HortScience 52(5):742–748. 2017. doi: 10.21273/HORTSCI11359-16

Estimating Strawberry Attributes' Market Equilibrium Values

Jong Woo Choi[1]
Korea Rural Economic Institute, Naju, South Korea

Chengyan Yue[2,7]
Departments of Applied Economics and Horticultural Science, University of Minnesota-Twin Cities, 1970 Folwell Avenue, St. Paul, MN 55108

James Luby[3]
Department of Horticultural Science, University of Minnesota-Twin Cities, Saint Paul, MN 55108

Shuoli Zhao[4]
Department of Applied Economics, University of Minnesota-Twin Cities, St. Paul, MN 55108

Karina Gallardo[5] **and Vicki McCracken**[3]
School of Economics, Washington State University, Pullman, WA 99163

Jim McFerson[6]
Washington Tree Fruit Research Commission, Wenatchee, WA 98801

Additional index words. fruit attribute, choice experiment, consumer, producer

***Abstract*. We conducted choice experiments with both strawberry producers and consumers. Consumer and producer willingness to pay (WTP) for the fruit attributes were estimated using mixed logit models. Through simulation using the mixed logit model results, we derived the market equilibrium prices, supply and demand curve, as well as quantities demanded and supplied for every fruit attribute. We found the highest equilibrium price was for strawberry internal color followed by flavor. Strawberry breeders can use the information when setting breeding targets, allocating resources appropriately during their breeding process and focusing on the improvement of attributes that produce the highest social surplus and total revenue.**

Strawberry is an important fruit crop to the U.S. economy, and the United States is the largest producer of strawberry worldwide. During the past 10 years, U.S. strawberry production averaged 1.24 million metric tons and was worth $2.12 billion dollars annually. Most of the strawberries were consumed fresh (80.8%) and 19.2% were processed (USDA, 2015a). The top production states were California, Florida, Oregon, North Carolina, Washington, and Michigan (USDA, 2015b). The production and value of strawberries has steadily increased since 2001. In 2005, U.S. strawberry production was at 1.05 million metric tons valued at $1.39 billion dollars, whereas in 2014, production was at 1.37 million metric tons valued at $2.86 billion dollars, deflated as the 2005 value (USDA, 2015a). The per capita consumption of strawberries has also been increasing steadily. In 2005, the per capita consumption was 5.83 pounds, and in 2014, the per capita consumption was 7.96 pounds. The per capita consumption growth has stagnated since 2009 (USDA, 2015c). New cultivar development and commercialization are essential to promote the industry's long-term economic viability. In fact, since 2006, 81 new strawberry cultivars have been released in the United States (U.S. Department of Commerce, Patent and Trademark Office, 2015).

Rosaceous fruit breeders have been breeding new strawberry cultivars for decades. Strawberries are herbaceous perennials, grown in many production regions as an annual crop, with a short reproductive cycle, which is different from other commercially produced rosaceous fruits (Qin et al., 2008). Previous studies have shown that the trait targets of strawberry breeding programs are highly influenced by geographical location and end market needs (Capocasa et al., 2008; Hancock et al., 2008; Khanizadeh et al., 1992; Whitaker et al., 2011). Although these studies provided insight into breeders' trait prioritization decisions, a systematic investigation that includes consumers' and producers' values of strawberry traits would assist breeders to further improve the efficiency of breeding programs.

The following studies have investigated consumer preferences for strawberry attributes. Ford et al. (1996) and Safley et al. (1999) concluded that strawberry flavor, sweetness, juiciness, freshness, and firmness are the most important attributes compared with color and size for consumers. More recently, Colquhoun et al. (2012) found that consumers preferred strawberries that are sweet and with rich and complex flavors, and He et al. (2015) found that freshness and color of strawberries have significant impacts on WTP before consumers taste them, and flavor and texture become the dominant attributes after they taste them. Other than fruit quality attributes, Darby et al. (2008) found that consumers prefer strawberries that are locally produced, and this preference is independent of other attributes that are often naturally associated with locally produced foods, such as greater freshness. In addition to U.S. consumers, it was found that German consumers prefer strawberries with lower sugar content, and Uruguay consumers prefer sweeter and firmer strawberry cultivars (Keutgen and Pawelzik, 2007; Lado et al., 2010). Even fewer studies have focused on investigating strawberry producers' preferences for strawberry traits. Yue et al. (2014) conducted audience surveys at several U.S. strawberry grower meetings and concluded that growers consider flavor, firmness, and shelf life at retail as the most important strawberry attributes compared with color and size. However, Yue et al. (2014) did not obtain growers' values for these attributes.

To our knowledge, no study has compared producers' and consumers' values of strawberry traits and synthesized these values into a market equilibrium analysis. This study will fill this knowledge gap and assist strawberry breeders in setting attributes and breeding priorities to efficiently meet market needs.

Methodology

Survey design and data collection

Researchers often used hedonic analysis to estimate the value for product attributes, which is limited to the valuation of existing traits. Survey samples are available to readers at https://sites.google.com/site/peacejchoi/food-economics/survey-samples. Choice experiments overcome this limitation and make it possible to estimate economic values of prospective traits. Many studies have employed choice experiments to explore various parties' WTP for goods (Tonsor et al., 2009; Wang et al., 2010). Lancaster's consumer demand theory assumed that consumers buy goods because they could derive utilities from attributes of a good instead of the good itself (Lancaster, 1966). Choice experiments represent goods with a combination of attributes, so researchers can estimate the value for various attributes simultaneously. In

Received for publication 6 Oct. 2016. Accepted for publication 16 Mar. 2017.
This project was funded by Specialty Crop Research Initiatives, U.S. Department of Agriculture.
[1]Research Fellow.
[2]Associate Professor, Bachman Endowed Chair in Horticultural Marketing.
[3]Professor.
[4]PhD Student.
[5]Associate Professor.
[6]Director.
[7]Corresponding author. E-mail: yuechy@umn.edu.

addition, choice experiments are similar to actual purchasing situations in which experimental subjects make choices from a number of goods (Lusk and Schroeder, 2004). Although choice experiments are often discussed within the context of utility maximization of consumers, this concept can also be extended to producers in the context of profit maximization (Gallardo et al., 2014; Lusk and Hudson, 2004).

The attributes and attribute levels in the choice experiment were selected by consulting with industry experts and interviewing a small group of producers and consumers. We have found that attribute levels for producers have specific measurements based on scientific research. But for consumers, nontechnical expressions and visual pictures were understood better than scientific figures. These levels have been pretested with a small group of consumers/producers before we collected the formal survey data.

The strawberry attributes we included in the choice experiments were external color, internal color, firmness, flavor, size, shelf life, and price (cost for producers). Table 1 summarizes strawberry attribute levels used in producer choice scenarios. The measure for larger size was "More than 25 g/fruit." Internal and external colors were represented as "Ideal red color" and "Too light or too dark color." Firmness had two levels: "Firm" and "Soft." Flavor was defined as a combination of sweetness and sweet/tart balance and had two levels: "Full/intense flavor" and "Weak/mild flavor." Longer shelf life was measured as "9 d after harvest." Lastly, the two levels of total cost of production/storage/handling were \$1.00 and \$1.15/lb, respectively. In the estimation, the baseline quality attributes were the undesired quality attributes. The desirable attributes are considered as improvements. For example, the baseline attribute for flavor is "weak/mild flavor," and "full/intense flavor" is considered as an improvement.

Pictures were used to show the colors and sizes of strawberries in the consumer choice experiments. The size of strawberry was compared with the size of a quarter. Firmness had two levels: "Firm" and "Soft." "Intense strawberry flavor" and "Mild strawberry flavor" were used for the two levels of flavor. Shelf life was specified as "Will last 9 d at home in your refrigerator" and "Will last 4 d at home in your refrigerator." Lastly, the two levels of *Price* were \$2.65 and \$2.99 by considering the high and low retail strawberry prices in different seasons (USDA, 2015c).

We procured the sample of strawberry producers from a nationally comprehensive list held by Meister Media Worldwide Inc., a trade magazine whose primary clientele are U.S. fruit growers. The list was supplemented by the list provided by various strawberry producer associations and Blue Book Online Services (a credit and marketing information agency serving the international wholesale produce industry). We allocated the sample size to each of the top five producing states based on the number of farms in each state.

In total, 86 producer surveys out of 300 and 1137 consumer surveys out of 1500 have been completed in the survey. Hence, the response rates were 28.7% for producers and 75.8% for consumers. The producer survey data were collected between Feb. and June 2012, and the consumer survey data were collected in Oct. 2013.

Every survey participant was asked to complete eight choice scenarios with each scenario consisting of two options (option A and option B). In each scenario, a participant was asked to choose one option. If a participant does not want to choose either of the two options, the participant can choose option C (neither A nor B). Each of the two options was represented by a combination of different levels of fruit quality traits and price (or production cost). Instead of asking each participant to choose from all possible scenarios, we used a fractional factorial design to minimize scenario number and maximize profile variation. The design was developed based on four principles: 1) level balance (levels of an attribute occurred with equal frequency), 2) orthogonality (the occurrences of any two levels of different attributes were uncorrelated), 3) minimal overlap (cases where attribute levels did not vary within a scenario were minimized), and 4) utility balance (the probabilities of choosing alternatives within a scenario were kept as similar as possible) (Louviere et al., 2000). The choice scenarios were designed using JMP® 8 software (SAS Institute Inc., Cary, NC).

Mixed logit model

Mixed logit models were used to analyze the choice experiment data. Compared with the standard logit model, mixed logit models do not need the independence of irrelevant alternatives (IIA) assumptions and allow for unrestricted substitution patterns. The mixed logit model does not require the IIA assumption, which means the model enables the taste parameters to randomly vary. The mixed logit model allows us to estimate each individual's WTP and thus simulates the demand and supply curves to generate the market equilibrium. Other methods such as the logit model and probit model do not have the function.

In addition, when participants make repeated choices, the mixed logit model could be used to account for the correlations between the choices made by the same individual. Bhat (2001) showed that mixed logit models can be used to capture heterogeneity across individual preferences by using random coefficients.

Suppose a choice set has I alternatives ($i = 1,2,\ldots,I$). For consumer $n(n = 1,2,\ldots,N)$, the utility derived from the ith alternative can be represented as:

Consumer n's utility can be represented as

$$U_{ni} = \beta_n x_{ni} + \varepsilon_{ni} \qquad [1]$$

U_{ni} : individual n's utility from choosing alternative i;

x_{ni} : a vector of observed variables representing the characteristics of individual n and alternative i;

β_n : an unobserved random coefficient vector for each n that varies in the population. Its density is $f(\beta|\theta)$, where θ is the true parameter of this distribution;

ε_{ni} : an error term for alternative i and individual n that is assumed to follow an extreme value distribution and is identically and independently distributed.

Among the I alternatives, a consumer would choose the alternative i, if and only if the alternative i maximizes the consumer's utility. Let Y_n be a random variable whose value indicates the choice made by consumer n. For a given β_n, the conditional probability of choosing alternative i is:

$$Pr(Y_n = i|\beta_n) = Pr(U_{ni} > U_{nk}|\beta_n) \text{ for all } k = 1,2,\ldots,I;\ k \neq i \qquad [2]$$

Because the error term follows extreme value distribution, then the conditional probability of choosing alternative i is:

$$Pr(Y_n = i|\beta_n) = \frac{e^{\beta_n x_{ni}}}{\sum_{k=1}^{M} e^{\beta_n x_{nk}}} \qquad [3]$$

Integrating (3) over the density of β, $f(\beta|\theta)$, we can get the unconditional choice probability in the mixed logit model.

$$Pr(Y_n = i) = \int Pr(Y_n = i|\beta_n) f(\beta|\theta) d\beta \qquad [4]$$

Brownstone and Train (1999) studied the unconditional probability [4] and noted that $Pr(Y_n = i)$ cannot be integrated analytically because it does not have a closed form solution in general. The integral can be estimated through simulation. In particular, the simulated probability is:

Table 1. Strawberry attribute levels in producer choice scenarios.

Attributes	Level 1	Level 2
Size	Greater than 25 g/fruit	Less than 25 g/fruit
Internal color	Ideal red color	Too light or too dark color
External color	Ideal red color	Too light or too dark color
Firmness	Firm	Soft
Flavor (combination of sweetness, sweet/tart balance, and aroma)	Full/intense flavor	Weak/mild flavor
Shelf life	9 d after harvest	4 d after harvest
Total cost of production/storage/handling	\$1.00/lb	\$1.15/lb

$$SPr(Y_n = i) = \left(\frac{1}{\mathcal{R}}\right)\sum_{r=1}^{\mathcal{R}} Pr(Y_n = i)(\beta^r) \quad [5]$$

Here, the logit function $Pr(Y_n = i)(\beta)$ is estimated by drawing β from $f(\beta|\theta)$ $\mathcal{R}$ times, and β^r represents rth draw of β. $SPr(Y_n = i)$ is the simulated probability for an individual's choice of alternative i. $Pr(Y_n = i)$ has been proven to be an unbiased estimator of P_{ni} by Brownstone and Train (1999).

Similar to consumers, a producer chooses the alternative from a choice set to maximize his/her profit. Suppose a choice set has I alternatives $(i = 1, 2, \ldots, I)$. For producer $m(m = 1, 2, \ldots, M)$, the profit derived from the ith alternative can be represented as:

$$\pi_{mi} = \alpha_m x_{mi} + \mu_{mi} \quad [6]$$

π_{mi} : producer m's profit from choosing alternative i;

x_{mi} : a vector of observed variables representing the characteristics of individual m and alternative i;

α_m : an unobserved random coefficient vector for each m that varies in the population. Its density is $f(\alpha|\Omega)$, where Ω is the true parameter of this distribution;

and μ_{ij} is an identical and independent error term that follows extreme value distribution.

Among the I alternatives, producer m would choose the alternative i, if and only if the alternative i maximizes the producer's profit. Let Y_m be a random variable whose value indicates the choice made by grower m. For a given α_m, the conditional probability of choosing alternative i is:

$$Pr(Y_m = i|\alpha_m) = Pr(\Pi_{mi} > \Pi_{mk}|\alpha_m) \text{ for all } k = 1, 2, \ldots, I;\ k \neq i \quad [7]$$

Because the error term follows extreme value distribution, then the conditional probability of choosing alternative i is:

$$Pr(Y_m = i|\alpha_m) = \frac{e^{\alpha_m x_{mi}}}{\sum_{k=1}^{M} e^{\alpha_m x_{mk}}} \quad [8]$$

Integrating [3] over the density of α, $f(\alpha|\Omega)$, we can get the unconditional choice probability in the mixed logit model.

$$Pr(Y_m = i) = \int Pr(Y_m = i|\alpha_m) f(\alpha|\Omega) d\alpha \quad [9]$$

An individual i's WTP for attribute k is calculated as Eqs. [10] and [11]

$$WTP_{nk} = -\left(\frac{\beta_{nk}}{\beta_{np}}\right) \quad [10]$$

where β_{nk} is consumer n's coefficient for the kth attribute, and β_{nc} is consumer n's coefficient for price.

$$WTP_{mk} = -\left(\frac{\alpha_{mk}}{\alpha_{mc}}\right) \quad [11]$$

where α_{mk} is consumer n's coefficient for the kth attribute, and α_{mc} is producer m's coefficient for cost.

Supply and demand simulation

We obtained the supply and demand curves for strawberry's attributes through simulated individual WTP for producers and consumers. We made two assumptions when we derived strawberry's supply and demand curves.

Assumption 1: Fixed total quantity supplied for strawberry. We assumed that the production quantity per acre was fixed by using the average production quantity in the top five producing states. Then, we multiplied the average production quantity by the ratio between the total acres in the top five producing states and total acres from the survey participants to approximate total quantity supplied. Based on the present strawberry production capability, this assumption enabled us to approximate the quantity supplied. The assumption did not reflect on the likelihood that the strawberry cultivar that had an enhanced attribute might result in higher/lower productivity per acre.

Assumption 2: Fixed total quantity demanded for strawberries. We assumed that the U.S. population and per capita consumption of strawberries were fixed at the levels when the study was conducted. The United States has about 310 million people, and we assume that each individual consumes 8 lbs of strawberries a year on average (USDA, 2015a, 2015b). This assumption allowed us to approximate the total strawberry demanded based on U.S. consumers' current consumption capacity. However, this assumption did not consider the possibility that the quantity demanded for strawberries with an improved attribute might increase/decrease.

These two assumptions did not take into account the possible changes in total quantity supplied/demanded brought by new cultivars, but they did allow us to approximate the quantity supplied/demanded for strawberries at their current production/consumption capacities. We made these assumptions based on the fact that about 10 new strawberry cultivars were introduced into the market in the past 5 years (U.S. Department of Commerce, Patent and Trademark Office, 2015), but we barely see any dramatic change in the total strawberry production/consumption during the last 5 years (USDA, 2015c). In addition, previous studies such as Jacobs et al. (1998) used the same assumptions when they estimated the total U.S. fish consumption.

Supply. To approximate the quantity supplied in the United States, the production quantity and acreage data in the top five producing states reported by the USDA and the acreage data from the producer survey were used. About 98% of the strawberries grown in the U.S. are produced by the top five producing states in 2012 (USDA, 2015b). Each individual producer's quantity supplied was approximated as follows:

$$\begin{aligned}&\text{Quantity Supplied per acre for strawberries}(lbs)\\ &\quad = \text{Average quantity}(lbs)\text{per acre in top 5 producing states}\\ &\quad * \frac{\text{Total acres in top 5 producing states}}{\text{Total acres from the survey}} * \frac{1}{0.98}\end{aligned} \quad [12]$$

Average quantity (*lbs*) per acre in the top five producing states multiplied by total acres in top producing states represented the total quantity supplied in the top five producing states. We had the total quantity supplied in the U.S. by dividing this number by 0.98 because the top five producing states produced 98% of the strawberries in the U.S. When this total quantity supplied was divided by total acres from the survey, we approximated how much each sampled acre needs to supply to reach the total national quantity supplied. Then, we used this quantity supplied per acre in Eq. [12] multiplied by the specific acres reported by each sampled representative producer to get the rescaled quantity supplied by that specific representative producer.

To develop the supply curve, we approximated every producer's highest production cost he/she was willing to pay (estimated WTP value) for a fruit characteristic based on the choice experiment data. Then, we added the difference between the production cost and theretail price (the retail margin) to the production cost to approximate the retail prices. Estimating producer WTP is a relatively new concept, and it is derived from the producers' profit maximization functions, which is different from the estimation of consumer WTP through utility maximization. In this study, we assume that the total production quantity is fixed, and the producers' WTP for improvement in fruit quality attributes is evaluated. The quantity supplied by each producer at the corresponding price level was estimated using Eq. [12] and then multiplied by the producer's number of acres. The total quantity supplied at a price level (e.g., price \$2.00/lb) was derived by summing all the quantities for those producers whose supplying prices were less than or equal to the price level (e.g., price \$2.00/lb).

Demand. When approximating the quantity of strawberry demanded, we used the U.S. population and per capita consumption of strawberry and the number of participants in the survey as follows:

$$\begin{aligned}&\text{Quantity Demanded per consumer for strawberries}(lbs)\\ &\quad = \text{Per capita consumption}(lbs)\\ &\quad * \frac{\text{U.S. population}}{\text{The number of participants in the survey}}\end{aligned} \quad [13]$$

The per capita consumption multiplied by the U.S. population gave the total strawberry consumption (or quantity demanded). This number was divided by the number of participants in the survey to approximate how much each representative consumer consumed to get the total national strawberry consumption level (or quantity demanded). The idea was to rescale the survey sample consumption level to the national level to approximate the national strawberry quantity demanded.

To construct the demand curve, we estimated each participant's WTP value for an attribute based on the choice experiment data. Eq. [13] was used to compute the quantity demanded by each consumer. Then, the quantity demanded for a price level (e.g., price $2) was approximated by adding the quantities demanded by the participants whose buying prices were greater than or equal to the price level (e.g., price $2).

Results

Table 2 presents the summary statistics of strawberry producers' background information. The average age of strawberry producers was 57.2. Most of the sampled strawberry producers were male. About 37% of participants' education level was 2-year college degree or 4-year college degree. About 78% of participants' total acreage was less than 25 acres. The sampled strawberry producers had, on average, 20.9 years of experience working as a farm owner, manager, or primary decision-maker. Sixty-three percent of the sampled strawberry producers were family or individualoperation farms and 88% of them were Caucasian.

Table 3 shows the consumer participants' demographic background information. The average age of consumer participants was between 35 and 44. Most of them were female (68%). Their average educational level was 2-year college or technical degrees. The average annual household income was between $35,000 and $49,999. On average, they ate fresh strawberries at least once a week. They bought about 2.21 pounds of strawberries at one time for about 2.72 people in their households. About 46% of the participants had children under age 12 in the household. About 74% of the participants bought their strawberries at conventional grocery stores or warehouse retailers, natural food stores or food cooperatives (13%), and farmers' markets (13%). About 72% of the participants were Caucasian. The demographic background for our sample strawberry consumers was very similar to U.S. census data except that our sample had a relatively higher proportion of female, and average income is a little low (U.S. Department of Commerce, Census Bureau, 2014).

The mixed logit model estimation results for strawberry consumers and producers are shown in columns (1) and (2) of Table 4. All coefficients were significant at the 5% significance level. As expected, the coefficients for *Cost* and *Price* were negative, and the coefficients for the quality attributes were positive. The significant coefficients indicated that producers preferred to grow firm strawberries with intense flavor, ideal external and internal red color, and longer shelf life. Consumers preferred strawberries with ideal red internal color, intense flavor, ideal external color, and longer shelf life. The size of strawberries was the least important attribute for both consumers and producers. There was evidence of heterogeneity in consumer and producer preferences for strawberry attributes as indicated by the significance of the standard deviation coefficients.

As described in the methodology section, the individual coefficient for each attribute was generated by simulation after the estimation of mixed logit models. Each

Table 2. Summary statistics for strawberry producer demographic background information.

Variable	Description	Mean	SD
Age	Participant's age in years	57.2	12.7
Gender	Gender of participant, 1 = male, 2 = female	1.08	0.27
Education	The highest level of education	4.52	2.12
	1 = Some high school or less	4.65%	
	2 = High school diploma or equivalent	19.77%	
	3 = Some college, but no degree	18.60%	
	4 = Vocational or extension certificate	2.33%	
	5 = 2-yr college degree	11.63%	
	6 = 4-yr college degree	25.58%	
	7 = Some graduate school	8.14%	
	8 = Graduate degree	9.30%	
Income	The gross annual income from participant's strawberries	2.86	2.42
	1 = Less than $25,000	50.59%	
	2 = $25,000–$49,999	9.41%	
	3 = $50,000–$74,999	8.24%	
	4 = $75,000–$99,999	4.71%	
	5 = $100,000–$249,999	10.59%	
	6 = $250,000–$499,999	5.88%	
	7 = $500,000–$999,999	2.35%	
	8 = $1,000,000–$2,499,999	5.88%	
	9 = More than $2,500,000	2.35%	
Acre	Participant's total acres of strawberries	2.25	1.57
	1 = Less than 5	47.06%	
	2 = 5–14	20.00%	
	3 = 15–24	10.59%	
	4 = 25–49	11.76%	
	5 = 50–99	4.71%	
	6 = 100–249	4.71%	
	7 = 250–499	1.18%	
	8 = 500–1,000	0%	
	9 = More than 1,000	0%	
Experience	Years involved in production of strawberries as a farm owner, manager, or primary decision-maker	20.9	14.6
Structure of Farms	Participant's farm business structures		
	Family or individual operation (excluding partnerships and corporations)	0.63	0.48
	Family partnership	0.14	0.34
	Family corporation	0.18	0.38
	Partnership, other than family	0.013	0.11
	Corporation, other than family	0.013	0.11
	Educational, research, or nonprofit farm	0	0
	Other	0.024	0.15
Race	Participant's race		
	1 = