificus* bacteria to nondetectable levels and thus would virtually eliminate the possibility of infection from eating raw oysters. On the other hand, harvesters and industry representatives were concerned about whether consumers would accept processed oysters and about the production costs associated with processing. Consumer attitudes toward PHP raw oysters were likely to be the most elusive component of the proposed policy since such attitudes typically are influenced by many factors, including subjective

beliefs and objective information regarding processed oysters. In this study, the experimental design elicits consumer valuations for PHP oysters and allows us to estimate both immediate and longer-term impacts of the proposed FDA policy on demand for raw Gulf oysters; that is, we estimate the difference in the WTP of naive and informed consumers.

## Experimental Design

Our experiment isolates the effects of various types of information on consumer WTP for a reduced risk of food-borne illness associated with consumption of raw oysters. After each round of bidding, we systematically manipulate the information gathered by participants regarding taste, risk, and the processing technology to measure the impact of each on consumer valuations. Consumers in the study were informed that there would be multiple rounds of bidding but were told nothing about the information they would receive before each round.

In the first round of bidding, we elicited consumers' homegrown WTP for traditional raw oysters and one of the processed types of oysters based only on their subjective beliefs.<sup>9</sup> Between bidding rounds one and two, subjects participated in a blind taste test in which they were given two samples—traditional raw oysters and PHP raw oysters—to consume and evaluate based on taste. The subjects did not know which sample was traditional and which was processed. We then revealed the identity of each type of oyster to participants before beginning the second round of bidding. Between the second and third rounds of bidding, subjects were provided with objective information on estimates of the health risk associated with consuming traditional raw Gulf oysters and the fact that PHP oysters carry virtually no risk. Finally, between the third and fourth rounds of bidding, they were given a detailed description of the four FDA-approved processing technologies.

## Experimental Protocol

In the experiment, the 30 subjects entered the room and were seated at tables. Each subject was endowed with \$15 that could be used to purchase oysters in auctions during the experiment. Any money remaining from the endowment that a participant did not spend purchasing oysters during the auctions was paid privately in cash at the end of the experiment. At each seat was a brief questionnaire that collected information on participants' demographic characteristics, oyster consumption behavior, perceptions of risks associated with consuming raw oysters, knowledge about the processing technologies, and prior beliefs regarding taste differences in traditional and processed oysters. After completing the questionnaire, subjects participated in a standard multiple-price risk-preference elicitation exercise (Holt and Laury 2002). Specifically, they completed ten binary choices for lottery pairs that involved a tradeoff between expected returns and degree of risk. One lottery choice paid either \$5 or \$3 with probability  $p$ ; the other choice paid \$0 or \$2 with probability  $1 - p$ . The probability of winning increased from 10 percent in the first choice to 100 percent in the tenth choice in increments of 10 percent to

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<sup>9</sup> The recruitment procedure informed the volunteer subjects that they would be given the opportunity to purchase raw oysters for consumption. Hence, the vast majority of our subjects consumed raw oysters on a regular basis.

induce subjects to switch from the safer choice to the riskier one. The choice at which subjects switched was used to create a risk-preference index normalized to zero for risk neutrality.<sup>10</sup>

After the participants' risk preferences were elicited, instructions regarding the auction mechanism were provided as a handout and projected at the front of the room, and the moderator read the instructions aloud. The instructions carefully explained the procedures of the random-price auction mechanism and included an example. In the auction mechanism, (i) each participant submitted a bid, (ii) each bid was rank-ordered from one to thirty, (iii) the auctioneer selected a random number ( $n$ ) indicating the  $n$ th highest bid amount, and (iv) the auctioneer sold the good to each of the  $n$  highest bidders at a price equal to the  $n$ th highest bid.

Our auction mechanism closely follows the random  $n$ th-price auction (Shogren et al. 2001) with one important exception: in our auction,  $n$  highest bidders purchase the good at a price equal to the  $n$ th highest bid. In an  $n$ th-price auction,  $n - 1$  highest bidders purchase the good at a price equal to the  $n$ th highest bid. Technically, our auction mechanism is not demand revealing since subjects have a strategic incentive to bid less than their actual WTP. This is analogous to the difference between a first-price and second-price auction. Our choice of auction mechanism was driven by three principal factors. First, because it was necessary to conduct all of the sessions in one day to ensure an equal degree of freshness for all of the oyster samples, we placed a time constraint on each session. Thus, while separation of the bid and price in an  $n$ th-price auction may be incentive-compatible, it is neither intuitive nor representative of any auction format employed outside the laboratory. Consequently, it can be difficult to explain the allocation rule to subjects (Lusk 2003). Prior studies have suggested that several repetitions may be required for experiment participants to grasp the allocation rule (Lusk and Shogren 2007). Corrigan et al. (2012), for example, conducted five practice rounds in a second-price auction. Our random-price auction simplified the allocation rule to facilitate subject learning, which allowed each session to be completed within the desired amount of time. Second, Kagel and Levin (1993) demonstrated that an increasing number of bidders reduces the strategic incentive to underbid. Since we had a relatively large number of bidders (30 subjects) in each of our markets, the incentive to underbid was diminished. Finally, there is considerable variation in the literature in elicited valuations via demand-revealing auction procedures (Ruström 1998, List 2003, Lusk et al. 2004). We thus concluded that the most useful and reliable estimates from experimental auctions are *differences* in WTP for two goods (Hoffman et al. 1993). Since we observe bids that are matched pairs, the data analysis is focused on *differences* in the simultaneous bids for traditional and processed oysters by each subject, and any strategic effect on bid amounts should have little or no bearing on differences in the bids.

The items auctioned in the experiment were a set of three traditional (unprocessed) raw oysters and a set of three PHP raw oysters, all on the half shell, for immediate consumption.<sup>11</sup> Once the moderator finished reading

<sup>10</sup> Subjects were told that one of the decisions would be randomly selected for payment using a bingo-ball cage at the end of the experiment.

<sup>11</sup> Subjects were told in advance that they would be given saltine crackers, hot sauce, cocktail sauce, and fresh sliced lemons to eat with raw oysters they purchased. In addition, each subject was provided with a bottle of water.

the instructions, subjects participated in a practice round of bidding, after which any remaining questions were answered. Subjects then participated in four auctions in which they made simultaneous bids for the traditional and PHP oysters. The participants were not told the number of bidding rounds in advance but were aware that there would be more than one round. They were told that one of the four rounds would be randomly selected and implemented as the binding round after all bidding had been concluded and that only the bids from the binding round would be revealed to participants. Subjects were informed that they would be paid in cash in private at the conclusion of the auction after they had consumed any oysters purchased.

In each bidding round, participants simultaneously submitted separate bids of between zero and five dollars for each set of oysters. In the first round, they were told which type of processing had been used on the PHP oysters and that processing reduced the risk of illness from raw oyster consumption. No other information was given. After the first round, we conducted the blind taste test. Each subject was given a single raw oyster that was labeled as "Oyster A" to consume and then was asked to indicate the type of oyster—traditional or processed—that they believed it to be and to rate the taste of the oyster on a Likert scale (the taste-test questionnaire is included in an appendix that is available from the authors upon request). They were then given a second raw oyster labeled "Oyster B" to consume and asked to rate the taste of the oyster. The order in which the traditional and PHP oyster was given was randomized across sessions with half receiving the traditional oyster first and half receiving the processed oyster first. Once participants had consumed and rated the oyster samples, the type of oyster in each sample was revealed before they were given bid cards for the second round. Thus, in the second round, the only difference relative to the first round was that they had tasted a traditional and a processed oyster. Participants made their bids in the second round and were then handed a new bid card that included information regarding the risk of illness associated with raw oysters, an estimate of the risk of contracting a *Vibrio vulnificus* infection from eating a traditional raw oyster, and a statement that processing raw oysters reduces *Vibrio vulnificus* to nondetectable levels, thereby significantly reducing the risk of illness.

The risk estimate we presented was calculated by pairing the results of two related studies. Hlady and Klontz (1996) reported on the incidence of *Vibrio vulnificus* infection among oyster consumers in Florida, estimating that an average of 10.3 adults annually contract a *Vibrio vulnificus* infection for every one million adults who consume raw oysters. Their estimate was based on cases reported to Florida's Department of Health and Rehabilitative Services between 1981 and 1993. Of course, many cases of foodborne illness never get reported because many infected individuals do not seek medical help. To account for this, we relied on the adjustment factor used by Mead et al. (1999) and used a frequency of *Vibrio vulnificus* infection of roughly twice the reported rate.<sup>12</sup> Therefore, we estimated an average annual incidence of 20 cases for every one million adult consumers of oysters in Florida (1 in 50,000).

