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RESEARCH ARTICLE

Combining sensory evaluations and experimental auctions to assess consumers' preferences for fresh fruit quality characteristics

R. Karina Gallardo[1] | Ines Hanrahan[2] | Chengyan Yue[3] | Vicki A. McCracken[4] | James Luby[5] | James R. McFerson[6] | Carolyn Ross[7] | Lilian Carrillo-Rodriguez[8]

[1]School of Economic Sciences and the Puyallup Research and Extension Center and the Center for Precision and Automated Agricultural Systems, Washington State University, 2606 W. Pioneer, Puyallup, WA 98371, USA

[2]Washington Tree Fruit Research Commission, 1719 Springwater Ave, Wenatchee, WA 98801, USA (Email: Hanrahan@treefruitresearch.com)

[3]Department of Horticultural Science and Department of Applied Economics,University of Minnesota, 1970 Folwell Avenue, St. Paul, MN 55108, USA (Email: yuechy@umn.edu)

[4]School of Economic Sciences,Washington State University, P. O. Box 646210, Hulbert Hall 101, Pullman, WA 99164, USA (Email: mccracke@wsu.edu)

[5]Department of Horticultural Science, University of Minnesota, 1970 Folwell Avenue, St. Paul, MN 55108, USA (Email: lubyx001@umn.edu)

[6]Wenatchee Tree Fruit Research and Extension Center, Washington State University, 1100 N. Western Ave., Wenatchee, WA 98801, USA (Email: jim.mcferson@wsu.edu)

[7]School of Food Science, Washington State University, P. O. Box 646376, FSHN 122, Pullman, WA 99164, USA (Email: cfross@wsu.edu)

[8]Department of Economic Sciences, Universidad Autónoma de Occidente, Cali-Colombia, Calle 5 No. 115–85, Km 2, Autopista Cali Jamundi #1252, Cali, Valle del Cauca, Colombia (Email: carrillo.li@hotmail.com)

Correspondence
R. Karina Gallardo, School of Economic Sciences and the Puyallup Research and Extension Center and the Center for Precision and Automated Agricultural Systems, Washington State University, 2606 W. Pioneer, Puyallup, WA 98371, USA.
Email: karina_gallardo@wsu.edu

Abstract

A combination of sensory evaluation and experimental auctions was used to analyze consumer preferences for external and internal quality characteristics of two fresh apple varieties "Honeycrisp" and "Gala." A group of 384 panelists in three locations in the United States evaluated the appearance, the internal quality characteristics, in three sequential rounds, for the two apple variety samples. Each panelist responded to a sensory evaluation questionnaire, and then bid on the samples in an incentive compatible second price auction. We found that panelists' bids increased with the amount of information given. Also, we found that for some attributes such as sweetness, panelists preferred levels closer to their ideal rather than objectively measured higher levels. When evaluating consumers' preference and valuation for different fresh fruit varieties, a greater explanatory power is obtained when including an indicator variable for the variety along with the set of quality attributes. The indicator variable could improve the control of inherent factors related with the varieties but cannot be observed or inferred easily. Finally, our findings add to previous studies in that flavor, when expressed as a combination of sweetness and acidity in addition to textural attributes, are important determinants of consumers' acceptance. [EconLit citations: Q13]

1 | INTRODUCTION

Research investigating consumer food choice is abundant. In general, most of such research has been conducted from the perspective of a single discipline—sensory science, economics, nutrition, food chemistry, psychology, etc. However, it is believed that a multidisciplinary approach, which includes perspectives of different disciplines, enables a more realistic modeling of food purchase behavior and thus improves results compared to what is achieved using a single discipline approach (Köster, 2003). Food choice in general is a complex decision process. A common belief held by economists studying food and nonfood decisions is that people are rational, their choices are guided by conscious motives, and explanations for their behavior can be explicitly reported (Köster, 2003). However, disciplines such as psychology postulate that consumers do not process information in a systematic way. In fact, psychologists propose that consumers use simple heuristics to select or eliminate products from their choice set on the basis of a few salient quality characteristics (Combris, Bazoche, Giraud-Héraud, & Issanchou, 2009). Hence, it is important to understand how consumers perceive and value a food product based on the available intrinsic and/or extrinsic information.

In this study we focus on consumer choice, that is, preferences and willingness to pay, for fresh apples. Fresh apples exhibit external characteristics enabling the consumer to visually differentiate across varieties. The apple variety "Red Delicious" is elongated with an external dark red color, the external surface of the variety "Gala" presents stripes with a red-orange blush color, variety "Granny Smith" has an external green color, and the external color of variety "Honeycrisp" is a combination of red and green. Apple varieties act like brand categories, in which members of one category share common characteristics that are different from other categories (Richards & Patterson, 2000). The salient differences in external appearance for fresh apples—that is, how the fruit looks, its color, shape, and size—is believed to drive a consumer's first impulse to buy the apple (Shapiro, 1983). However, subsequent purchasing decisions are influenced by a consumer's previous experiences with the eating quality of similar products or varieties (Shapiro, 1983). Some practitioners claim that a complete assessment of consumer purchase behavior requires an integration of the purchase process, driven by the food product external appearance, with the consumption process, driven by the internal quality (Mueller, Osidacz, Francis, & Lockshin, 2010).

The goal of this study is to improve the understanding of consumers' preferences for food using a dual-discipline approach by combining sensory science and applied economics. The specific objective is to investigate how consumers' ratings and standard industry instrumental measures for a selected set of quality attributes impact their willingness to pay (hereafter WTP) for two fresh apple varieties "Honeycrisp" and "Gala." We rely on sensory science by having participants evaluate appearance, taste, and texture of the apple samples; and use applied economics by having the same individuals participate in an experimental auction and bid on the same samples previously evaluated. We measure how participants like the intensity of each quality attribute by having them rate each attribute and measure the level of each attribute using standard industry instrumental measures. This allows comparing between consumers' perceptions and objective measures—provided by a laboratory instrument—for the same quality attribute.

We selected varieties "Honeycrisp" and "Gala" due to the salient differences in appearance and eating quality attributes. "Honeycrisp" is a relatively new variety, whose market acceptance has been steadily increasing since its release in 1990 by the University of Minnesota breeding program (U.S. Department of Commerce, 1990). "Honeycrisp" popularity among growers has increased as well. In Washington State, the largest producer of fresh apples in the United States, the cultivated area for "Honeycrisp" increased from 300 acres in 2001 to 9,098 acres in 2011, whereas cultivated areas for the traditional "Red Delicious" fell from 82,000 to 43,379 acres, between 2001 and 2011 (U.S. Department of Agriculture, Washington Field Office, 2011). The market success of "Honeycrisp" stems on its distinctive eating experience described as ultra crisp texture and juiciness, with a subacid taste and aromatic flavor (Luby & Bedford, 1992). Market acceptance is directly reflected in the price premiums "Honeycrisp" commands compared to other apple varieties. The 2012–2017 U.S. average retail price of "Honeycrisp" commanded a price premium of 55% compared to "Gala," 57% compared to "Fuji," and 73% compared to "Red Delicious" (U.S. Department of Agriculture, Agricultural Marketing Service, 2017). However, different from the aforementioned varieties, "Honeycrisp" requires significantly more intense and costly management to deal with production problems like biennial bearing, nutrient deficiencies,

and uneven fruit maturity, as well as postharvest disorders like soggy breakdown, bitter pit, and soft scald (DeEll & Ehsani-Moghaddam, 2010; Watkins & Nock, 2012; Watkins et al., 2005).

The rapid adoption of "Honeycrisp" and a number of other newly introduced varieties (e.g., "Ambrosia," "Envy," "Jazz," "Pacific Rose," "Piñata") is compelling evidence the fresh apple industry is more consumer oriented and even willing to invest additional resources (funds, time, and knowledge) to overcome production and handling challenges in order to satisfy consumer demands. The findings in this study provide valuable information to the industry, including the plant breeding programs developing new apple varieties, who require a solid understanding of consumer preferences and valuation of external and internal apple quality attributes.

