Willingness to Pay for Blueberries: Sensory Attributes, Fruit Quality Traits, and Consumers' Characteristics

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Abstract. **Understanding consumers' preferences for fruit quality attributes is key to informing breeding efforts, meeting consumer preferences, and promoting increased market demand. The objective of this study was to assess the effect of fruit quality traits and hedonic sensory evaluation on consumers' willingness to pay (WTP) for a selection of fresh northern and southern highbush blueberry cultivars. The WTP was elicited by using a double-bounded contingent valuation conducted in conjunction with a consumer sensory test. Two types of models were estimated using either sensory evaluations (i.e., consumer preference and consumer intensity) or instrumental measurement data (i.e., measures of soluble solids, titratable acidity, sugars, acids, and firmness) as explanatory variables to model WTP. Results using sensory evaluations indicated that flavor liking, flavor intensity, and sweetness intensity are key factors that influence consumers' acceptance and WTP for blueberries. A regression analysis using instrumental measurements indicated that measures related to sweetness and acidity traits are important factors that determine WTP. Higher WTP was associated with higher total sugar content across different levels of total organic acid. The WTP increases with organic acid content, because this is needed for enhanced flavor; however, WTP declines at high concentrations of organic acid. Except for extreme values of firmness, the WTP increased as measures of fruit firmness increased, indicating a consumer preference for firmer blueberries. Overall, the results provided new insights into the relationships between consumer preference and WTP and fruit quality benchmarks to select for improved quality.**

Blueberries are one of the most economically important berries produced in the United States. The annual per capita consumption of blueberries increased from 0.09 kg per person in 2000 to 1.04 kg in 2021, which is an increase of 879% (US Department of Agriculture, Economic Research Service 2023). Year-round demand for blueberries has also increased; to meet this demand, domestic production and imports have expanded (Brazelton et al. 2023). For example, US blueberry production grew 346% from 2000 to 2021, and imports grew more than 1460% during this same period (US Department of Agriculture, Economic Research Service 2023). The growth in supply is the result of new acres planted, new producers, and new cultivars in the market. However, the surge in US blueberry imports has surpassed the growth in domestic production during the last decade, thus raising fears of import competition for domestic growers (Yeh et al. 2023). In view of this growth, Brazelton et al. (2023) suggested that the North American blueberry market has become more selective and quality-driven and, as such, genetic gains will play a key role in sustaining the growth of the US industry. Therefore, it is important for the US industry and blueberry breeders to identify the fruit quality-related traits that would increase demand and per capita consumption.

Despite the significant growth experienced by the blueberry industry, a 2023 consumer survey showed that only 37% of shoppers purchased fresh blueberries within the past 12 months, with larger market participation (42%–47%) among households with incomes more than $50,000 (The Packer 2023). This survey also revealed that 14% of survey respondents were new blueberry shoppers. Insights from this survey suggest that there are opportunities for the blueberry industry to attract new blueberry customers and turn first-time purchases into repeat purchases to further drive market expansion. Meeting consumer preferences for fruit quality attributes is key to promoting demand-driven growth. Therefore, the use of consumer-informed selection of fruit quality traits demanded by the market is an important element that can guide breeding decisions (Gilbert et al. 2014).

The demand for blueberry quality attributes in the market is driven by both retailers and consumers. In many instances, fruit traits are selected based on agronomic (e.g., yields) and storage performance, which are geared toward meeting production and supply chain needs (Edger et al. 2022; Gilbert et al. 2014). However, consumers usually demand different fruit quality attributes such as flavor, texture, and appearance. In addition, although not a direct indicator of quality, fruit size is another attribute that increasingly demands a premium in the market (Brazelton et al. 2023). Flavor attributes, particularly sweetness and sourness, are generally thought to be the main drivers of consumers' acceptance and willingness to buy blueberries (Brazelton et al. 2023; Saftner et al. 2008). For example, Gilbert et al. (2015) found that fructose was the main factor that explained overall liking,

and they also identified the importance of firmness in the sensory liking of blueberries. Similarly, a study by Gilbert et al. (2014) identified flavor as the main sensory characteristic that impacts purchasing intentions. Volatile organic compounds have been shown to play an important role in aroma perception and, therefore, overall liking (Colantonio et al. 2022; Ferrão et al. 2022). Colantonio et al. (2022) recently showed that aroma perception, which is dictated by the type and concentration of volatile organic acids, had the same effect on overall consumer liking as total sugar and acids contents in tomato and blueberry fruits. Many of the fruit quality traits (e.g., flavor, aroma, and texture) demanded by consumers coincide with breeding priorities reported by the blueberry industry (Gallardo et al. 2018).

A standard approach used to assess consumer preferences for food products involves determining the consumers' willingness to pay (WTP) and evaluating the factors (e.g., food attributes, consumer characteristics) that affect consumers' purchase intentions and levels of WTP. Although hedonic traits play an important role in consumers' preferences for food products and repeat purchase rates, sensory attributes are not always included when determining the WTP (Yang et al. 2009). Although sensory analyses are used to elicit consumer preferences for intrinsic sensory characteristics, studies do not always assess consumers' WTP for the products evaluated. This aspect is important because consumers face budget constraints and economic trade-offs when making purchasing decisions (Combris et al. 2009). Some studies have used both sensory evaluations and chemical analyses to relate consumer liking and sensory intensity ratings with biochemical

instrumental measures of blueberry quality traits (Gilbert et al. 2014, 2015; Saftner et al. 2008). The use of sensory analysis in conjunction with WTP elicitation methods have been adopted to study consumer acceptability of other fruits, including apples and pears (Gallardo et al. 2018, 2023; McCluskey et al. 2013; Yang et al. 2009).

The main goal of our study was to evaluate how consumers' hedonic sensory liking, sensory intensity scores, and fruit biochemical instrumental measures influence what consumers are willing to pay for blueberries. Therefore, we elicited WTP and sensory scores from participants in Oregon and Florida using a blind sensory test followed by a double-bounded contingent valuation of blueberry cultivars over the course of 2 years. We used regression analyses to examine the relationship between the WTP for blueberries and sensory (hedonic liking or sensory intensities) or instrumental measures of fruit quality traits. Thus, rather than focusing on the specific cultivars tasted by participants, we focused on the attributes of the blueberries evaluated and how these attributes correlated to participants' sensory evaluation and influenced consumers' WTP for blueberries. To the best of our knowledge, this is the first study of blueberries to relate WTP to both consumer preferences and instrumental measurements.

Materials and Methods

Plant material. Fifty-two blueberry cultivars, including 26 predominantly northern highbush (NHB) and 26 southern highbush (SHB), were used in this study. The blueberry cultivars were harvested and evaluated in 2021 and 2022. These cultivars are listed in the Supplemental Appendix (Table A1). The NHB cultivars were grown in Oregon at a commercial farm (Fall Creek Farm & Nursery, Inc.) located in Lowell, OR, USA. The SHB cultivars were grown in Florida at the Plant Science Research and Education Unit in Citra, FL, USA. The materials were grown using standard agronomic management practices. For each cultivar, approximately 3 kg of fully ripe blueberry fruits were harvested 1 d before each sensory test. Fruit were randomly subsampled for the sensory analysis and instrumental chemical and texture analysis. Samples for sensory and texture analyses were stored at 4 °C with 95% relative humidity until evaluations were performed (within 24 h). Samples intended for the fruit chemistry analysis were frozen and stored at −80 °C until they were processed.

Chemistry analysis. The chemistry analysis included an evaluation of the soluble solids content (SSC), pH, titratable acidity (TA), sugars (fructose, glucose, and sucrose), and organic acids (citric acid, malic acid, shikimic acid, quinic acid). Puree from three replicates

Table 1. Summary statistics of demographic, sensory test, biochemical, and texture variables.