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<sup>12</sup> To account for the total number of food-borne illnesses, Mead et al. (1999) attached multipliers to the reported cases. Their multipliers ranged from 2 to 38, and they attached low multipliers to pathogens that cause serious illness. Their reasoning was that people infected with something that severely impacts their health are likely to seek medical help so more of those cases would be documented. We take a conservative approach and use the lowest multiplier in our estimate.



In our experiment, we presented the illness estimate on the bid card in the context of oyster meals. That is, before the third round of bidding, subjects were informed that, on average, oyster consumers face a risk of 1 in 50,000 of becoming ill every time they consume an untreated raw oyster. We framed the risk information as follows to make the link between risk of illness and consumption decisions made in the experiment as salient as possible.

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.

The [PHP technology] of raw oysters after harvest reduces naturally occurring harmful bacteria to nondetectable levels, thereby reducing the risk of food-borne illness.<sup>13</sup>

After the third round of bidding was completed, subjects received the final bid card, which provided information about the processing technology used to treat the oysters via the following one- or two-sentence descriptions of the relevant process.

**Individual quick freezing** involves rapid freezing of half shell oysters on trays and 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 three to five 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.

Once the fourth round of bidding concluded, draws were made from a bingo-ball cage to randomly select the binding round and the price for each type of oyster. The bids from the binding round were displayed at the front of the room in ascending order of the subjects' identifiers. The participants then purchased the oysters they bid for in the binding round and were served a set of three freshly shucked oysters along with condiments. After all had consumed their oysters, the subjects' remaining endowments were calculated and they were paid accordingly.

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<sup>13</sup> Each bidding round, the information on the bid cards replaced the term "PHP technology" with the appropriate FDA-approved process.

**Table 1. Descriptive Statistics of Subject Demographics**

Variable	Description	Mean	Std. Dev.	Min.	Max.
<i>Gender</i>	1 if male	0.55	0.50	0	1
<i>Age</i>	Age of participant	27.67	10.34	18	66
<i>Caucasian</i>	1 if Caucasian	0.66	0.48	0	1
<i>Family income</i>	1 = less than \$10,000; 2 = \$10,000–\$24,999; 3 = \$25,000–\$49,999; 4 = \$50,000–\$99,999; 5 = \$100,000 or more	3.11	1.16	1	5
<i>Oyster months</i>	Number of months per year oysters are consumed	4.70	3.26	0	12
<i>Oyster meals</i>	Number of oyster meals per month	4.22	4.80	0	25
<i>PHP knowledge</i>	1 if subject had knowledge about the processing technology	0.42	0.49	0	1
<i>Taste difference</i>	1 if subject believed traditional and PHP oysters taste different	0.66	0.47	0	1
<i>Risk difference</i>	Difference in perceived risk: less than 0 = PHP riskier; greater than 0 = traditional riskier	0.63	1.22	–3	4
<i>Risk attitude index</i>	Less than 0 = risk-loving; 0 = neutral; greater than 0 = risk-averse	0.91	2.22	–5	5

Note: Reported values are based on 120 subject responses.

### *Subject Recruitment and Oyster Procurement*

Upper-division undergraduate and graduate students and staff and faculty members at University of West Florida (UWF) were invited to participate in the experiments using university email and electronic announcement systems. Those interested in participating self-selected into the study via a website at which they registered for one of four experiment sessions and were required to answer questions concerning existing health conditions. Respondents who indicated that they were at high risk of becoming seriously ill from eating raw oysters were precluded from participating.<sup>14</sup> Participants were informed that the session would last roughly one hour and that they must eat raw oysters during the experiment. Sessions were held in the university conference center. Table 1 summarizes participants' responses to the questionnaire and the risk preferences elicited.

In total, 120 subjects participated in the experiment through four sessions of 30 participants each. The subject pool was fairly diverse in terms of gender, age, income, and ethnicity. Fifty-five percent of subjects were male. Approximately 60 percent were 18 to 24 years of age, and the other 40 percent were fairly uniformly distributed between 25 and 66 years of age. About 66 percent were Caucasian, 12.5 percent were Latino, 8 percent were Asian, and 7 percent were African American. In terms of household annual incomes, 9 percent earned

<sup>14</sup> Individuals could not participate if they suffered from chronic liver disease, iron overload disease, diabetes, cancer, HIV, or AIDS.

less than \$10,000, 32 percent earned less than \$25,000, 60 percent earned less than \$50,000, 88 percent earned less than \$100,000, and 12 percent earned \$100,000 or more. On average, participants consumed oysters during 4.7 months of the year and in four meals per month.<sup>15</sup> More than half (58 percent) consumed both raw and cooked oysters while 35 percent ate raw oysters only. The majority of subjects were risk-averse. On average, approximately six of their ten choices in the risk-preference-elicitation exercise were safe ones (they chose the lottery with the smaller amount of variance). This pattern of risk preference is consistent with several earlier studies (Holt and Laury 2002, Lusk, Feldkamp, and Schroeder 2004).

Five types of raw oysters were used: traditional, quick-frozen, pasteurized, pressure-treated, and irradiated. The experimental market was a joint project between the authors and the Food Science and Human Nutrition Department at University of Florida, which aimed to assess sensory characteristics that influence acceptance of PHP oysters by both consumers and industry experts and their preferences for the various processes available.

For both projects, the logistically challenging component was procuring the five types of oysters. All of the raw oysters were harvested on September 6 and 7, 2010, from a single, private, open-water-lease area in Apalachicola Bay, Florida, to assure that the products were homogenous.<sup>16</sup> The oysters to be processed for use in the sensory tests and experimental auction were then transported under appropriate refrigeration to the respective treatment facility while subject to a continuous chain of custody to insure the products' identity and appropriate handling. The quick-frozen and low-heat-pasteurized oysters were processed by Webb's Seafood in Youngstown, Florida. Pressure-treated and irradiated oysters were processed by Motivati Seafood in Houma, Louisiana, and FTS, Inc. in Mulberry, Florida, respectively. All of the oysters were processed within 48 hours of harvest. The requisite quantity of oysters by type was then transported to Pensacola, Florida, to UWF for use in the experiment, which took place on September 16, 2010. It was necessary to conduct all of the sessions on the same day to ensure the same level of freshness across oyster types. In total, to account for all possible consumer behavior scenarios, 960 oysters were transported to UWF. Of that amount, 480 were traditional raw oysters and the remaining 480 oysters were processed using one of the four PHP methods (120 each of frozen, pasteurized, pressure-treated, and irradiated oysters).<sup>17</sup>

At the time of the experiment, the oysters had been harvested nine to ten days earlier, a period that is typical for commercial oyster products. Shucking was conducted by a professional shucker from a local seafood restaurant so that purchased oysters could be delivered to the participants in a timely manner with restaurant-quality presentation.

Since the experiment involved use of human subjects, institutional review board approval was obtained from both University of West Florida and Appalachian State University.

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<sup>15</sup> The average subject thus consumed oysters about 18.8 times per year, a figure that is consistent with surveys of oyster consumer behavior (Morgan, Martin, and Huth 2009).

<sup>16</sup> Apalachicola Bay was not affected by the British Petroleum oil spill in the Gulf of Mexico in 2010. Subjects were informed that the oysters were safe for human consumption.

<sup>17</sup> An approximate 20 percent oversupply of each type of oyster was required to account for any spoilage.

**Table 2. Average Bids for Three Traditional and Three Processed Oysters in Dollars**

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

Notes: Reported values are based on 120 subject bids. Average bids in U.S. dollars are reported along with standard errors in parentheses. Asterisks indicate significance levels: \* represents 10 percent, \*\* represents 5 percent, and \*\*\* represents 1 percent.

## Results

### *Aggregate Results*

Table 2 reports the average bids for traditional and PHP raw oysters for all four experimental sessions and the difference in average bid between traditional and PHP oysters for each bidding round. A positive difference indicates that, on average, subjects were willing to pay more for the traditional oysters than for PHP oysters. Dividing the differences by three (the number of oysters in each serving) determines the average premium by consumers for a single traditional oyster relative to a processed one. The difference estimate from the first round of bidding (\$0.05) shows that consumers who have only homegrown valuations are willing to pay about the same amount for traditional and less risky processed oysters. While the bids for traditional raw oysters are similar in each bidding round, the mean bid for PHP oysters declines after the blind taste test, leading to a significant difference in the average bid in the second round that persists (at the 0.01 significance level) in the third and fourth rounds.

The change in the premium for traditional oysters as bidding progressed is captured by difference-in-differences. Consider the second round of bidding, which occurred after subjects had tasted both types of oysters. In that round, the average premium for traditional oysters jumps from \$0.05 to \$0.62. In the table, the significance of the formal difference-in-differences tests is indicated by asterisks (see Wooldridge 2002). These tests are particularly powerful because they remove any confounding fixed effects (e.g., subjects' understanding of the auction mechanism or the time of day). The difference-in-differences tests indicate that actually tasting the oysters significantly reduced average WTP for PHP oysters relative to traditional oysters (i.e., information regarding taste generates a significant premium for traditional oysters). After subjects receive 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 PHP oysters significantly reduces but does not eliminate the premium for traditional oysters. This result

is not entirely surprising in light of the responses to the questionnaire eliciting subjective beliefs. Since our subjects had relatively unbiased beliefs (beliefs not influenced by us) regarding the risk of food-borne illness associated with oyster consumption, the information we provided would not induce a significant change in their beliefs. The results from the fourth round of bidding indicate that information about the processing technologies does not significantly alter the premium for traditional oysters.

Table 3 reports average bids, the difference between the bids for traditional and PHP oysters, and difference-in-difference tests of information effects in each round by PHP technology. Note that the differences in average bids are positive in nearly every case.<sup>18</sup> The first-round differences, however, are insignificant for all of the PHP technologies. This result suggests that consumers, when basing their WTP solely on their subjective, homegrown beliefs, are indifferent between a risky traditional oyster and a riskless processed oyster. As with the aggregated results shown in Table 2, the technology-specific results shown in Table 3 demonstrate that providing information about the taste of traditional and processed oysters significantly diminishes consumer valuations of PHP oysters and results in a premium for traditional oysters.

The significant effect of taste observed in the auction results is consistent with the results of the blind taste test, which are reported in Table 4. Before tasting the oysters, 59 percent of the participants believed that traditional oysters would taste better than PHP oysters. After tasting both types, 72 percent stated a preference for traditional oysters. Average ratings (on a Likert scale of 1–10) of the taste of the oysters were 7.2 for traditional oysters and 5.5 for processed oysters. Furthermore, almost 70 percent of the participants correctly identified which oysters were traditional and which were PHP based on taste. These results are consistent with Otwell et al. (2011), in which 700 consumers participated in a sensory assessment of PHP oysters from a single harvest. The authors found that the primary sensory attributes that affected consumer preferences were flavor and texture.

In our study, quick-frozen oysters were perhaps the closest substitute for traditional raw oysters. The difference-in-differences tests indicate that the information provided to the consumers did not significantly affect the difference in average bids for traditional and quick-frozen oysters. Hence, consumers may be essentially indifferent between consuming risky traditional raw oysters and safer quick-frozen oysters. Based on the premise that consumers are likely more accustomed to freezing food products to preserve their quality and not very familiar with the other PHP technologies, this result is consistent with Fox et al. (1994), which showed that familiarity with a new technology may increase consumer acceptance. For the pressure-treated and pasteurized oysters, the only significant effect is from information regarding their taste, which results in a premium for the traditional product. Bids for irradiated oysters were the most responsive to information. While the information about taste results in a significant premium for traditional oysters, information about the risk of illness significantly decreases but does not eliminate the premium. Furthermore, information describing the irradiation process is the only type of processing information that significantly increases the premium for traditional oysters.

<sup>18</sup> The one exception is the first round of bidding for pasteurized oysters.

**Table 3. Average Bids for Traditional and Processed Oysters by Technology**

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

Notes: Reported values are based on 120 subject bids. Average bids in U.S. dollars are reported along with standard errors in parentheses. Asterisks indicate significance levels: \* represents 10 percent, \*\* represents 5 percent, and \*\*\* represents 1 percent.

**Table 4. Descriptive Statistics of Taste-Test Results**

Variable	Description	Mean	Std. Dev.	Min.	Max.
<i>Prefer trad before</i>	1 if thought traditional tasted better before blind taste test	0.59	0.49	0	1
<i>Prefer trad after</i>	1 if indicated traditional tasted better after blind taste test	0.72	0.45	0	1
<i>Traditional rank</i>	Taste ranking given to traditional (1 = worst, 10 = best)	7.22	2.14	1	10
<i>PHP rank</i>	Taste ranking given to processed (1 = worst, 10 = best)	5.50	2.40	1	10
<i>Rank difference</i>	Difference between rankings (traditional rank – PHP rank)	1.72	2.73	–9	8
<i>Taste identified</i>	1 if the oyster type was correctly identified in blind taste test	0.66	0.47	0	1

Notes: Reported values are based on 120 subject responses.

### Conditional Analysis

We turn now to a conditional analysis of the WTP measures. Subject-level information from the questionnaire and the elicited risk preferences (described in Table 1) were used as controls in the regression analysis presented in Table 5. The analysis employs three models to identify factors that influence oyster consumers' WTP for traditional and PHP oysters and the premiums for traditional oysters relative to processed oysters. The dependent variables in the models are the bids for the traditional and PHP oysters. We report regression results for differences between the two bids for the pooled data set that includes all four bidding rounds using robust standard errors clustered by subject. All of the estimates are from Tobit regression models that account for censored observations.<sup>19</sup> Individual bids were restricted to between zero and five dollars for a set of three oysters of each type, and 15 percent of the bids for traditional oysters and 6 percent of the bids for PHP oysters were upper-censored.

The first four estimated coefficients shown in Table 5 represent conditional WTP for traditional and PHP oysters in the first round of bidding. The next three coefficients estimate the conditional treatment effects of information about taste, risk, and processing technologies. They indicate that the blind taste test significantly reduced WTP for PHP oysters. The average bid for both oyster types increased significantly as the number of months in a year a subject consumed oysters expanded. Average WTP for traditional oysters declined significantly as the average number of oyster meals consumed per month increased and rose significantly with household income. Risk aversion significantly decreased average WTP for both types of oysters.

In terms of premium (difference in WTP), the estimated coefficients on processing method in the first round of bidding were not significantly different from zero, confirming that the average naive consumer is indifferent between

<sup>19</sup> The local retail price of raw oysters on the half shell was approximately \$5 per half dozen (or \$2.50 for a set of three).

traditional and PHP oysters. The estimated coefficients for the information treatments confirm our main result that comparing the taste of traditional and PHP oysters results in a premium for the traditional product. While information about the risk of food-borne illness slightly reduced the premium for the traditional product, information regarding the processing technology increased the premium. In general, the regression results confirm the results from the difference-in-differences analysis.

**Table 5. Regression Analysis of Bids and Premiums**

Variable	WTP Traditional	WTP Processed	Difference All Rounds
Round 1 of Bidding			
<i>Frozen</i>	0.492* (0.284)	1.244*** (0.273)	-0.370 (0.296)
<i>Pressure-treated</i>	1.266*** (0.278)	1.145*** (0.270)	0.461 (0.297)
<i>Pasteurized</i>	1.232*** (0.288)	1.772*** (0.277)	-0.208 (0.302)
<i>Irradiated</i>	0.410 (0.256)	0.523** (0.249)	0.293 (0.270)
Bidding Round 2: <i>Taste test</i>	-0.071 (0.176)	-0.883*** (0.171)	0.814*** (0.183)
Bidding Round 3: <i>Risk info</i>	-0.175 (0.176)	-0.819*** (0.171)	0.673*** (0.183)
Bidding Round 4: <i>Technology info</i>	-0.161 (0.176)	-0.891*** (0.171)	0.764*** (0.184)
<i>Oyster months</i>	0.109*** (0.020)	0.070*** (0.020)	0.020 (0.021)
<i>Oyster meals</i>	-0.026** (0.013)	-0.009 (0.013)	-0.029** (0.014)
<i>Risk difference</i>	0.029 (0.055)	-0.016 (0.053)	0.012 (0.057)
<i>PHP knowledge</i>	-0.075 (0.129)	-0.019 (0.125)	-0.033 (0.135)
<i>Taste difference</i>	-0.083 (0.143)	-0.227 (0.141)	0.096 (0.151)
<i>Risk preference</i>	-0.071** (0.030)	-0.080*** (0.029)	0.001 (0.031)
<i>Income</i>	0.127** (0.055)	0.077 (0.053)	0.034 (0.057)

Notes: Reported values are based on 480 subject bids, four bids per subject. Estimated coefficients are reported along with standard errors in parentheses. Asterisks indicate significance levels: \* represents 10 percent, \*\* represents 5 percent, and \*\*\* represents 1 percent. There are 60 and 122 left-censored observations (at \$0) and 18 and 7 right-censored observations (at \$5) in the first and second models, respectively. The third model allows for censoring values to vary by observation; there are 19 left-censored observations and 131 right-censored observations.



## Conclusions

This study is motivated by FDA's recently proposed policy mandating that all raw oysters harvested from the Gulf of Mexico during the warmest months of the year undergo postharvest processing prior to being sold and consumed. On one hand, the policy would reduce *Vibrio vulnificus* bacteria in the oysters to nondetectable levels and, as a result, would virtually eliminate the possibility of infection from eating raw oysters. On the other hand, even with reduced risk of serious illness and potential death, consumers may not be interested in the processed raw oyster products for various reasons, including their taste. Consumer attitudes toward PHP oysters are likely influenced by many factors, including both subjective beliefs and objective information regarding them. We examine potential implications of FDA's proposed policy on consumer WTP for both traditional and PHP raw oysters. And while our WTP estimates are specific to oyster consumers' acceptance of new processing technologies, the unique experimental methodology we use to disentangle various information effects (including taste) presents a novel way to examine food-safety technologies experimentally.

We hypothesized that consumer valuations of a new food product relative to a traditional variety are composite measures of their valuations of actual and/or perceived differences in the two products' individual characteristics and that the valuations are subject to change as consumers gain additional and more objective information about the products. Our experimental design allows us to isolate individual effects of several kinds of information regarding taste, risk of food-borne illness, and processing technologies on consumers' WTP for traditional and processed oysters.

When we pool the data for the four processing technologies, our difference-in-differences tests suggest that consumers who determine WTP based solely on their homegrown subjective beliefs about the two types of oysters are willing to pay about the same amount for traditional and processed oysters.

Our results strongly indicate that processing technologies degrade the taste of raw oysters since WTP for PHP oysters declines significantly once consumers make a side-by-side comparison of the taste. The taste information creates a premium for traditional oysters relative to PHP counterparts. We find that objective information about the reduced risk of illness associated with PHP oysters slightly reduces the premium for traditional oysters and that there is no significant effect on consumer valuations from providing information describing the processing technology used. These results are supported by our regression analysis, which controlled for subject characteristics and accounted for censoring in the bid distributions.

Analysis of the information treatment effects by PHP type reveals that the negative effect taste has on consumers' WTP for PHP oysters is significant for three of the four PHP methods (pasteurized, pressure-treated, and irradiated). None of the information treatment effects are significant for oysters processed by quick-freezing. These results suggest that the quick-freezing method creates the closest substitute for traditional raw oysters.

Though the main result of the experiment—that consumers prefer traditional raw oysters to safer PHP oysters—is robust, there are some issues regarding the experiment that are worth noting. First, it is possible that the participants viewed the oysters that were auctioned as imperfect substitutes for oysters they would buy outside the laboratory. It is unlikely, however, that there is

much of a demand curve effect associated with winning three raw oysters, and the lack of statistical difference in the first-round bids suggests that this was not an issue. Second, as previously discussed, the auction mechanism allowed for the possibility of strategic underbidding. However, that was true for both traditional and PHP oysters and is a primary reason for our focus on differences between bids. Furthermore, Kagel and Levin (1993) demonstrated that the incentive to underbid is decreasing in the number of bidders. Given the size of our markets (30 bidders per experiment), strategic underbidding should be minimized. Finally, the disproportionate number of subjects who were students (evidenced by predominantly low incomes) is less than ideal. A nonstudent population would presumably have greater wealth and thus could have greater WTP, but it is unclear whether such a population would change the differences in the bids for traditional and PHP oysters since every participant was an oyster consumer.

It is intuitive that a processing technology that degrades the taste of oysters would significantly reduced consumers' WTP for such oysters, but the effect of food-safety processing on the taste of the product has largely been ignored. This research considers the effects of new processing technologies on a raw food product. Cooked foods also may be susceptible to changes in taste as processing technologies change. Our findings suggest that future research should carefully consider the role that taste perceptions and taste preferences play in consumer valuations of new food-safety technologies.

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