2 | LITERATURE REVIEW

A number of single discipline-oriented investigations have analyzed consumer preferences and estimated the value consumers place on specific apple fruit attributes including appearance, eating quality, and credence. Abundant research followed a sensory science approach to elicit the drivers for consumer preferences for apples (e.g., Cliff, Sanford, & Johnston, 1999; Cliff, Stanich, & Hampson, 2014; Daillant-Spinnler, MacFie, Beyts, & Hedderley, 1996; Dinis, Simoes, & Moreira, 2011; Hampson et al., 2000; Hampson & Kemp, 2003; Harker et al., 2003; Harker, Kupferman, Marin, Gunson, & Triggs, 2008; Jaeger, Andani, Wakeling, & MacFie, 1998). In general, these studies concluded that textural and flavor eating quality characteristics were important determinants of consumer preference for fresh apples.

Numerous studies in the applied economics discipline also focused on eliciting WTP for fresh apples quality characteristics (e.g., Costanigro, Kroll, Thilmany, & Bunning, 2014; Jesionkowska & Konopacka, 2006; Kajikawa, 1998; Lund et al., 2006; Manalo, 1990; McCluskey, Horn, Durham, Mittelhammer, & Hu, 2013; McCluskey, Mittelhammer, Marin, & Wright, 2007; Yue et al., 2007Yue & Tong, 2009). Similar to findings in the sensory science literature, investigators emphasized the importance of both flavor and textural eating quality and external appearance attributes on the prices consumers were WTP for fresh apples. Fewer studies have compared hedonic panelists' ratings with WTP information. Zhang and Vickers (2014) underscored the impact on the WTP of the order of presenting information related to a product to be sensory evaluated. Seppa, Latvala, Akaichi, Gil, and Tuorila (2015) found a positive relationship between perceived pleasantness after tasting an apple and WTP. Different from the study by Seppa et al. (2015), we measured quality attributes using instrumental measures for each apple sample tasted by panelists. The sensory evaluation plus experimental auctions had also been applied to products other than apples. Melton, Huffman, Shogren, and Fox (1996) analyzed consumers' acceptance of pork chops and concluded that predicting consumer demand for fresh food based on appearance without tasting was unproductive. Lange, Martin, Chabanet, Combris, and Issanchou (2002) studied consumer acceptance and WTP for Champagnes and found that a Vickrey auction and a sensory evaluation test yielded different results according to the type of information panelists received. Killinger, Calkins, Umberger, Feuz, and Eskridge (2004) studied consumer acceptance of marbling levels on beef cuts and found that consumers' WTP was positively correlated with overall liking. Stefani, Romano, and Cavicchi (2006) conducted a sensory evaluation and WTP for spelt, a type of grain common in Europe. They found that country of origin impacted sensory evaluation and WTP. Bi, House, Gao, and Gmitter (2011) conducted a sensory taste and experimental auction on clementines and found that external appearance had a positive and statistically significant effect on bids; but this result changed when internal attributes were evaluated. Ginon, Combris, Loheac, Enderli, and Issanchou (2014) studied a group of food products such as bread, cooked ham, cheese, and orange juice to measure how consistent auction bids were with hedonic scores, they found that consumers were more consistent with the most-liked attribute compared to the least-liked attribute.

There are a handful of value elicitation methods that had been used in the applied economics literature to obtain consumers' valuation for food quality (e.g., hedonic price models, discrete choice methods, contingent valuation, and experimental auctions). Experimental auctions offer significant advantages over other value elicitation methods, since individuals participate in an active market environment, are exposed to market feedback, and face real economic consequences to the responses given. Experimental auctions are incentive compatible, that is, participants are induced to submit a bid that sincerely reflects their true value for the product being studied (Lusk & Shogren, 2007). In addition,

the auctions typically take place in a laboratory setting, enabling the control of external factors that can influence preferences and valuation. We used a Vickrey second price experimental auction. In this auction format, each participant submits a sealed bid; the highest bidder wins the auction and pays the second-highest bid for the product. The reason for using a second price auction was the advantage of being demand revealing, being relatively simple to explain to participants, and having an endogenous market-clearing price. Caveats of the Vickrey auction include individuals' overbidding behavior and loss of interest in multiple bidding rounds for low-value bidding individuals (Colson, Huffman, & Rousu, 2011). Although other mechanisms, such as the random *n*th-price auction, offer an alternative to these caveats, there is no conclusive evidence indicating which mechanism is superior. Some practitioners have claimed that second price auctions are better for individuals whose valuations are close to the market value and that random *n*th-price auctions are better for individuals whose valuations are far below the market price (Lusk & Shogren, 2007). We point to the ease of implementation of the second price auction, building on evidence that participants with no prior training and understanding of the auction mechanism could systematically bias auction results (Corrigan & Rousu, 2008).

3 | DATA

Experiments took place during October and November of 2012 in Pullman, Washington, St. Paul, Minnesota, and Portland, Oregon. In Pullman and St. Paul, recruiting advertisements were posted in different outlets (local newspapers and flyers distributed to adjacent communities) to get a representative sample of apple consumers. Individuals willing to participate registered with our research team. In Portland, the experiment took place at the Food Innovation Center. Participants were recruited from the Center's listserv of individuals with different backgrounds. The single criterion to participate in the study in all locations was that individuals had eaten fresh apples in the last three months. The experiments took place over two days at each location with four sessions on each day or eight sessions in each location, totaling 24 sessions. Each session included 16 different participants, resulting in a total of 384 participants.

All apples were procured from packinghouses in eastern Washington. We procured test fruit with a sufficient range of variability for the five quality characteristics to explain consumer preference: size, external defects, crispness, firmness, and sweetness. This variation helped ensure that panelists could differentiate the quality characteristics of the fruit used in the experiment. For example, identifying either small or large apples, or fruits with and without cosmetic external defects, was done by visual evaluation. To obtain sample fruit with contrasting levels of sweetness, we selectively procured fruit from specific sites within commercial orchards in eastern Washington that differed in the amount of sunlight received. Fruit grown in higher sunlight conditions are highly likely to have higher sweetness levels than those grown in lower sunlight conditions (Hanrahan, 2012). To ensure that the fruit had contrasting firmness, we used samples that had been held in different storage regimes: controlled atmosphere versus refrigerated atmosphere (Bavay et al., 2013). The crispness trait exhibits a high degree of genetic control and shows little response to growing location or storage conditions. Thus, we used two different varieties known to differ in crispness: "Gala," with relatively low crispness, and "Honeycrisp," with relatively high crispness (Cliff et al., 1999). To validate the necessary contrasting levels of quality characteristics, each apple fruit sample was tested and classified prior to each session. The test for sweetness was performed using a handheld refractometer (Atago, Japan), and the test for firmness used a fruit texture analyzer penetrometer (Guss Manufacturing, Stand, South Africa) The attributes and levels used in the study are in Table 1.

On the day of the experiment, researchers gave participants an overview of the goals of the research and the dynamics of the session to follow, provided $40 compensation, and conducted two trial rounds of auctions to make sure participants were familiar with the second price auction mechanism. There were in total three rounds, with the sensory evaluation occurring in the first two rounds and the auction in all three rounds. In the first round, researchers presented participants with a single pair of trays that all participants in the session viewed. The trays contained whole fresh apples, each labeled with random letters. To avoid variety recognition influencing participants' evaluation of external appearance, the apple samples exhibited in this round, were from the same apple variety—either "Honeycrisp" or "Gala"—but with contrasting sizes and external defects. We used an orthogonal experimental design where each external quality attribute had two levels, $2^2 \times 2$. We had four different attribute combinations for each apple sample,

TABLE 1 Apple attributes and the attribute levels used in the experimental design

Attributes	Attribute Levels
Size (binary variable)	Large: larger than 2.9 inches diameter
	Small: smaller than 2.9 inches diameter
External defect (binary variable)	With external defects: apples with defects at more than 3% per 40-lb box
	With no external defects: apples with defects at less than 3% per 40-lb box
Honeycrisp (binary variable)	Yes, No
Firmness (lb per square foot)	Low at 8.3, high at 24.5
Soluble solid concentration (°Brix)	Low at 9.4, high at 16.8
Acidity (g/L malic acid)	Low at 1.8, high at 6.3

for a total of eight combinations. These eight combinations were assigned to the eight sessions; these eight sessions were repeated in each of the three locations. This first round of the experiment resembled decision making in the grocery store, based on external appearance only. After viewing the apples, participants filled out a questionnaire with sensory-related questions based on their evaluation of external appearance. They were asked to rate how they liked each appearance-related quality characteristic (size and color) and the overall appearance of the apple that they were presented with using a 1–9 Likert scale (1 = dislike extremely, 9 = like extremely). They were then asked to submit a bid, in $/lb, for each of the two apple samples based on the visual inspection only. The highest and second-highest bids for the session (for round 1, referred to as round 1) were displayed to all participants.

During the second round, each respondent was presented two apple samples, each labeled with the same random letters as in the previous round. To minimize any influence of variety-distinct external characteristic on the perception of the eating quality, each sample served was peeled and sliced. To ensure variability in sweetness, crispness, and firmness at two levels ($2^3 \times 2$), we used a total of eight combinations for each apple sample, for a total of 16 combinations. Each participant received half of an apple sample for tasting. The remaining half was used to obtain standard industry instrumental measures: Acidity was measured in g/mL of malic acid, sweetness measured as soluble solid concentration (SSC) expressed in °Brix, and firmness measured as pounds per square inch (PSI). Participants were asked to taste each sample. After tasting each sample they rinsed their palate with water. Next, they responded to a questionnaire containing sensory-related questions. Similar to the process in round 1, participants were asked to rate how they liked each fruit taste and texture related quality characteristic (aroma, crispness, firmness, juiciness, apple flavor intensity, sweetness, and acidity) and how they liked the overall taste and texture of the apple sample that they tasted using a 1–9 Likert scale (1 = dislike extremely, 9 = like extremely). They were then asked to submit a bid, in $/lb, for each of the two apple samples, based on taste only. The highest and second-highest bids for the session (for round 2, referred to as round 2) were displayed to all participants.

In the third round, participants were informed that each sample they had visually evaluated in round 1 corresponded to the same sample they had tasted in round 2. Then, they were asked to submit bids considering both sets of information: appearance and taste. As in previous rounds, the highest and second-highest bids for the session (round 3) were displayed to all participants. To identify the winner of the second price auction, a binding round and a binding sample were randomly chosen in each session. Finally, participants were asked to respond to a questionnaire about their apple consumption, purchasing habits, and sociodemographic information. In sum, each panelist submitted a total of six bids, three rounds of bidding on two samples: round 1 focused on external appearance, round 2 focused on internal taste and texture, and round 3 focused on the whole apple with both external and internal attributes.

4 | EMPIRICAL SPECIFICATION

Typically censored models are used to analyze auction data. For this study, Ordinary least squares(OLS) models were appropriate because there was no evidence of censoring, as the incidence of zero bids was less than 2% in the three

rounds of bids. Three sets of regressions were analyzed, one for each bid round. In each set, the corresponding bid was the dependent variable, that is, set 1 had bid in round 1, set 2 had bid 2, and set 3 had bid 3 as the dependent variable. To measure the effect of variety-induced quality on bids, we estimated three subsets of regressions for each set: (1) including quality attribute variables plus an indicator variable for Honeycrisp, (2) including quality attribute variables and omitting indicator variable for Honeycrisp, and (3) including indicator variable for Honeycrisp by omitting quality attribute variables. In (1) and (2), we conducted two regressions one having standard industry instrumental measures and the other having participants' rating scores as independent variables. The specification for the regressions for round 1 bids is as follows:

$$Bid1_{ij} = \alpha_1 EX_{ij} + \alpha_2 Z_{ij} + \alpha_{3l} P_l + \alpha_{4d} D_{di} + \alpha_{5f} F_{fl} + e_{ij}, \quad (1)$$

where $Bid1_{ij}$ represents the bid given by participant i for apple sample j in round 1; EX_{ij} depicts appearance quality attributes: presence of external defects and fruit size measured either using instrumental measures and panelists' ratings; Z_{ij} is a binary variable that equals 1 if apple variety is "Honeycrisp," 0 otherwise; P_l is the binary indicators for location, l = Pullman, St. Paul and Portland; D_{di} is the vector of demographic variables and purchasing habits, d = age[1], ethnicity, income, presence of children, and frequency of consumption; F_{fl} is the vector of binary indicator variables depicting the eight sessions f resulting from the experimental design and conducted in each location l; α_1- α_5 are the parameter vectors to be estimated; and e_{ij} is the error term distribution with mean zero and standard deviation σ^2.

The specification for the regressions for round 2 bids is as follows:

$$Bid2_{ij} = \beta_1 IN_{ij} + \beta_2 Z_{ij} + \beta_{3l} P_l + \beta_4 W1_{fl} + \beta_{5d} D_{di} + \beta_{6f} F_{fl} + u_{ij}, \quad (2)$$

where $Bid2_{ij}$ represents the bid given by participant i for apple sample j in round 2; IN_{ij} depicts internal quality attributes: acidity, sweetness, and firmness measured either using instrumental measures and panelists' ratings; $W1_{fl}$ is the winning bid in round 1 of bids in each session f and location l; variables Z_{ij}, P_l, D_{di}, F_f are the same as for Equation (1); β_1-β_6 are the parameter vectors to be estimated; and u_{ij} is the error term distribution with mean zero and standard deviation σ^2.

The specification for the regressions for round 3 bids is as follows:

$$Bid3_{ij} = \gamma_1 EX_{ij} + \gamma_2 IN_{ij} + \gamma_3 Z_{ij} + \gamma_{4l} P_l + \gamma_5 W2_{fl} + \gamma_{6d} D_{di} + \gamma_{7f} F_{fl} + v_{ij}, \quad (3)$$

where $Bid3_{ij}$ represents the bid given by participant i for apple sample j in round 3, EX_{ij} depicts appearance quality attributes; IN_{ij} depicts internal quality attributes; $W2_{fl}$ is the winning bid in round 2 of bids in each session f and location l; variables Z_{ij}, P_l, D_{di}, F_f are the same as for Equations (1) and (2); γ_1-γ_7 are the parameter vectors to be estimated; and v_{ij} is the error term distribution with mean zero and standard deviation σ^2. Parameter estimates in all regressions were obtained using Proc Reg in SAS® v. 9.3.

In each session, the highest and second highest bids were disclosed, and the highest winning bid was included in the regressions to mitigate any effect of disclosing such information on subsequent rounds. Vickrey auctions typically involve multiple rounds to improve participants' understanding of the market mechanism and to improve the accuracy of the bids. Usually, winning bids are posted for participants to observe before the next round of bids begins (Shogren et al., 2001). However, practitioners noted that posting winning bids in subsequent rounds might affect bidding behavior. The literature concerning this issue is somewhat contrasting; some studies have shown that participants are more rational after several rounds of bidding with exposure of price feedback (Cox & Grether, 1996; Shogren et al., 2001). Another group of studies showed that the price feedback could affect subsequent bids (Corrigan, Drichoutis, Lusk, Nayga, & Rousu, 2012; Corrigan & Rousu, 2006; List & Shogren, 1999; Milgrom & Weber, 1982). In this study, we

[1] Age = 1, if age > 43, 0 otherwise, 43 was the average age of respondents. If ethnic group was white then ethnic group white = 1, 0 otherwise. If annual income >$55,938, then income = 1, 0 otherwise, $55,938 was the average income of respondents. If no children in the household, then no children = 1, 0 otherwise. If frequency of consumption <2.45, that is less than 2–3 times per month, then not frequent apple consumption = 1, 0 otherwise.

TABLE 2 Survey sample compared to U.S Census by city (in percentage)

	Pullman		St. Paul		Portland	
Variable	Census	Survey	Census	Survey	Census	Survey
Gender						
Male	51.26	34.38	48.88	26.56	49.54	32.03
Education						
Bachelor's degree or higher	66.90	76.56	35.53	60.94	40.57	67.19
Ethnicity						
White	79.26	78.91	60.11	83.59	76.09	85.16
Asian	9.38	11.20	9.38	15.00	4.69	7.10
Income						
No data	–	0.00	–	2.34	–	2.34
Less than $25,000/yr	20.67	39.06	21.43	17.97	18.00	8.59
$25,000–$34,999/yr	5.16	10.94	11.05	6.25	8.92	10.94
$35,000–$49,999/yr	12.28	15.63	11.71	20.31	12.86	24.22
$50,000–$74,999/yr	16.13	10.16	19.02	24.22	19.36	15.63
$75,000–$99,999/yr	13.72	14.06	13.40	10.94	13.79	18.75
$100,000/yr or more	32.05	10.16	23.39	17.97	27.07	19.53
Age						
18–24	58.37	21.09	18.41	7.81	12.05	3.91
25–34	17.06	29.69	22.71	18.75	24.22	21.09
35–64	19.22	46.89	46.89	57.81	50.86	62.51
65+ years	5.35	2.34	11.99	15.63	12.87	12.50

Source: U.S. Department of Commerce, United States Census Bureau, Census 2010.

posted the winning bids of each sample in each round of bids to improve the understanding of the market mechanism and including the previous round winning bid to control for any effect of posting the winning bids.

5 | RESULTS AND DISCUSSION

Table 2 compares our sample of panelists' demographics to U.S. census data for each city. In general, our sample was overrepresented in women and individuals with higher education; ages 18–24 years were underrepresented. On panelists' consumption and purchase habits, on average, participants ate apples at least once a week, shopped for two persons, and bought more than four apples.

We conducted an ANOVA test to test for bid mean differences across rounds. In all three locations, bids submitted in round 3 are statistically higher compared to bids in round 1 and 2 (Table 3). When participants have more information, here specifically information on both external and internal quality characteristics, they were WTP more compared to being presented with only external quality cues, such as in the store or only internal quality cues, such as in taste tests. In addition, we conducted the Levene (Levene, 1960) and Brown–Forsythe (Brown & Forsythe, 1974)[2] tests to compare pairwise bids variances across rounds. Results from these tests showed that bid variances were not statistically significant different across rounds (Table 3).

[2] Both tests—Levene and Brown–Forsythe—are routinely used to test for equal variances. The Levene's test performs better when the underlying population is symmetric but with moderate fat tails; while Brown–Forsythe's test performs better when the underlying population follows a heavily skewed distribution. For a specified significance level, both tests have the same decision rule: rejecting the hypothesis of equal variance if $F \geq F_{\alpha, df_1, df_2}$.

TABLE 3 Comparison of the mean and the variances of bids submitted across rounds

Mean and variance comparisons				
Mean comparison				
Location	**Bid 1**	**Bid 2**	**Bid 3**	**ANOVA *F*-test**
Pullman	1.03	1.10	1.21	3.96**
St. Paul	2.04	2.22	2.40	3.80**
Portland	1.27	1.27	1.35	1.24
Mean	1.45	1.53	1.63	6.24***
		Levene's test		**Brown–Forsythe's test**
Variance comparison		***F*-value**		***F*-value**
Ho: Var bid round 1 = Var bid round 2		0.20		2.18
Ho: Var bid round 1 = Var bid round 3		0		1.29
Ho: Var bid round 2 = Var bid round 3		0.20		0.16

** and *** denote statistically significant at the 5% and 1% level.

We conducted pairwise *t*-tests to determine whether quality attributes were different across varieties "Honeycrisp" and "Gala" (Table 4). In general, "Honeycrisp" apple samples exhibited higher acidity and lower firmness compared to "Gala." Recall that we used an experimental design in which we used a random assignment of defects, size, sweetness, and firmness. However, attributes like acidity, firmness, and sweetness were very difficult to control a priori, due to their biological nature. Interestingly, we found no differences in the panelists' ratings for acidity between "Honeycrisp" and "Gala." In contrast, we found that in general panelists assigned higher ratings for sweetness and firmness to "Honeycrisp" compared to "Gala" (Table 4).

Recall there are three sets of regressions depicting bids in each round and three subsets of regressions for each round. These subsets of regressions differ by their inclusion of the binary variable "Honeycrisp" and fruit quality variables. Regression denoted by (1) include both sets of variables; (2) include fruit quality variables but not the binary variable "Honeycrisp"; and (3) include the binary variable "Honeycrisp" but not fruit quality variables.

Results for the round 1 are presented in Table 5. In general, the parameter estimates in subset (1) are very similar to the estimates in subset (2), that is, with and without the "Honeycrisp" indicator variable. In both regressions, the presence of external defects was more salient than fruit size. In evaluating the literature describing sensory evaluation of apples, no previous studies included the presence of external defects as an apple appearance variable. A previous study reported that a large fruit size is an important quality but did not consider defects (Cliff et al., 1999). The binary variable indicator for "Honeycrisp," when included, was not statistically significant, implying that when evaluating fruit external appearance, panelists were indifferent to the "Honeycrisp" or "Gala" samples. There were significant location effects controlling for the impacts of all other variables, with bids in St. Paul higher than in the other two locations. For sociodemographic variables only panelist age was positive and statistically significant. This result contrasts with McCluskey et al. (2013) who found that older panelists were WTP less for apple samples. Some of the session dummy variables are significant (Table 5).

Results for the empirical specification explaining variations in round 2 are presented in Table 6. In the model including quality attributes and the "Honeycrisp" variable, the instrumental measure for firmness was positive and statistically significant; and the panelists' ratings for acidity, sweetness, and firmness were positive and statistically significant. When the binary Honeycrisp variable was not included, the instrumental measure for acidity was positive and statistically significant; and the panelists' ratings for acidity, sweetness, and firmness had a positive and statistically significant effect on bids. Our results for the statistical significance of sweetness concur with McCluskey et al. (2013) who found consumers' ratings for fresh apple samples sweetness were positive and statistically significant and instrumental measures were not. The lack of significance for instrumental measures on bids could reflect that panelists had

TABLE 4 Summary statistics and pairwise comparison of external and internal quality attributes, and bid submitted by apple sample variety "Honeycrisp" versus "Gala"

Variable	Units	Gala	Honeycrisp	Pairwise *t*-test Gala–Honeycrisp mean difference
Defects	Binary	0.500	0.500	0
		(0.501)	(0.501)	(0.434)
Size	Binary	0.500	0.500	0
		(0.501)	(0.501)	(0.434)
Acids	g/mL malic acid	2.890	3.300	−0.409***
		(0.395)	(0.614)	(0.675)
Sweetness	TSS (total soluble solids) °Brix	12.153	12.170	−0.010
		(1.023)	(1.109)	(1.417)
Firmness	PSI (lb per square inch)	14.845	13.658	1.187***
		(2.423)	(2.139)	(3.179)
Appearance rating	Score 1–7	6.357	6.471	−0.115
		(1.548)	(1.475)	(1.978)
Size rating	Score 1–7	6.362	6.464	−0.102
		(1.721)	(1.746)	(2.378)
Acidity rating	Score 1–7	5.461	5.630	−0.169
		(1.839)	(1.806)	(2.479)
Sweetness rating	Score 1–7	5.969	6.203	−0.234*
		(1.838)	(1.773)	(2.499)
Firmness rating	Score 1–7	5.863	6.432	−0.569***
		(1.974)	(1.719)	(2.594)
Bid round 1	$/lb	1.460	1.432	0.027
		(1.070)	(0.953)	(1.217)
Bid round 2	$/lb	1.402	1.662	−0.260***
		(1.019)	(1.048)	(1.180)
Bid round 3	$/lb	1.517	1.744	−0.226***
		(1.002)	(1.020)	(1.112)

Note: Numbers in parenthesis are standard deviations.
*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

heterogeneous preferences for the level of sweetness, that is, panelists preferred sweetness close to what they desire, and higher levels of sweetness were not necessarily better (McCluskey et al., 2013).

Results for firmness and acidity vary between the model including quality attributes and variable "Honeycrisp" (subset 1) and the model including quality attributes but not "Honeycrisp" (subset 2). For firmness, in (1) both instrumental measures and panelists' ratings were positive and statistically significant; whereas in (2) the panelists' ratings for firmness were positive and statistically significant but not the instrumental measure (Table 6). For acidity, in (1) the panelists' ratings were positive and statistically significant but not the instrumental measure; whereas in (2) both instrumental measures and panelists' ratings were positive and statistically significant. The inconsistent results for firmness and acidity could be attributed to variety-induced factors inherent to each apple variety and not captured by the variables included in the model. Also, on average firmness levels were higher for "Gala" and acidity content higher for "Honeycrisp" and no statistically significances in sweetness were found between the two varieties. Note that in both (1) and (2) the adjusted R^2 is higher for regressions including panelists' ratings compared to those including instrumental measures, indicating (1) has a better explanatory power than (2).

TABLE 5 Effects of external quality characteristics represented by instrumental measures and panelists' ratings on WTP for fresh apple samples "Honeycrisp" and "Gala"—Bid in round 1

	Parameter estimates – External quality				
	(1)		(2)		(3)
Variables	Instrumental measure	Panelists' ratings	Instrumental measure	Panelists' ratings	
Intercept	0.913***	0.165	0.899***	0.147	0.975***
	(0.188)	(0.216)	(0.185)	(0.214)	(0.166)
Fruit defect/overall appearance[a]	−0.160*	0.095***	−0.160*	0.094***	–
	(0.090)	(0.026)	(0.090)	(0.026)	
Fruit size	0.062	0.035	0.062	0.035	–
	(0.090)	(0.022)	(0.090)	(0.022)	
Honeycrisp	−0.024	−0.039	–	–	−0.024
	(0.064)	(0.063)			(0.064)
St. Paul	1.099***	1.087***	1.099***	1.087***	1.099***
	(0.084)	(0.084)	(0.084)	(0.083)	(0.085)
Portland	0.315***	0.265***	0.315***	0.265***	0.315***
	(0.083)	(0.082)	(0.083	(0.082)	(0.083)
Age	0.214**	0.199***	0.214***	0.200**	0.214**
	(0.074)	(0.073)	(0.074)	(0.073)	(0.074)
Caucasian	0.003	−0.008	0.003	−0.008	0.003
	(0.089)	(0.087)	(0.089)	(0.087)	(0.089)
Income	−0.023	−0.044	−0.023	−0.044	−0.023
	(0.071)	(0.070)	(0.071)	(0.070)	(0.071)
No children	−0.029	−0.009	−0.028	−0.008	−0.029
	(0.076)	(0.075)	(0.076)	(0.075)	(0.076)
No frequent apple consumption	0.007	0.007	0.008	0.008	0.007
	(0.067)	(0.066)	(0.067)	(0.066)	(0.067)
Session 1	−0.297*	−0.424***	−0.297*	−0.425***	−0.519***
	(0.181)	(0.127)	(0.180)	(0.126)	(0.128)
Session 2	0.249*	0.163	0.249*	0.163	0.139
	(0.143)	(0.126)	(0.143)	(0.126)	(0.128)
Session 3	0.187	0.119	0.177	0.119	0.125
	(0.156)	(0.126)	(0.156)	(0.125)	(0.128)
Session 4	−0.164	−0.269*	−0.162	−0.269**	−0.275**
	(0.143)	(0.125)	(0.143)	(0.125)	(0.128)
Session 5	0.454***	0.318**	0.453**	0.318**	0.344**
	(0.143)	(0.126)	(0.143)	(0.126)	(0.128)
Session 6	−0.008	−0.210*	−0.008	−0.210*	−0.168
	(0.157)	(0.127)	(0.157)	(0.127)	(0.129)
Session 7	−0.110	−0.156	−0.110	−0.157	−0.220*
	(0.144)	(0.127)	(0.144)	(0.127)	(0.129)

(Continues)

TABLE 5 (Continued)

Variables	Parameter estimates – External quality				
	(1)		(2)		(3)
	Instrumental measure	Panelists' ratings	Instrumental measure	Panelists' ratings	
N observations	768	768	768	768	768
Adj. R^2	0.240	0.268	0.241	0.269	0.238

Note: (1) is the regression including a binary indicator variable for "Honeycrisp," (2) is the regression omitting the binary indicator variable for "Honeycrisp," and (3) is the regression not including quality attributes. Numbers in parenthesis are standard errors.

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

[a]Presence of defects was used as instrumental measure although not measured by an instrument, the panelists' ratings for overall appearance was used when using panelists' ratings.

TABLE 6 Effects of internal quality characteristics represented by panelists' ratings and instrumental measures, on WTP for fresh apple samples "Honeycrisp" and "Gala"—Bid round 2

Variables	Parameter estimates – Internal quality				
	(1)		(2)		(3)
	Instrumental measure	Panelists' ratings	Instrumental measure	Panelists' ratings	
Intercept	−1.067**	−0.386*	−0.838**	−0.319	0.438**
	(0.416)	(0.215)	(0.415)	(0.216)	(0.185)
Fruit acidity	0.099	0.040*	0.224***	0.037*	–
	(0.075)	(0.022)	(0.067)	(0.022)	
Fruit sweetness	0.054	0.062***	0.036	0.063**	–
	(0.036)	(0.021)	(0.036)	(0.021)	
Fruit firmness	0.036***	0.041**	0.018	0.051**	–
	(0.015)	(0.019)	(0.015)	(0.019)	
Honeycrisp	0.261***	0.218***	–	–	0.263***
	(0.072)	(0.060)			(0.061)
St. Paul	0.917***	0.846***	0.898***	0.843***	0.822***
	(0.105)	(0.100)	(0.105)	(0.101)	(0.103)
Portland	0.303***	0.217***	0.288***	0.222***	0.164**
	(0.085)	(0.079)	(0.086)	(0.079)	(0.080)
Win bid round 1	0.179**	0.190***	0.178***	0.191***	0.194***
	(0.033)	(0.033)	(0.034)	(0.033)	(0.033)
Age	0.146*	0.078	0.138*	0.071	0.129*
	(0.071)	(0.070)	(0.071)	(0.070)	(0.071)
Caucasian	−0.227	−0.198**	−0.223**	−0.199**	−0.223***
	(0.086)	(0.083)	(0.086)	(0.084)	(0.085)
Income	0.024	0.032	0.032	0.034	0.034
	(0.068)	(0.067)	(0.069)	(0.067)	(0.069)
No children	−0.052	−0.018	−0.076	−0.022	−0.031
	(0.074)	(0.071)	(0.074)	(0.072)	(0.073)

(Continues)

TABLE 6 (Continued)

Variables	Parameter estimates – Internal quality				
	(1)		(2)		(3)
	Instrumental measure	Panelists' ratings	Instrumental measure	Panelists' ratings	
No frequent apple consumption	0.063	0.076	0.059	0.067	0.079
	(0.064)	(0.063)	(0.065)	(0.063)	(0.064)
Session 1	−0.079	−0.123	−0.056	−0.127	−0.080
	(0.132)	(0.128)	(0.132)	(0.129)	(0.132)
Session 2	0.268**	0.222*	0.285**	0.217	0.238*
	(0.123)	(0.120)	(0.124)	(0.121)	(0.123)
Session 3	0.240*	0.151	0.279**	0.146	0.200
	(0.124)	(0.120)	(0.125)	(0.121)	(0.123)
Session 4	−0.179	−0.156	−0.154	−0.156	−0.157
	(0.132)	(0.125)	(0.133)	(0.126)	(0.129)
Session 5	0.228*	0.206	0.257**	0.204	0.189
	(0.130)	(0.126)	(0.131)	(0.127)	(0.130)
Session 6	0.196	0.137	0.216*	0.137	0.150
	(0.127)	(0.123)	(0.128)	(0.124)	(0.127)
Session 7	0.010	−0.007	0.047	−0.012	0.013
	(0.127)	(0.123)	(0.128)	(0.124)	(0.127)
N observations	768	768	768	768	768
Adj. R^2	0.354	0.375	0.343	0.365	0.336

Note: (1) is the regression including a binary indicator variable for "Honeycrisp," (2) is the regression omitting the binary indicator variable for "Honeycrisp," and (3) is the regression not including quality attributes. Numbers in parenthesis are standard errors.

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

For round 2, when the quality variables were not included, subset (3), the binary variable "Honeycrisp" was positive and statistically significant indicating that the panelists had a strong preference for this variety, although they were not able to visually recognize it (Table 6). The estimated premium for "Honeycrisp" compared to "Gala" apples ranged between $0.218 and $0.26/lb, was lower than the premiums observed in real markets, at $0.90/lb. On average, retail prices in the Midwest and Pacific Northwest regions "Gala" apples during the month of November 2012 were sold at $1.46/lb and "Honeycrisp" at $2.36/lb (U.S. Department of Agriculture, Agricultural Marketing Service, 2017). Similar to round 1, bids in round 2 in St Paul were higher compared to other two locations. In addition, disclosing the winning bid in round 1 had a positive effect on the bids in round 2.

Panelist age had a positive and statistically significant affect on bids in round 2 (Table 6). The coefficient for ethnic group Caucasian was negative and statistically significant implying that other ethnic groups were willing to bid higher prices for the apple samples. In our sample Asian panelists were the second largest ethnic group after Caucasian, and stated a higher WTP than their Caucasian counterpart: average bids (1, 2, 3) for Asians were $1.77/lb and for Caucasians were $1.51/lb. Cliff et al. (2014) found that a higher proportion (88%) of Asian consumers preferred sweet apples compared to European/Caucasian consumers (55%). Consistent with the findings for round 1, there were some significant session dummy variables.

Results for the empirical specifications for round 3 bids are presented in Table 7. When the attributes and the "Honeycrisp" variable were included, subset (1), both the instrumental measures and panelists' ratings for firmness were positive and statistically significant, and the panelists' ratings but not the instrumental measures for sweetness

TABLE 7 Effects of external and internal quality characteristics represented by panelists' ratings and instrumental measures, on WTP for "Honeycrisp" and "Gala"—Bid round 3

	Parameter estimates – External and internal quality				
	(1)		(2)		(3)
Variables	Instrumental measure	Panelists' ratings	Instrumental measure	Panelists' ratings	
Intercept	−1.051**	−0.543**	−0.824**	−0.488**	0.367**
	(0.407)	(0.226)	(0.404)	(0.227)	(0.173)
Fruit defect/overall appearance[a]	0.005	0.034	0.022	0.035	–
	(0.084)	(0.024)	(0.085)	(0.024)	
Fruit size	0.075	0.004	0.050	0.004	–
	(0.084)	(0.020)	(0.084)	(0.020)	
Fruit acidity	0.089	0.034	0.201**	0.032	–
	(0.071)	(0.020)	(0.064)	(0.021)	
Fruit sweetness	0.047	0.037*	0.031	0.038*	–
	(0.034)	(0.020)	(0.034)	(0.020)	
Fruit firmness	0.032**	0.047**	0.016	0.056***	–
	(0.015)	(0.018)	(0.014)	(0.018)	
Honeycrisp	0.229***	0.184***	–	–	0.230***
	(0.068)	(0.057)			(0.058)
St. Paul	0.761***	0.706***	0.739***	0.705***	0.679***
	(0.098)	(0.094)	(0.099)	(0.094)	(0.095)
Portland	0.241**	0.151**	0.226***	0.155**	0.116
	(0.080)	(0.075)	(0.080)	(0.076)	(0.075)
Win bid round 2	0.310***	0.313***	0.311***	0.313***	0.323***
	(0.039)	(0.037)	(0.039)	(0.037)	(0.038)
Age	0.095	0.031	0.088	0.024	0.079
	(0.067)	(0.066)	(0.067)	(0.066)	(0.067)
Caucasian	−0.202**	−0.183**	−0.198**	−0.184**	−0.199**
	(0.081)	(0.078)	(0.081)	(0.079)	(0.080)
Income	−0.022	−0.025	−0.015	−0.024	−0.016
	(0.065)	(0.063)	(0.065)	(0.063)	(0.065)
No children	0.050	0.094	0.029	0.091	0.075
	(0.070)	(0.068)	(0.070)	(0.068)	(0.069)
No frequent apple consumption	0.058	0.076	0.055	0.068	0.075
	(0.061)	(0.059)	(0.061)	(0.060)	(0.061)
Session 1	−0.074	−0.168	−0.091	−0.172	−0.156
	(0.163)	(0.117)	(0.164)	(0.117)	(0.118)
Session 2	0.005	−0.071	−0.002	−0.074	−0.067
	(0.139)	(0.119)	(0.140)	(0.120)	(0.122)
Session 3	0.168	0.006	0.178	0.000	0.050
	(0.143)	(0.114)	(0.144)	(0.114)	(0.116)
Session 4	−0.203	−0.222*	−0.199	−0.224**	−0.223*

(Continues)

TABLE 7 (Continued)

Variables	Parameter estimates – External and internal quality				
	(1)		(2)		(3)
	Instrumental measure	Panelists' ratings	Instrumental measure	Panelists' ratings	
	(0.132)	(0.114)	(0.133)	(0.114)	(0.117)
Session 5	0.331**	0.272**	0.334**	0.271**	0.269**
	(0.135)	(0.117)	(0.136)	(0.117)	(0.119)
Session 6	−0.058	−0.126	−0.057	−0.127	−0.109
	(0.146)	(0.115)	(0.147)	(0.115)	(0.117)
Session 7	−0.032	−0.078	−0.018	−0.082	−0.072
	(0.130)	(0.115)	(0.130)	(0.116)	(0.117)
N observations	768	768	768	768	768
Adj. R^2	0.395	0.413	0.387	0.405	0.380

Note: (1) is the regression including a binary indicator variable for "Honeycrisp," (2) is the regression omitting the binary indicator variable for "Honeycrisp," and (3) is the regression not including quality attributes. Numbers in parenthesis are standard errors.

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

[a]Presence of defects was used as instrumental measure although not measured by an instrument, the panelists' ratings for overall appearance was used when using panelists' ratings.

were positive and statistically significant. When the "Honeycrisp" variable was not included, subset (2), acidity instrumental measures but not panelists' ratings were positive and statistically significant, and firmness panelists' ratings but not instrumental measures were positive and statistically significant. Round 3 results for sweetness are consistent with those from round 2; that is, panelists preferred sweetness close to what they desire, and not necessarily higher objectively measured consistent measures. However this was not observed for firmness and acidity and we attribute this lack of consistency to variety-induced attributes plus other flavor and textural factors inherent to the variety "Honeycrisp" affecting panelists' bids. Similar to round 2 regressions, the adjusted R^2 is higher for regressions including panelists' ratings compared to instrumental measures, indicating (1) has a better explanatory power compared to (2).

The estimated premium for "Honeycrisp" over "Gala" in round 3, ranged from $0.184 to $0.230/lb, a value similar to that in round 2. Consistent with the bids from round 1 and 2, bids in round 3 were higher in St. Paul compared to the other two locations. The winning bid in the previous round and panelist age had positive and statistically significant effects on bids in round 2. The coefficient for ethnic group Caucasian was negative and statistically significant. And similar to the prior two rounds, session was a significant factor impacting bids.

These results support some conclusions reached in previous studies. Generally, consumer acceptance for apples is impacted by the interaction of texture and taste. For example, Daillant-Spinnler et al. (1996) and Cliff et al. (2014), found apple consumers can be segmented into two groups: one group that liked a sweet, hard apple and a second group that preferred a juicy, acidic apple. Another study reported that although fruit firmness was the dominant factor in consumer acceptance, both sugar content and acid content were important in defining quality for specific apple varieties (Harker et al., 2008). In our study, we found that when comparing both samples side by side, consumers' WTP was driven by the attribute that was salient in one apple variety compared to the other. These attributes were acidity and firmness, with acidity levels higher for "Honeycrisp" and firmness higher for "Gala." However, we were not able to identify a precise value for acidity and firmness for which consumers were willing to pay a price premium.

Significant differences among the three locations were also found even after controlling for sociodemographic differences across the locations in the sample. Participants in sessions in St. Paul submitted the highest bids, followed by Portland, and finally by Pullman. Numerous studies have reported differences in consumer acceptance of food

products across different locations. Cliff et al. (1999) compared the consumer acceptance of seven apple varieties between two Canadian provinces, and showed that location significantly influenced both consumer acceptance and willingness to purchase. As consumers are a diverse group, identification of regional preferences and valuation of food products, including apples, would be important in the identification of market niches (Hollingsworth, 1998).

Determining key external and internal quality attributes that drive preferences and WTP remains challenging. The tendency persists to consider consumers as a homogenous group from a physiological standpoint or to characterize them by their sociodemographic information. However, as research has shown, consumer preference is based on many factors, including familiarity with the product, socioeconomic status, age, gender, culture, and social norms (Lyman, 1989).

6 | CONCLUSIONS

Evidence has shown that a multidisciplinary approach has the potential to advance the modeling the effects of the food quality profile on consumers' choice behavior. In this study, we combined sensory evaluation with monetary bids submitted in three different rounds in which information was disclosed progressively, first appearance, then taste, and finally appearance and taste. We obtained instrumental measures for salient quality attributes for each apple sample evaluated by each panelist, in this way we were able to make a side-by-side comparison of the effects of instrumental measures and panelists' ratings on bidding behavior. Findings from this study could be generalized to other food products in addition to fresh apples. For example, panelists' bids increased with the amount of information given. The highest bids were observed when panelists were presented with both appearance and experience quality characteristics. The existence of horizontal quality attributes, such as fresh apple sweetness, where panelists prefer attribute levels close to their ideal level rather than higher—objectively measured—levels. Findings with implications for fresh fruits were also presented. For example, when evaluating consumers' preference and valuation for different fresh fruit varieties, a better explanatory effect is gained when including an indicator variable for the variety along with the set of quality attributes. The indicator variable could improve the control of inherent factors related with the varieties that cannot be observed or inferred. Our findings imply that the inclusion of consumer ratings exhibit a better explanatory power for WTP, than instrumental measures. However, we should notice that more is gained when analyzing both consumer ratings and instrumental measures in an attempt to capture objective measures for consumers' most preferred levels of each quality attribute. In relation to implications for the fresh apple industry and breeding programs, our findings support previous studies in that flavor expressed, as a combination of sweetness and acidity besides textural attributes are determinant for consumers' acceptance.

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ORCID

R. Karina Gallardo http://orcid.org/0000-0002-6609-4711

REFERENCES

Bavay, C., Symoneaux, R., Maitre, I., Kuznetsova, A., Brockhoff, P. B., & Mehinagic, E. (2013). Importance of fruit variability in the assessment of apple quality by sensory evaluation. *Posharvest Biology and Technology*, *77*, 67–74.

Bi, X., House, L., Gao, Z., & Gmitter, F. (2011). Sensory evaluation and experimental auctions: Measuring willingness to pay for specific sensory attributes. *American Journal of Agricultural Economics*, *94*(2)562–568.

Brown, M. B., & Forsythe, A. B. (1974). Robus tests for the equality of variances. *Journal of the American Statistical Association*, *69*(356), 364–367.

Cliff, M. A., Sanford, K., & Johnston, E. (1999). Evaluation of hedonic scores and R-indices for visual, flavour and texture preferences of apple varieties by British Columbian and Nova Scotian consumers. *Canadian Journal of Plant Science*, *79*(3), 395–399.

Cliff, M. A., Stanich, K., & Hampson, C. (2014). Consumer research explores acceptability of a new Canadian apple - Salish™. *Canadian Journal of Plant Science*, *94*, 99–108.

Colson, G. J., Huffman, W. E., & Rousu, M. C. (2011). Improving the nutrient content of food through genetic modification: Evidence from experimental auctions on consumer acceptance. *Journal of Agricultural and Resource Economics*, *36*(2), 343–364.

Combris, P., Bazoche, P., Giraud-Héraud, E., & Issanchou, S. (2009). Food choices: What do we learn from combining sensory and economic experiments? *Food Quality and Preference*, *20*(8), 550–557. https://doi.org/10.1016/j.foodqual.2009.05.003

Corrigan, J. R., Drichoutis, A. C., Lusk, J. L., Nayga, R. M., & Rousu, M. C. (2012). Repeated rounds with price feedback in experimental auction valuation: An adversarial collaboration. *American Journal of Agricultural Economics*, *94*(1), 97–115.

Corrigan, J. R., & Rousu, M. C. (2006). Posted prices and bid affiliation: Evidence from experimental auctions. *American Journal of Agricultural Economics*, *88*(4), 1078–1090.

Corrigan, J. R., & Rousu, M. C. (2008). Testing whether field auction experiments are demand revealing in practice. *Journal of Agricultural and Resource Economics*, *33*(2), 290–301.

Costanigro, M., Kroll, S., Thilmany, D., & Bunning, M. (2014). Is it love for local/organic or hate for conventional? Asymmetric effects of information and taste on label preferences in an experimental auction. *Food Quality and Preference*, *31*(1), 94–105. https://doi.org/10.1016/j.foodqual.2013.08.008

Cox, J. C., & Grether, D. M. (1996). The preference reversal phenomenon: Response mode, markets, and incentives. *Economic Theory*, *7*(3), 381–405.

Daillant-Spinnler, B., MacFie, H. J. H., Beyts, P. K., & Hedderley, D. (1996). Relationships between perceived sensory properties and major preference directions of 12 varieties of apples from the Southern Hemisphere. *Food Quality and Preference*, *7*(2), 113–126. https://doi.org/10.1016/0950-3293(95)00043-7

DeEll, J. R., & Ehsani-Moghaddam, B. (2010). Preharvest 1-methylcyclopropene treatment reduces soft scald in "Honeycrisp" apples during storage. *HortScience*, *45*(3), 414–417.

Dinis, I., Simoes, O., & Moreira, J. (2011). Using sensory experiments to determine consumers' WTP for traditional apple varieties. *Spanish Journal of Agricultural Research*, *9*(2), 351–362. https://doi.org/10.5424/sjar/20110902-133-10

Ginon, E., Combris, P., Loheac, Y., Enderli, G., & Issanchou, S. (2014). What do we learn from comparing hedonic scores and willingness to pay data? *Food Quality and Preference*, *33*, 54–63.

Hampson, C. R., & Kemp, H. (2003). Characteristics of important commercial apple varieties. In D. Ferree (Ed.), *Apples: Botany, production and uses* (pp. 61–89). New Zealand: CABI.

Hampson, C., Quamme, H., Hall, J., MacDonald, R., King, M., & Cliff, M. (2000). Sensory evaluation as a selection tool in apple breeding. *Euphytica*, *111*, 79–90.

Hanrahan, I. (2012). Project Manager. Washington Tree Fruit Research Commission. Personal communication on October 1.

Harker, F. R., Gunson, F. A., & Jaeger, S. R. (2003). The case for fruit quality: An interpretive review of consumer attitudes, and preferences for apples. *Postharvest Biology and Technology*, *28*, 333–347.

Harker, F. R., Kupferman, E. M., Marin, A. B., Gunson, F. A., & Triggs, C. M. (2008). Eating quality standards for apples based on consumer preferences. *Postharvest Biology and Technology*, *50*, 70–78.

Hollingsworth, P. (1998). Demographic targeting comes of age. *Food Technology*, *52*, 38–45.

Jaeger, S. R., Andani, Z., Wakeling, I. N., & MacFie, H. J. (1998). Consumer preferences for fresh and aged apples: A cross-cultural comparison. *Food Quality and Preference*, *9*(5), 355–366. https://doi.org/10.1016/S0950-3293(98)00031-7

Jesionkowska, K., & Konopacka, D. (2006). The quality of apples – Preferences among consumers from Skierniewice. *Poland*, *14*, October, 173–182.

Kajikawa, C. (1998). Quality level and price in Japanese apple market. *Agribusiness An International Journal*, *14*(3), 227–234. https://doi.org/10.1002/(SICI)1520-6297(199805/06)14:3<227::AID-AGR5>3.0.CO;2-2

Killinger, K. M., Calkins, C. R., Umberger, W. J., Feuz, D. M., & Eskridge, K. M. (2004). Consumer sensory acceptance and value for beef steaks of similar tenderness, but differing in Marbling level. *Journal of Animal Science*, *82*, 3294–3301.

Köster, E. P. (2003). The psychology of food choice: Some often encountered fallacies. *Food Quality and Preference*, *14*(5-6), 359–373. https://doi.org/10.1016/S0950-3293(03)00017-X

Lange, C., Martin, C., Chabanet, C., Combris, P., & Issanchou, S. (2002). Impact of the information provided to consumers on their willingness to pay for Champagne: Comparison with hedonic scores. *Food Quality and Preference*, *13*, 597–608.

Levene, H. (1960). In contributions to probability and statistics: Essays in honor of Harold Hotelling. In I. Olkin (Ed.), *Standford studies in mathematics and statistics*. Stanford, CA: Stanford University Press.

List, J. A., & Shogren, J. F. (1999). Price information and bidding behavior in repeated second-price auctions. *American Journal of Agricultural Economics*, *81*(4), 942–949.

Luby, J. J., & Bedford, D. S. (1992). 'Honeycrisp' apple. Univ. Minnesota, Agr. Expt. Sta. Rpt. 225–1992 (AD-MR-5877-B).

Lund, C. M., Jaeger, S. R., Amos, R. L., Brookfield, P., & Harker, F. R. (2006). Tradeoffs between emotional and sensory perceptions of freshness influence the price consumers will pay for apples: Results from an experimental market. *Postharvest Biology and Technology*, *41*(2), 172–180. https://doi.org/10.1016/j.postharvbio.2006.03.011

Lusk, J. L., & Shogren, J. F. (2007). Experimental auctions Methods and applications in economic and marketing research. Cambrigde, UK: University Press.

Lyman, B. (1989). *A psychology of food – More than a matter of taste*. New York, NY: AVI. Van Nostran Reinhold Company.

Manalo, A. (1990). Assessing the importance of apple attributes: An agricultural application of conjoint analysis. *Northeastern Journal of Agricultural and Resource Economics*, *19*(2), 118–124. Retrieved from https://ageconsearch.umn.edu/bitstream/29032/1/19020118.pdf

McCluskey, J. J., Horn, B. P., Durham, C. A., Mittelhammer, R. C., & Hu, Y. (2013). Valuation of internal quality characteristics across apple varieties. *Agribusiness An International Journal*, *29*(2), 228–241. https://doi.org/10.1002/agr.21334

McCluskey, J. J., Mittelhammer, R. C., Marin, A. B., & Wright, K. S. (2007). Effect of quality characteristics on consumers' WTP for gala apples. *Canadian Journal of Agricultural Economics*, *55*(2), 217–231. https://doi.org/10.1111/j.1744-7976.2007.00089.x

Melton, B. E., Huffman, W. E., Shogren, J. F., & Fox, J. A. (1996). Consumer preferences for fresh food items with multiple quality attributes: Evidence from an experimental auction of pork chops. *American Journal of Agricultural Economics*, *78*(4), 916–923.

Milgrom, P. R., & Weber, R. J. (1982). A theory of auctions and competitive bidding. *Econometrica*, *50*(5), 1089–1122.

Mueller, S., Osidacz, P., Francis, I. L., & Lockshin, L. (2010). Combining discrete choice and informed sensory testing in a two-round process: Can it predict wine market share? *Food Quality and Preference*, *21*(7), 741–754. https://doi.org/10.1016/j.foodqual.2010.06.008

Richards, T. J., & Patterson, P. M. (2000). New varieties and the returns to commodity promotion: The case of Fuji apples. *Agricultural and Resource Economics Review*, *29*(April), 10–23.

Seppa, L., Latvala, T., Akaichi, F., Gil, J. M., & Tuorila, H. (2015). What are domestic apples worth? Heconic responses and sensory information as drivers of willingness to pay. *Food Quality and Preference*, *43*, 97–105.

Shapiro, C. (1983). Premiums for high quality products as returns to reputation. *Quarterly Journal of Economics*, *98*, 659–680.

Shogren, J. F., Cho, S., Koo, C., List, J., Park, C., Polo, P., & Wilhelmi, R. (2001). Auction mechanisms and the measurement of WTP and WTA. *Resource and Energy Economics*, *23*(2), 97–109.

Stefani, G., Romano, D., & Cavicchi, A. (2006). Consumer expectations, liking and WTP for specialty foods: Do sensory characteristics tell the whole story? *Food Quality and Preference*, *17*(1-2), 53–62. https://doi.org/10.1016/j.foodqual.2005.07.010

U.S. Department of Agriculture, Agricultural Marketing Service. (2017). Market News Specialty Crops Fruits. 01 April 2017. Retrieved from https://www.marketnews.usda.gov/mnp/fv-nav-byCom?navClass=FRUITS&navType=byComm

U.S. Department of Agriculture, Washington Field Office. (2011). Washington Tree Fruit Acreage Report. 20 June 2016. Retrieved from https://www.nass.usda.gov/Statistics_by_State/Washington/Publications/Fruit/

U.S. Department of Commerce. (1990). United States Patent Plant 7,197. 5 May 2015. Retrieved from https://webcache.googleusercontent.com/search?q=cache:4Ki5HQbjr4UJ:pAtentimages.storage.googleapis.com/pdfs/USPP7197.pdf+&cd=1&hl=en&ct=clnk&gl=us

Watkins, C. B., Erkan, M., Nock, J. F., Iungerman, K. A., Beaudry, R. M., & Moran, R. E. (2005). Harvest date effects on maturity, quality, and storage disorders of "Honeycrisp" apples. *HortScience*, *40*(1), 164–169.

Watkins, C. B., & Nock, J. F. (2012). Controlled-atmosphere storage of "Honeycrisp" apples. *HortScience*, *47*(7), 886–892.

Yue, C., Jensen, H. H., Mueller, D. S., Nonnecke, G. R., Bonnet, D., & Gleason, M. L. (2007). Estimating consumers' valuation of organic and cosmetically damaged apples. *HortScience*, *42*(6), 1366–1371. Retrieved from: https://doi.org/

Yue, C., & Tong, C. (2009). Organic or local? Investigating consumer preference for fresh produce using a choice experiment with real economic incentives. *HortScience*, *44*(2), 366–371.

Zhang, K. M., & Vickers, Z. (2014). The order of tasting and information presentation in an experimental auction matters. *Food Quality and Preference*, *36*, 12–19.

AUTHOR'S BIOGRAPHIES

Gallardo holds a BS in Food Science from Universidad Nacional Agraria La Molina in Lima, Peru, a MS in Agricultural Economics from Mississippi State University, and a PhD in Agricultural Economics from Oklahoma State University. Her primary research and outreach program goal is to enhance value-added agribusiness opportunities for specialty crops in the state of Washington. Her areas of research are focused on consumer demand analysis and economics of technological change. Gallardo is conducting research assessing consumers' preferences for fresh fruit quality, and understanding the profitability and various other factors affecting growers' adoption of new technologies, such as new cultivars, improved pest management systems, and labor enhancing mechanisms.

Hanrahan holds a BS in Horticulture from Humboldt University, Berlin, Germany and a PhD in Horticulture from Washington State University. She is Project Manager with the Washington Tree Fruit Research Commission (WTFRC) since 2005. Her expertise includes the management of technical projects related to temperate tree fruit quality such as: apple fruit finish improvement, methods to prevent rain-induced cherry cracking, apple postharvest physiological disorder prevention, optimization of cropping and storage systems to produce consistently high yields of target fruit, management of plant material evaluation from breeding programs for commercial suitability, and applied food safety research in the areas of water quality, preharvest die-off, and postharvest systems management. Hanrahan primary focus is on managing these various projects, expedite transfer of research results to implementation, to provide an ongoing link between scientists and the industry, and to train the next generation of industry professionals.

Yue holds a BA in English from Tianjin University in China, a B.Eng. from Tianjin University, a MS in Quantitative Economics and Management from Tianjin University, a MS in Statistics from Iowa State University, and a PhD in Economics from Iowa State University. Her research interests are analysis of horticultural product trade and marketing, development of estimation methodology of technical barriers to trade, evaluation of alternative strategies for addressing statewide and national demand for, and distribution of, horticultural crops through the application of marketing and economic principles and tools.

McCracken hold a BA in Economics and Home Economics from Indiana University, a MS in Agricultural Economics from Purdue University, and PhD in Agricultural Economics from Purdue University. Her research interest is in consumer marketing and econometrics.

Luby holds a BS in Agronomy Crop Science from Purdue University and a PhD in Plant Breeding and Genetics from University of Minnesota. The primary goal of his research is to develop, evaluate, and introduce fruit cultivars with horticultural, disease and pest resistance, and fruit quality characters desired by growers and consumers in Minnesota and surrounding areas. The breeding programs concentrate on apple and grape. Research aims to determine the inheritance of these traits and, where appropriate, map important loci using molecular markers for use in marker-assisted breeding. Recent or current examples include traits related to fruit quality and scab resistance in apple, resistance to apple scab, and low temperature responses, disease resistance, sex type, and fruit quality in grape derived from wild Vitis riparia.

McFerson holds a BS in Horticulture from University of Wisconsin-Madison, a MS in Horticulture from Texas A&M, and a PhD in Plant Breeding and Genetics from the University of Wisconsin-Madison. Jim has been the manager of the Washington Tree Fruit Research Commission since 1999, and is also an adjunct faculty member with WSU's Horticulture Department. He has been active in pursuing the National Tree Fruit Technology Roadmap and many industry research groups including Rosaceous Genomics, Genetics, and Breeding Executive Committee, Tree Fruit Technical Advisory Committee, Prunus, Pyrus, and Malus Crop Germplasm Committees, and U.S. Apple Research Committee Specialty Crops Research Team.

Ross holds a BS in Human Ecology and Nutrition from University of Manitoba, a MS in Food Science from University of Guelph, and PhD in Food Science/Environmental Toxicology from Michigan State University. Her research expertise combines sensory evaluation with analytical chemistry techniques to identify and describe changes in foods and wines. As the importance of sensory properties to food/beverage acceptance and enjoyment is critical, her research focus is to explore all sensory dimensions of foods and beverages, including aromas, flavors, tastes, texture, and sound.

Carrillo-Rodriguez holds a BS and MS in Economics from Pontificia Universidad Javeriana in Bogota Colombia, a PhD in Economics from Washington State University. Her research interests are consumer demand, marketing of foods, and price analyses.

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