	Pooled sample	Florida 2021	Florida 2022	Oregon 2021	Oregon 2022
Demographics			Mean ± *SD*		
Age	38.96 ± 16.34	28.99 ± 10.65	28.83 ± 11.40	48.60 ± 14.84	47.28 ± 15.23
Female	0.63 ± 0.48	0.62 ± 0.48	0.64 ± 0.48	0.72 ± 0.45	0.53 ± 0.50
Income (>$50,000)	0.50 ± 0.50	0.61 ± 0.49	0.62 ± 0.49	0.36 ± 0.48	0.43 ± 0.50
Weekly blueberry consumption	0.61 ± 0.49	0.50 ± 0.50	0.47 ± 0.50	0.79 ± 0.41	0.62 ± 0.49
Liking scores (1 dislike extremely–9 like extremely)					
Appearance	7.19 ± 1.59	7.05 ± 1.45	7.01 ± 1.52	7.48 ± 1.60	7.15 ± 1.74
Texture	6.80 ± 1.68	6.81 ± 1.56	6.69 ± 1.68	6.99 ± 1.68	6.62 ± 1.78
Flavor	6.55 ± 1.87	6.50 ± 1.80	6.43 ± 1.89	6.81 ± 1.79	6.37 ± 1.99
Overall	6.61 ± 1.79	6.57 ± 1.71	6.46 ± 1.84	6.89 ± 1.69	6.44 ± 1.92
Attribute intensity ratings (0 low–100 high)					
Sweetness	53.50 ± 25.77	48.26 ± 23.86	44.87 ± 25.36	62.57 ± 24.11	55.81 ± 26.20
Sourness	40.98 ± 27.67	39.31 ± 27.14	43.20 ± 27.83	39.90 ± 27.18	42.14 ± 28.55
Firmness	58.94 ± 24.95	55.38 ± 23.16	53.11 ± 24.20	67.37 ± 24.20	57.53 ± 25.73
Juiciness	60.09 ± 23.85	55.68 ± 21.93	54.58 ± 24.38	66.70 ± 23.39	61.71 ± 23.70
Overall flavor	61.03 ± 25.16	56.97 ± 23.37	56.14 ± 25.82	67.51 ± 24.22	61.83 ± 25.77
Instrumental measures					
Height (mm)	17.58 ± 2.09	18.31 ± 1.50	17.59 ± 1.62	16.76 ± 2.21	17.82 ± 2.49
pH	3.47 ± 0.34	3.59 ± 0.35	3.34 ± 0.32	3.55 ± 0.30	3.36 ± 0.30
SSC	12.06 ± 1.74	11.10 ± 1.23	10.07 ± 0.88	13.52 ± 0.94	13.14 ± 1.00
TA	0.49 ± 0.20	0.41 ± 0.16	0.58 ± 0.28	0.44 ± 0.13	0.55 ± 0.19
SSC:TA ratio	29.29 ± 12.30	32.88 ± 12.01	20.70 ± 8.10	33.30 ± 9.20	28.20 ± 14.84
Total sugars (mg/g dw)	692.41 ± 65.86	728.26 ± 44.71	625.15 ± 53.84	697.39 ± 60.64	709.52 ± 55.96
Organic acids (mg/g dw)	61.87 ± 33.50	44.77 ± 19.40	96.40 ± 45.25	50.31 ± 17.03	63.34 ± 22.96
Total sugars:organic acids ratio	14.70 ± 8.90	20.25 ± 10.84	8.07 ± 3.81	15.41 ± 5.14	13.81 ± 9.38
Mean internal force (N)	0.39 ± 0.09	0.37 ± 0.06	0.40 ± 0.08	0.39 ± 0.09	0.41 ± 0.13
Maximum force (N)	1.87 ± 0.36	1.91 ± 0.34	1.91 ± 0.26	1.79 ± 0.33	1.87 ± 0.45
Young's modulus (MPa%)	4.24 ± 1.51	5.69 ± 1.07	4.28 ± 0.88	3.48 ± 1.34	3.46 ± 1.39
Cultivars, no.		20	16	20	16
Panelists, no.	389	90	95	104	100

dw = dry weight; SSC = soluble solids content; TA = titratable acidity.

(fruits were collected from one plant and sub-sampled as three aliquots prior to processing) per cultivar were prepared and used to measure SSC, pH, and TA, as outlined by Perkins-Veazie et al. (2021). Sugars and organic acids of freeze-dried blueberry powders were evaluated using high-performance liquid chromatography and a Hitachi LaChrom (Tokyo, Japan) according to the methods described by Perkins-Veazie et al. (2016, 2021).

Texture analysis. For the texture analysis, 10 fully ripened berries that were free of visible external defects and disease were selected for each genotype, placed into plastic 188-mL portion cups (Uline, Pleasant Prairie, WI, USA), and covered with lids with five equidistant holes with a 3-mm diameter. The containers were placed on shallow cardboard box trays, covered with large plastic bags, and kept in a cooler set at 3 °C with 95% relative humidity. After storage, fruits were evaluated to determine texture parameters and size or weight. Before measurement, the 10 berries were warmed to room temperature. Texture parameters and size were evaluated using the penetration method and a TA.XTPlus Texture Analyzer (Stable Micro Systems, Hamilton, MA, USA), as previously described by Oh et al. (2024). The penetration test was performed using a 2-mm flat cylinder probe (TA-52) at a test speed of 1 mm/s to a final depth of 80% strain on the equatorial axis of the fruit perpendicular to the probe. The trigger force was set to 0.5 N, with 100 data points collected per second.

Mean values obtained from the chemical and mechanical analyses are reported in Table 1. These instrumental measurements were used as explanatory variables in a series of regression analyses to identify the quality traits that affect participants' WTP for the blueberry cultivars evaluated during the sensory taste test.

Sensory taste evaluation. In 2021 and 2022, consumer sensory tests were conducted to evaluate a selection of blueberry cultivars at the sensory laboratories of both the University of Florida and the Oregon State University Food Innovation Center in Portland. Each year, these evaluations were performed from late March and April in Florida and from July to August in Oregon (Supplemental Appendix Table A2). A total of 389 panelists participated in the study. In Florida, 90 panelists participated in the study and evaluated 20 SHB cultivars in 2021, and 95 panelists evaluated 16 cultivars in 2022. In Oregon, a panel of 104 participants evaluated 20 NHB cultivars in 2021, and 100 panelists evaluated 16 cultivars in 2022 (Table 1). Panelists were recruited from the area surrounding Gainesville, FL, USA, for the Florida tasting, and from Portland, OR, USA, for the tasting in Oregon. During each year, the same panelists evaluated all the cultivars at both locations. Participants received a small monetary incentive for their participation. Each year, the sensory test was conducted across four separate sessions at each location, thus allowing panelists to evaluate a maximum of five cultivars per session. This approach was adopted to mitigate fatigue and reduce the cognitive burden during each session.

When panelists arrived at each sensory laboratory, they received instructions about the sensory test and contingent valuation survey. Panelists were assigned to a booth and presented five samples per session. Samples were served using a balanced Williams design and equally assigned across panelists in each location. Each sample consisted of approximately five to six berries served in glass bowls labeled with three-digit random numbers. Panelists were first asked to evaluate the appearance without tasting the sample. Next, panelists were asked to eat two to three blueberries to evaluate flavor and texture attributes. Panelists evaluated each cultivar and indicated how much they liked or disliked the appearance, flavor, texture, and the sample overall using a 9-point hedonic scale (1 = dislike extremely; 9 = like extremely). Next, using a 100-point scale, panelists rated the sweetness (0 = low sweetness; 100 = high sweetness), sourness (0 = low sourness; 100 = high sourness), firmness (0 = soft; 100 = very firm), juiciness (0 = not juicy at all; 100 = very juicy), and overall flavor (0 = low flavor intensity; 100 = high flavor intensity) of each sample. Panelists cleansed their palate in between samples with a bite of an unsalted cracker and a sip of water.

Willingness to pay elicitation and estimation methodology. The study used a double-bounded dichotomous contingent valuation to elicit participants' WTP for each cultivar in conjunction with the sensory test. The contingent valuation method consists of asking participants whether they would purchase a product at an offered price using a dichotomous choice (i.e., "yes/no" question) in a hypothetical setting. With the double-bounded method, participants are shown two consecutive bid prices—with the second bid being contingent upon the answer to the first bid—to help narrow the potential range of WTP values (Hanemann et al. 1991). The "yes/no" questions were used because they are simpler for respondents to evaluate compared with open-ended WTP questions.

After completing a sensory evaluation of a blueberry sample and subsequently completing the hedonic questionnaire of the corresponding blueberry cultivar, participants were asked if they would be willing to pay $3.29 for a 6-ounce (170-g) clamshell of the same cultivar. This initial price shown to participants was based on a representative average market price at national grocery stores at the time of the sensory tasting. Every panelist was shown the same initial bid (B^1) for each of the cultivars evaluated. Then, participants were presented with a follow-up question showing a lower or higher bid price (B^2) contingent upon their response to the first question. If participants responded "yes" to the first question—meaning they were willing to pay the first bid amount ($B^1 = 3.29$)—then they were randomly shown a higher price from a set of five price options ($3.39, $3.49, $3.59, $3.69, or $3.79). If participants responded "no" to the first question—meaning they were not willing to pay the initial price offered—then they were shown a lower bid price randomly selected from set of five price options ($3.19, $3.09, $2.99, $2.89, or $2.79). Participants also completed a survey with questions regarding demographics and blueberry consumption preferences.

Although we did not directly observe an individual's true WTP, we knew it was within the $[B^1, B^2]$ interval based on participants' responses to the two consecutive WTP questions. Respondents were expected to answer "yes" to each WTP question if their WTP was greater than or equal to the bid price B offered (i.e., $WTP_i^* \geq B$). Based on participants' responses to the two consecutive WTP questions, we obtained four potential intervals for the WTP for each participant:

1. "yes/yes" if a participant accepted both bids, indicating that the participant i's WTP was greater than or equal to the second (higher) bid B^2. Thus, $B^2 \leq WTP_i^* < \infty$.

2. "yes/no" if a participant accepted the first bid but rejected the second bid, indicating that the WTP was between the initial first bid B^1 and second (higher) bid B^2. That is, $B^1 \leq WTP_i^* < B^2$.

3. "no/no" if a participant rejected both bids, indicating that the WTP was less than the second (lower) bid B^2, and $0 < WTP_i^* < B^2$.

4. "no/yes" if a participant rejected the first bid but accepted the second bid, indicating that the WTP was less than the first price bid B^1 but greater than the second (lower) price bid B^2. Hence, $B^2 \leq WTP_i^* < B_1$.

We assumed that each participant i had WTP for the blueberries evaluated during the sensory test that was equal to WTP_i^* and could be modeled as a function of a set of explanatory variables ($_t$) such that:

$$WTP_i^* = \boldsymbol{\beta}' \boldsymbol{x}_i + u_i \quad \text{for } i = 1, .., n \qquad [1]$$

where β is a vector of parameters to be estimated and u_i is the error term assumed to be normally distributed [$u_i \sim N(0, \sigma_2)$]. The unit of analysis during this study was the participant, not the cultivar. That is, each observation represented the respondent i's evaluation of a cultivar.

The model parameters could be estimated using the maximum likelihood approach. The contribution of each potential response from the WTP questions to the likelihood function is as follows: the probability from the "yes/no" and "no/yes" responses were written as $Pr(B^1 \leq WTP_i^* < B^2) = Pr(B^1 \leq '\boldsymbol{x}_i + u_i < B^2)$ and $Pr(B^2 \leq WTP_i^* < B^1) = Pr(B^2 \leq \boldsymbol{\beta}' \boldsymbol{x}_i + u_i <)$, respectively. For the "yes/yes" case, for which the upper bound WTP value was unknown, the probability was written as $Pr(B^2 \leq \boldsymbol{\beta}' \boldsymbol{x}_i + u_i)$. For the "no/no" case, for which the lower bound WTP value was unknown, the probability was $Pr(\boldsymbol{\beta}' \boldsymbol{x}_i + u_i < B^2)$. The regressions were

estimated using STATA version 18 using the interval regression command (StataCorp 2023).

The explanatory variables included in x_i can vary based on the regression estimated and can include sensory preferences, sensory intensity scores, instrumental measures of fruit quality traits, and participant characteristics. Note that instrumental measures of fruit quality do not vary at the respondent level (i) but rather at the cultivar level. For ease of presentation of the regression notation, we generalized that x_i include all set of explanatory variables. Following the approach of Yang et al. (2009), we estimated the WTP regressions. First, we estimated a consumer preference model in which sensory liking scores for appearance, texture, flavor, and overall liking were measured using a Likert scale of 1 to 9 and used as explanatory variables. Second, we estimated a consumer intensity model in which the sensory intensities of sweetness, sourness, firmness, juiciness, and overall flavor were measured using a scale of 0 to 100 as the explanatory factors. Finally, we estimated an instrumental measurement model in which instrumental measures related to acidity (pH, TA, and total organic acids), sweetness (total sugars and SSC, which is often used as a proxy measurement for sweetness), and firmness (mean internal force, maximum force, and Young's modulus) were used as the explanatory variables. We included participants' characteristics, location, and year controls in all regressions. We calculated the marginal effects and the average predicted WTP using regression results to estimate the impact of sensory and intrinsic fruit quality attributes on the WTP.

Data. Summary statistics of the sensory tests, biochemical and mechanical measures of fruit quality traits, and respondents' demographic characteristics are summarized by state and year in Table 1. The sample of participants was 63% female, which was a larger proportion of female representation compared with the that of US population of 51% (US Census Bureau 2020). Fifty percent of the participants had an annual income more than $50,000, which is lower than that of 66% of the general US population. The average age of participants in our sample was 39 years, which was closer to the median age of the US population but relatively younger when considering that adults account for the majority of food purchase decisions in a household. The distribution of participants' incomes and ages varied between Florida and Oregon; the participants in Florida were generally younger with higher incomes compared with those of the participants in Oregon. Regarding the frequency of blueberry consumption, 61% of participants indicated that they consumed blueberries weekly. Notably, respondents in Oregon consumed blueberries more frequently than respondents in Florida (Table 1).

Eating blueberries as a snack by themselves was cited as the most common way to consume blueberries by 46% of participants, 16% indicated that the most common method of consumption was via smoothies, and 14% indicated that they commonly ate blueberries as a snack mixed with other fruits or foods. Not all participants in our study consumed blueberries frequently (e.g., daily or weekly). Therefore, we asked those participants about their main reason for not buying blueberries frequently. The main reason for infrequent purchases, cited by 36% of participants, was price. The second most commonly cited reason, by 24% of participants, was the short shelf life (i.e., blueberries spoil too fast). Twenty percent of respondents indicated that year-round availability was a barrier to more frequent consumption. These results are consistent with those of other studies that found that economic factors such as price, short shelf life, and lack of fresh availability were the main deterrents to blueberry consumption decisions (Ma et al. 2024). Respondents were also asked to indicate how important different attributes were when purchasing blueberries (Fig. 1). Ninety-two percent of respondents indicated that freshness was very or extremely important, and 85% indicated that flavor was very or extremely important. Ripeness (79%), juiciness (68%), sweetness (68%), and firmness (65%) were also of extreme importance to respondents.

Results and Discussion

Sensory results. On average, participants liked all the blueberry cultivars tested. The mean overall liking scores across each cultivar, location, and year was 6.61 based on a hedonic scale of 1 to 9. The mean flavor liking score was 6.55, and the mean texture liking score was 6.80. The mean appearance liking score of 7.19 was higher than the texture and flavor liking scores. Hedonic scores of liking were generally higher in Oregon than those in Florida (Table 1). Consistent with a study by Gilbert et al. (2015), sourness intensity had the lowest intensity (40.98 based on a rating scale of 0–100) according to the panelists. Overall flavor had the highest intensity score (61.03). Overall, participants rated sweetness intensity lower than flavor, with an average sweetness rating of 53.50.

Correlation analysis. We estimated Pearson's correlation coefficients using individual participant sensory data and mean instrumental values for each cultivar. Correlation coefficients and statistical significance are depicted in Fig. 2. Overall liking had the strongest correlation with flavor liking ($r = 0.91$), followed by texture ($r = 0.68$) and appearance ($r = 0.39$). This finding was consistent with previous findings that suggested that flavor plays a key role in consumers' acceptance (Gilbert et al. 2014). Overall liking had a strong correlation with sweetness intensity ($r = 0.60$) and flavor intensity ($r = 0.59$) and a negative correlation with sourness intensity ($r = -0.18$). The correlation between overall liking and firmness intensity was weaker ($r = 0.33$) compared with the correlation between overall liking and juiciness intensity ($r = 0.41$), suggesting that juiciness is also an important textural quality attribute that affects consumers' preferences. Texture and flavor hedonic likings were also positively and strongly correlated ($r = 0.60$). Similarly, overall flavor intensity was positively and strongly correlated with firmness ($r = 0.50$) and juiciness intensity ($r = 0.63$), thus highlighting the interactions between flavor and texture perceptions (Blaker et al. 2014). Sweetness and sourness intensity scores were negatively correlated ($r = -0.17$), which could be explained by the potential suppression effect of sweet and sour attributes in foods (Junge et al. 2020). For example, Beaudry (1992) estimated that a 0.1% decline in organic acid was associated with a 1% increase in perceived sweetness in blueberries.

The correlation coefficients among sensory scores and instrumental variables were generally weak (Fig. 2). For example, the correlations between pH and hedonic liking scores were all close to zero. The pH was positively correlated with sweetness intensity ($r = 0.11$) and negatively correlated with sourness intensity ($r = -0.32$). Overall liking was positively but weakly correlated with SSC ($r = 0.10$) and the SSC:TA ratio ($r = 0.07$). Sweetness intensity had a stronger positive correlation with SSC ($r = 0.27$) than with the SSC:TA ratio ($r = 0.15$), and sourness intensity had a stronger negative correlation with the SSC:TA ratio ($r = -0.30$) than it did with SSC ($r = -0.04$). Similarly, total sugars were positively and weakly correlated with flavor liking ($r = 0.12$), overall liking ($r = 0.13$), overall flavor intensity ($r = 0.10$), and sweetness intensity ($r = 0.16$). The weak correlation between sweetness intensity and total sugar content could be explained by the added role that organic acids that are present in the fruit have in mitigating the perception of sweetness. Consistent with the findings by Bett-Garber et al. (2015), we also found that the correlation between sweetness intensity and SSC ($r = 0.27$) was stronger than the correlation with the total sugar content ($r = 0.16$). Organic acids were weakly and negatively correlated with flavor liking ($r = -0.08$) and overall liking ($r = -0.08$). This weak correlation could be attributable to a nonlinear relationship showing that some level of acidity is needed to improve flavor (Beaudry 1992; Saftner et al. 2008). The organic acid content and sweetness intensity were negatively correlated ($r = -0.18$), showing that the organic acid content influences consumers' perceptions of sweetness intensity (Beaudry 1992). Overall liking was statistically significant but negligibly correlated with mechanical measures of the firmness maximum force ($r = 0.06$) and Young's modulus ($r = 0.04$). The correlation between overall liking and mean internal force was not statistically significant. The perception of firmness intensity was also positively but weakly correlated with mean internal force ($r = 0.09$), maximum force ($r = 0.15$), and Young's modulus ($r = 0.04$). A study by Rowland et al. (2020) also found a weak correlation between mechanical measures of firmness and subjective (finger-squeezing fruit) measures of firmness.

The weak correlation among sensory scores and instrumental variables could be partially explained by the characteristics of the data because mean values for the instrumental measures associated with each cultivar tested were
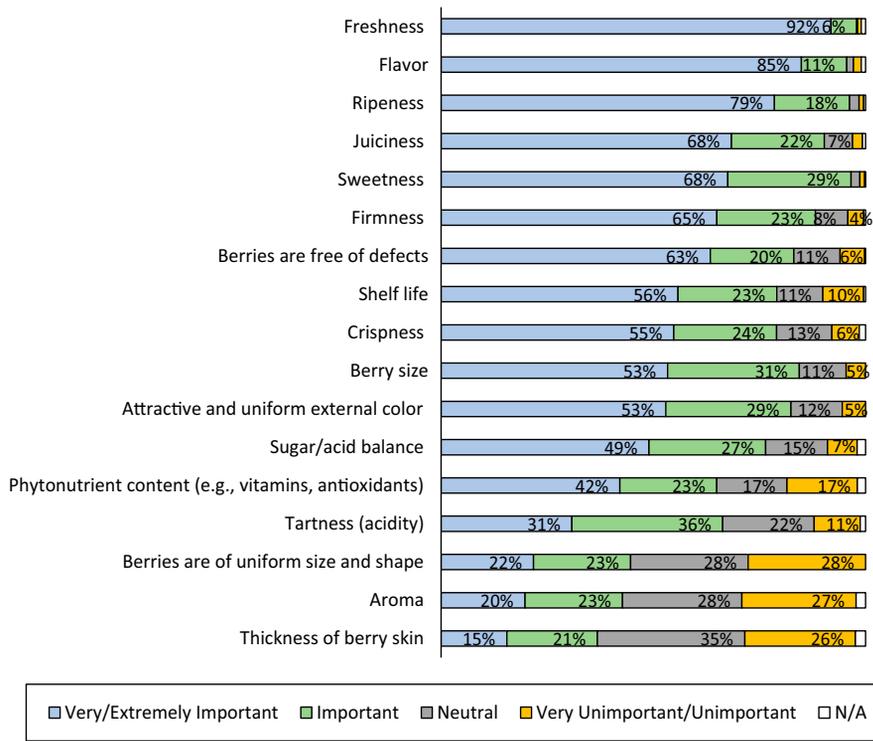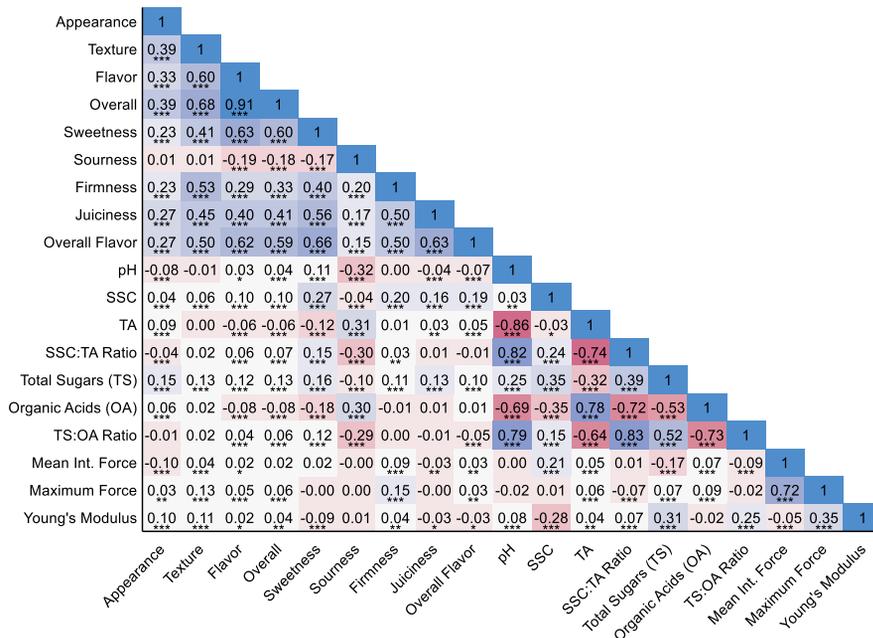
Fig. 1. Importance assigned by sensory test participants to various blueberry quality traits.

used. Means may not capture the variability within each cultivar tested by participants and, hence, the correlation with the panelists' individual sensory scores. In addition, participants were not trained panelists; because consumers are less familiar with the assessment of texture, this could lead to inconsistent responses across panelists. In contrast, consumers are generally more familiar with the perceptions of sweetness, sourness, or flavor, for which we observed higher correlations. Some studies have found that instrumental quality measures correlated well with blueberry sensory attributes; however, these studies have used trained panelists (Bett-Garber et al. 2015; Sater et al. 2021). Furthermore, Pearson's correlation coefficient is limited because it only measures linear relationships. Notwithstanding these limitations, we focused our discussion on correlations that were statistically significant to provide insights

regarding the direction of the relationship among sensory scores and instrumental quality measures. Later during this study, we explored nonlinearities in the relationship between WTP and instrumental quality measures.

WTP: Consumer preference and consumer intensity models. The results of the consumer preference and consumer intensity models are reported in Table 2. For the consumer preference model, we estimated two specifications. The first specification included appearance, texture, flavor, and overall liking as explanatory variables. The second specification excluded overall liking because this measure is highly correlated with (and influenced by) appearance, texture, and flavor liking. We included sociodemographic factors such as age, sex, income level, and frequency of blueberry consumption to control for differences in WTP across consumer segments with varying characteristics. We also included state–year indicators to control for the variability in WTP across states and years.

The regression parameters in Table 2 can be directly interpreted as the marginal effect on the WTP for a 170-g clamshell of blueberries resulting from a one-unit increase in the explanatory variables. Sensory liking was measured using a hedonic scale of 1 to 9 (1 = dislike extremely; 9 = like extremely). As expected, the signs of the regression coefficients for appearance, texture, flavor, and overall liking were positive, and all values were statistically significant, indicating that the more participants liked a blueberry cultivar, the more they were willing to pay for it. The magnitude of the marginal effect based on the specification excluding overall liking can be seen in Fig. 3. As the results indicated, the preference for flavor seemed to be the most important predictor of WTP, with the WTP increasing $0.21 for each 1-point (based on a Likert scale of 1–9) increase in flavor liking. Texture liking was the second-best predictor of WTP, with the WTP increasing $0.06 for each 1-point increase in texture liking. Appearance liking was less important in terms of magnitude, with only a $0.02 increase associated with a 1-point increase in appearance liking. However, it is possible that we were not able to capture the real magnitude of the effect of appearance during our study because of the low variability in the external appearance of the fruit presented to participants in the study because all the fruits tested were freshly harvested (e.g., no visual cues of overripening or spoilage).

Similar to the consumer preference model, two specifications were estimated for the consumer-intensity model. The first specification included overall flavor intensity in addition to sweetness, sourness, firmness, and juiciness intensity. The second specification excluded the overall flavor intensity. The results are reported in Table 2, and marginal effects based on the model specification that excluded overall flavor intensity are graphically depicted in Fig. 3. When excluding overall flavor intensity in the regression [specification (2) in Table 2], the perception of sweetness intensity was the most important sensory attribute based on the magnitude of its effect. We found that WTP increased

Note: Asterisks indicate statistical significance: ***p < 0.01, **p < 0.05, *p < 0.01.

Fig. 2. Correlations matrix of sensory hedonic liking scores, intensity scores, and instrumental measures of quality traits.

Table 2. Regression estimates of willingness to pay (WTP) for blueberries according to the consumer preference (sensory liking scores) and consumer intensity (sensory intensity ratings) models. Parameters represent the WTP for a 170-g clamshell of blueberries based on a 1-unit increase in the explanatory variables.

	Preference model Liking scores (1–9)		Intensity model Intensity ratings (1–100)	
	Specification 1	Specification 2	Specification 1	Specification 2
Constant	1.297***	1.287***	2.165***	2.251***
	(0.068)	(0.069)	(0.062)	(0.065)
Age	0.000	0.001	0.009***	0.006**
	(0.003)	(0.003)	(0.003)	(0.003)
Age squared	−0.000*	−0.000*	−0.000***	−0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Female	0.031**	0.032**	0.039***	0.054***
	(0.014)	(0.014)	(0.014)	(0.015)
Income (>$50,000)	−0.008	−0.007	0.004	0.005
	(0.014)	(0.014)	(0.014)	(0.015)
Weekly blueberry consumption	0.072***	0.074***	0.079***	0.095***
	(0.014)	(0.014)	(0.015)	(0.016)
Appearance liking	0.012**	0.018***		
	(0.005)	(0.005)		
Texture liking	0.039***	0.059***		
	(0.006)	(0.005)		
Flavor liking	0.137***	0.205***		
	(0.009)	(0.006)		
Overall liking	0.095***			
	(0.010)			
Sweetness intensity			0.005***	0.010***
			(0.000)	(0.000)
Sourness intensity			−0.003***	−0.001***
			(0.000)	(0.000)
Firmness intensity			0.000	0.002***
			(0.000)	(0.000)
Juiciness intensity			0.001**	0.004***
			(0.000)	(0.000)
Overall flavor intensity			0.012***	
			(0.000)	
Ln sigma	−0.800***	−0.791***	−0.718***	−0.652***
	(0.016)	(0.016)	(0.016)	(0.017)
State−year FE	Yes	Yes	Yes	Yes
Observations	7,000	7,000	7,000	7,000
Log likelihood	−7,329	−7,374	−7,799	−8,147
AIC	14,686	14,773	15,628	16,323

The SDs are inside parentheses.
Coefficients were statistically significantly different from zero as follows: ***P < 0.01, **P < 0.05, *P < 0.01.
In the preference model, specification 1 includes appearance, texture, flavor, and overall liking as explanatory variables. Specification 2 excludes overall liking because this measure is highly correlated with (and influenced by) appearance, texture, and flavor liking.
In the intensity model, specification 1 includes overall flavor intensity in addition to sweetness, sourness, firmness, and juiciness intensity. Specification 2 excludes overall flavor intensity.
AIC = Akaike information criterion; FE = fixed effects; ln = natural logarithm.

by $0.01 for each 1-unit increase in intensity (measured using a scale of 0–100). Given the minimum and maximum sweetness intensity scores (0 and 100) reported in the summary statistics table (Table 1), this marginal effect would represent a $1.00 difference between a blueberry cultivar with low perceived sweetness and a cultivar rated with high sweetness
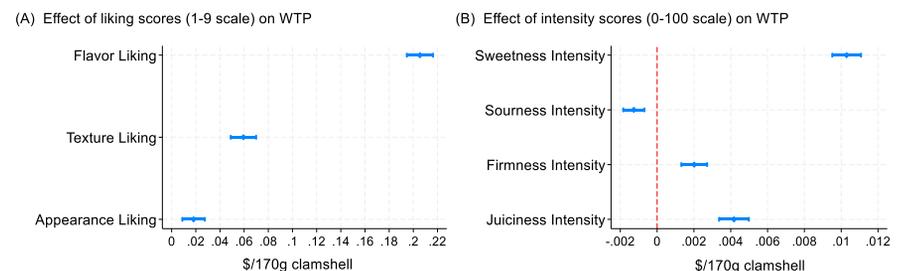

Fig. 3. Average marginal effects of (**A**) sensory liking scores ranked using a hedonic scale of 1 to 9 and (**B**) sensory intensity scores ranked using a scale of 1 to 100 for willingness to pay (WTP). Values represent the change in WTP for a 170-g clamshell of blueberries with a 1-point increase in sensory ratings. Results are based on the consumer preference and intensity WTP regression models (Table 2, specification 2).

while keeping everything else constant. When overall flavor intensity was included in the regression [specification (1) in Table 2], flavor intensity was the most important factor at $0.012 per 1-unit change in intensity, followed by sweetness now at $0.05. This result was consistent with those of Gilbert et al. (2014), who found that sweet and intense blueberry flavors were the most important factors that affect the purchase intention.

The effect of sourness intensity on WTP was negative and statistically significant, but small in magnitude, when compared with the effect of sweetness intensity, particularly when the overall flavor intensity was excluded from the regression. Sweetness can suppress the intensity of sourness perception, but sourness can enhance the perception of sweetness and flavor (Beaudry 1992; Junge et al. 2020). Therefore, it may be difficult to capture the separate effects of these individual factors on the WTP. When overall flavor intensity was included in the model, overall flavor intensity was the main factor that explained the WTP; however, when excluded, sweetness intensity was the factor associated with the largest marginal effect (Table 2). Juiciness intensity was associated with a $0.04 increase in WTP per 1-point increase in intensity, which was higher than the impact of firmness at $0.02. Regarding the model specification with overall flavor intensity included in the regression, the coefficient for firmness was no longer statistically significant. These results suggest that juiciness had an effect larger than firmness on respondents' preferences for blueberries. However, it is important to note that participants in our study were not trained panelists and may not have been able to accurately recognize and evaluate the differences between sensory attributes such as juiciness and firmness. Nonetheless, these results are consistent with those of a study of consumers' preferences for quality traits of blueberries by (Gilbert et al. 2014) that also found that juiciness was among the five most important traits driving fruit favorability (with the other traits being sweetness, bold intense flavor, antioxidants, and dark blue color), and that the texture traits such as seediness, chewiness, mealiness, or mushiness were factors strongly associated with disliking blueberries.

Together, the results from the consumer preference and consumer intensity models indicated that flavor attributes such as flavor liking and flavor and sweetness intensity are key factors that influence consumer acceptance and WTP for blueberries. Previous studies have also shown that flavor factors are the best predictors of consumers' preferences for blueberries, with flavor acceptability and flavor intensity being the main drivers of overall consumer eating satisfaction (Saftner et al. 2008).

WTP: Instrumental measurement model. We estimated different specifications using instrumental measures of SSC, TA, sugars, acids, and firmness. The following five regression specifications reported in Table 3 include variables that account for different measures related to sweetness and acidity available as explanatory variables in the WTP estimation: (1) pH and SSC; (2) TA and SSC; (3) SSC:TA ratio; (4) total sugar-to-total

Table 3. Regression estimates of willingness to pay (WTP) for blueberries according to the instrumental measurement model including measures of soluble solids, titratable acidity, sugars, acids, and firmness.

	Regression 1	Regression 2	Regression 3	Regression 4	Regression 5	Regression 6	Regression 7
Constant	−2.859***	−0.496	1.904***	1.628***	2.252	3.070**	6.177***
	(1.024)	(0.658)	(0.513)	(0.510)	(1.469)	(1.471)	(1.440)
Age	0.014***	0.014***	0.014***	0.014***	0.014***	0.014***	0.012***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Age squared	−0.000***	−0.000***	−0.000***	−0.000***	−0.000***	−0.000***	−0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Female	0.034*	0.034*	0.034*	0.033*	0.034*	0.034*	0.033*
	(0.017)	(0.017)	(0.018)	(0.017)	(0.017)	(0.017)	(0.018)
Income (>$50,000)	0.034*	0.034*	0.033*	0.033*	0.033*	0.033*	0.032*
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Weekly consumption	0.128***	0.128***	0.128***	0.128***	0.128***	0.128***	0.129***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)
Height	−0.030	0.001	−0.072	−0.047	−0.210***	−0.191***	−0.281***
	(0.063)	(0.060)	(0.060)	(0.059)	(0.062)	(0.061)	(0.068)
Height squared	0.002	0.001	0.003*	0.003	0.006***	0.006***	0.008***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
TA			−0.053				
			(0.156)				
TA squared			−0.088				
			(0.119)				
pH	1.308***						
	(0.438)						
pH squared	−0.180***						
	(0.061)						
SSC	0.337***	0.302***					
	(0.074)	(0.072)					
SSC squared	−0.012***	−0.010***					
	(0.003)	(0.003)					
SSC:TA ratio			0.009***				
			(0.003)				
SSC:TA ratio squared			−0.000***				
			(0.000)				
Total sugars:total acids ratio				0.018***			
				(0.003)			
Total sugars:total acids ratio squared				−0.000***			
				(0.000)			
Total sugars					0.001	−0.001	−0.006
					(0.004)	(0.004)	(0.004)
Total sugars squared					0.000	0.000	0.000**
					(0.000)	(0.000)	(0.000)
Total organic acids					0.016***	0.011*	0.005
					(0.006)	(0.006)	(0.006)
Total organic acids squared					−0.000***	−0.000***	−0.000***
					(0.000)	(0.000)	(0.000)
Total sugars × total acids					−0.000**	−0.000	−0.000
					(0.000)	(0.000)	(0.000)
Mean internal force	3.869***	3.819***	4.254***	4.243***	3.857***		
	(0.617)	(0.614)	(0.609)	(0.608)	(0.623)		

Table 3. (*Continued*)

	Regression 1	Regression 2	Regression 3	Regression 4	Regression 5	Regression 6	Regression 7
Mean internal force squared	−3.840***	−3.787***	−4.153***	−4.053***	−3.798***		
	(0.673)	(0.670)	(0.670)	(0.669)	(0.681)		
Maximum force						0.657***	
						(0.207)	
Maximum force squared						−0.140***	
						(0.054)	
Young's modulus							0.104***
							(0.032)
Young's modulus squared							−0.009**
							(0.004)
Ln sigma	−0.483***	−0.483***	−0.478***	−0.480***	−0.487***	−0.485***	−0.491***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
State–year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7,000	7,000	7,000	7,000	7,000	7,000	6,800
Log likelihood	−9,064	−9,062	−9,090	−9,081	−9,038	−9,049	−8,796
AIC	18,165	18,160	18,213	18,195	18,114	18,136	17,629

The SDs are inside parentheses. Coefficients are statistically significantly different from zero as follows: ***$P < 0.01$, **$P < 0.05$, *$P < 0.01$.

The first five regressions include variables that account for different measures related to sweetness and acidity as follows: regression 1, pH and SSC; regression 2, TA and SSC; regression 3, SSC:TA ratio; regression 4, total sugar to total acid ratio; and regression 5, total sugars, total acids, and their interaction. The mean internal force was included to control for texture in regressions 1 to 5.

Regressions 5 to 7 contain the same measures related to sweetness and acidity, with the only difference being the inclusion of mean internal force to account for texture traits in regression 5, maximum force in regression 6, and Young's modulus in regression 7. Because of missing Young's modulus values for some cultivars, regression 7 has fewer observations.

AIC = Akaike information criterion; FE = fixed effects; ln = natural logarithm; SSC = soluble solids content; TA = titratable acidity.

acid ratio; and (5) total sugars, total acids, and their interaction. The mean internal force was included to control for texture in these five regressions. Regressions 5 to 7 included the same measures related to sweetness and acidity as explanatory variables, with the only difference being the inclusion of mean internal force to account for texture traits in regression 5, whereas maximum force was included in regression 6, and Young's modulus was included in regression 7. Because of Young's modulus values were missing for some cultivars in our data, regression 7 had fewer observations (Table 3). We included sociodemographic variables and indicator variables to control for WTP differences across years and locations in our regressions. Quadratic terms for each trait were included to capture nonlinearities in the effects of quality traits on consumers' preferences. To facilitate the interpretation of our regression results, we estimated the average predicted WTP for different values of the quality traits and showed those results in Figs. 4 and 5. Figures depicting the effects of SSC, TA, sugars, acids, and size on WTP are shown in Fig. 4. Figures depicting the effects of textural properties are shown in Fig. 5.

In general, the results indicated a nonlinear relationship of instrumental measures of SSC, TA, sugars, acids, and firmness and WTP (Table 3). The effect of pH on WTP was statistically significant (Table 3, regression 1), and the effect was positive but decreased with higher pH levels (Fig. 4A), indicative of the need for some level of acidity to enhance flavor. Figure 4A shows a higher WTP for blueberries associated with pH values between 3.4 and 3.8, with the highest WTP observed at pH values closer to 3.6. This was consistent with pH values ranging from 3 to 4 that were recommended as quality standards by Retamales and Hancock (2018). The results of Azevedo et al. (2024) also indicated higher consumer overall liking scores associated with blueberries with pH values of approximately 3.5.

The effects of SSC on WTP was also statistically significant (Table 3, regressions 1 and 2). Figure 4B shows that participants' WTP increased as the SSC in blueberries increased; however, WTP increased at a decreasing rate. That is, there were higher marginal gains in the WTP with the increasing SSC of lower quartiles of SSC values relative to the upper quartiles of SSC values. Note that quartiles of the distribution of SSC and other traits are denoted using vertical dashed lines in Fig. 3 and 4. Studies that assessed consumers' preferences for blueberries broadly found that consumers prefer blueberries with higher SSC and higher fructose content (Mennella et al. 2017). Fruit quality standards for blueberries more specifically recommend fruit with SSC more than 11% (Retamales and Hancock 2018), and similar results were found by Azevedo et al. (2024). Although the effect of TA on WTP showed a downward effect (Fig. 4C), the regression parameters were not statistically significant at conventional levels (Table 3, regression 2). We also explored the effect of the SSC:TA ratio and found a significant nonlinear effect on WTP (Table 3, regression 3). We found that WTP increased as the SSC:TA ratio increased up to a ratio of 45; at that point, WTP started to decline with higher SSC:TA ratios (Fig. 4D). Higher

WTP was observed for ratios between 35 and 45; however, we did not find a statistical difference between the predicted WTP at 35 and 45 SSC:TA ratios. This value was somewhat higher than the quality standard of 15 to 30 recommended in the literature (Retamales and Hancock 2018). Thus, the effect of the SSC:TA ratio on consumers' preferences for blueberries warrants further examinations by future studies.

We also explored the effect of the total sugar-to-total acid ratio and found a statistically significant nonlinear effect (Table 3, regression 4). Similar to the effect of the SSC:TA ratio, we found that WTP increased as the ratio of total sugar to total acid increased, up to a ratio of 30; after that point, the WTP started to decline with higher ratios (Fig. 4E). Accordingly, the highest predicted WTP values in our study were associated with a total sugar-to-acid ratio of approximately 30. However it is important to note that we did not find a statistical difference in the WTP associated with a total sugar-to-total acid ratio of 25 and 35. It is also important to note that the marginal benefit of the total sugar-to-total acid ratio for WTP was positive for most of the ratio distribution observed in our dataset (see quartile delineation for the distribution of the total sugar-to-acid ratio in Fig. 4E).

The results of a model with nonlinear terms for total sugar and total acid as well as an interaction term between total sugar and total acid are shown in Table 3 regression 5. The average predicted WTP as a function of total organic acid estimated at averaged levels of the total sugar content observed in the data are depicted in Fig. 4F. In Fig. 4G, we
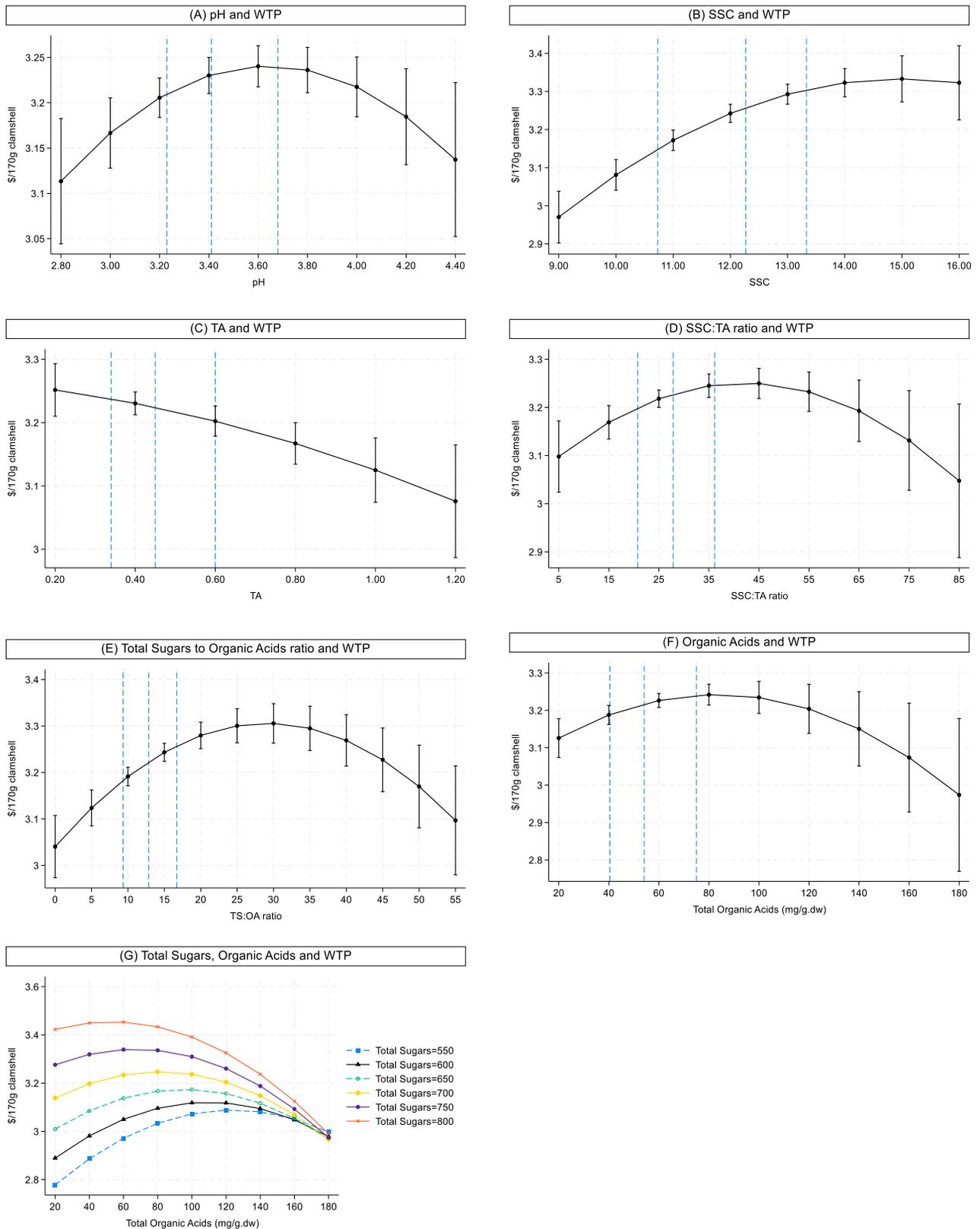
Fig. 4. Average adjusted predictions for willingness to pay (WTP) for a 170-g clamshell of blueberries as a function of instrumental measures of the soluble solids content (SSC), titratable acidity (TA), sugars, and acids. All predicted values plotted are based on the regression results (Table 3). The effects of pH (**A**) and SSC (**B**) on WTP are estimated using the results from regression 1. The effect of TA (**C**) is based on the results from regression 2. The effect of the SSC-to-TA ratio (**D**) is based on the results from regression 3. The effect of the total sugar-to-total acid ratio (**E**) are estimated using the results from regression 4. The mean effects of organic acids (**F**) or for various levels of total sugars (**G**) are based on results from regression 5. Vertical dashed lines denote quartiles of the distribution of observed values for each quality trait.

depicted the predicted WTP at varying levels of both total sugar and total acid contents. Averaged across observed total sugar values, an increasing WTP was observed for total organic acid contents up to 80 mg/g of dry weight (mg/g dw), and a decreasing WTP was observed for organic acid contents higher than 80 mg/g dw; however, we did not find a statistical difference between the predicted WTP for the total organic acid contents of 80 and 100 mg/g dw (Fig. 4F). This is consistent with the need for organic acids to enhance
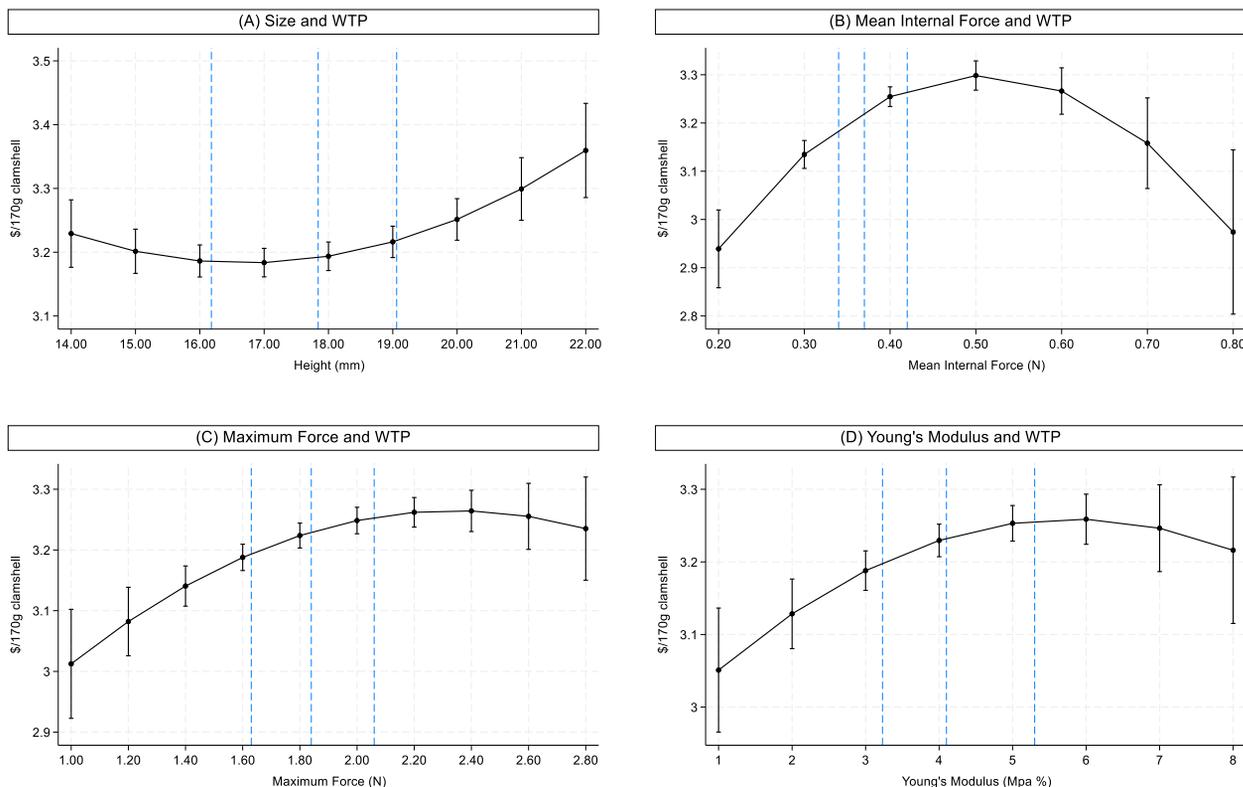
Fig. 5. Average adjusted predictions of willingness to pay (WTP) for a 170-g clamshell of blueberries based on changes in size and texture quality trait values. (**A**) The effect of size based on regression 5 (Table 3). (**B**) The effect of mean internal force on WTP. (**C**) The effect of maximum force. (**D**) The effect of Young's modulus based on regressions 5, 6, and 7 (Table 3).

flavor in fruits (Shi et al. 2022) when the perception of flavor is influenced by the presence of organic acids (Zampini et al. 2008). In addition, increasing WTP values in the presence of increasing organic acids could be explained by the need for a certain level of organic acids to suppress the sweetness perception, and the present sugars also suppress the perception of sourness (Savant and McDaniel 2004). Disaggregating the effect of the total organic acid content for different levels of total sugar showed higher WTP values associated with higher total sugar contents across total organic acid levels spanning from 20 to 160 mg/g dw (Fig. 4G). The sugar content had an overall positive effect on WTP. However, for organic acid contents higher than 160 mg/g dw, we observed similar predicted WTP values regardless of the total sugar content. With high levels of organic acids, additional sugar contents may not suppress the perception of sourness (Marsh et al. 2006), which explained similar WTP regardless of the sugar content when the fruits had a high acid content.

Fruit size, which was measured as height in millimeters, had a general positive effect on WTP (Fig. 5A). However, we did not find a statistical difference in the predicted WTP for fruits 14 to 17 mm in size. For fruits larger than 17 mm, we found an increase in WTP associated with an increase in fruit size (Fig. 5A). Fruits larger than 15 mm are recommended as a quality standard for blueberries (Retamales and Hancock 2018). Recent results of a study by Azevedo et al. (2024) found that 17.7 mm was a new quality trait

benchmark for blueberries, which was similar to the trend depicted in Fig. 5A. A study by Donahue et al. (2000) also found that panelists preferred larger blueberries.

Texture traits are also important determinants of fruit acceptance. We generally found higher WTP associated with firmer fruits as measured by mean internal force (Fig. 5B), maximum force (Fig. 5C), and Young's modulus (Fig. 5D). We found a positive effect on WTP for most of the distribution of those variables, except for extreme values that would indicate a hard fruit. For mean internal force, we found optimal (highest WTP) values of approximately 0.5 N. For maximum force, we found the highest predicted WTP associated with a maximum force of 2.4 N; however, the predicted level of WTP for a maximum force of 2.6 N was not statistically different from that associated with 2.4 N. Similarly, we found higher predicted WTP values for Young's modulus of approximately 6 MPa%, but the difference in the WTP predicted for values between 5 and 7 MPa% was not statistically significant. Although, together, these results suggest that consumers generally prefer firmer fruit, comparisons of specific values with other firmness measures in the literature should consider differences in the settings of the study and equipment used (Rivera et al. 2022).

Across all regression models (consumer preference, consumer intensity, and instrumental measurement models) and specifications, the results showed heterogenous preferences across participants' characteristics (Tables 2 and 3).

The effect of age was nonlinear, and the effect on WTP was initially positive (i.e., positive linear term); however, WTP subsequently decreased with age (i.e., negative quadratic term). This could be explained by differences in the levels of purchasing power and price consciousness across age groups. Female participants were also willing to pay more relative to male participants. Consistently across regression specifications, our results showed that frequent consumers of blueberries were willing to pay between $0.07 to $0.12 more for a 170-g clamshell of blueberries (Tables 2 and 3). Surprisingly, although income generally plays a significant role in the WTP, we found that the indicator variable for income more than $50,000 was not statistically significant for explaining WTP in the consumer preference or intensity models (Table 2). However, we found a small but statistically significant difference in the WTP for those with higher incomes in the instrumental measurement model (Table 3). Insights from a market trend analysis revealed that the likelihood of blueberry purchases increased with income, and that individuals who earned more than $50,000 were more likely to purchase blueberries (The Packer 2022).

To determine whether the regressions estimated explained the WTP elicited from study participants, we estimated the number of fully correctly classified cases ("yes/yes", "yes/no", "no/no", and "no/yes") predicted by our models as a measure of goodness of fit (Kanninen and Khawaja 1995; McCluskey et al. 2013). We found that the consumer preference and intensity models accurately predicted 55% and 50% of the

cases (they also accurately predicted between 70% and 75% of the answers to the first WTP bid question). For comparison, a similar study of apples accurately predicted 48% of the cases (McCluskey et al. 2013). In contrast, the instrumental measurement models only accurately predicted 39% to 40% of the cases, suggesting that the models using sensory evaluation were better at predicting WTP relative to instrumental measures of quality. There is a potential explanation for these results. First, we did not include information regarding blueberry volatile organic compounds in our regression. Volatile organic compounds contribute to the sensory experience of sweetness and sourness (Colantonio et al. 2022; Fan et al. 2021; Gilbert et al. 2015), and metrics of sugar or acid contents alone may not adequately capture the variability in flavor characteristics and consumers' preferences for the blueberry cultivars. Second, consumers' preferences are heterogenous, and not all consumers prefer the same level of an attribute (e.g., same level of sugar content). Other studies have similarly indicated the difficulty of predicting sensory data using instrumental measures of blueberry quality (Donahue et al. 2000). Notwithstanding these limitations, the instrumental measurement models provided important insights regarding consumers' preferences for blueberry quality traits.

Conclusions

We elicited WTP and sensory liking and intensity scores for SHB and NHB blueberry cultivars using an experiment that combined both consumer sensory tests and a double-bounded contingent valuation. The experiment was performed in Florida and Oregon over the course of 2 years. Consistent with previous studies that showed that flavor plays a key role in consumer acceptance, our correlation analysis showed that overall liking had the strongest correlation with flavor liking, followed by texture liking. Similarly, overall liking had a strong correlation with sweetness intensity and flavor intensity and a negative correlation with sourness intensity. The correlation coefficients among hedonic sensory scores and instrumental fruit quality measures were generally weak, which could be explained by nonlinearities in the relationship or the nature of the data used. However, we offer key insights regarding the association among variables that we observed. We found that the overall liking was positively correlated with the pH, SSC, SSC:TA ratio, and negatively correlated with the organic acid content. Overall liking and firmness intensity scores were both positively but weakly correlated with mechanical measures of firmness, such as mean internal force, maximum force, and Young's modulus.

We estimated different WTP regressions. First, we estimated a consumer preference model in which sensory liking scores for appearance, texture, and flavor were used as explanatory variables in the WTP regression. We found that preference for flavor was the most important predictor of WTP, followed by texture liking. Then, we estimated a

consumer intensity model in which sensory intensity evaluations of sweetness, sourness, firmness, juiciness, and overall flavor were used as explanatory factors in the WTP regression. We found that the perception of sweetness intensity was the most important sensory attribute based on the magnitude of its effect, resulting in a $1.00 difference between a blueberry cultivar with low perceived sweetness and a cultivar with high sweetness. When overall flavor intensity was included in the regression, flavor intensity was the most important factor, followed by sweetness. Results from the consumer preference and consumer intensity models indicated that flavor attributes such as flavor liking and flavor and sweetness intensity were the most important factors that influenced consumers' WTP for blueberries.

Finally, we estimated instrumental measurement models in which chemistry and mechanical measures of blueberry quality traits were included in the regression model to explain WTP. We showed the predicted WTP values for different levels of blueberry quality traits, which allowed the identification of values of those traits associated with higher WTP values. These instrumental measurement values could be used as benchmarks to select for higher quality. The WTP regression results showed heterogenous preferences across participants with varying characteristics. We generally found that age played a role, and that female participants and frequent consumers of blueberries were generally willing to pay more for blueberries relative to their counterparts. The WTP models that used sensory evaluation attributes were better at predicting participants' WTP responses relative to instrumental measures of quality traits. Future studies could include additional measures of quality traits such as volatile organic compounds and evaluate cultivars with a wider range of quality traits to capture consumers' preferences across the distribution of fruit quality available to them in the market.

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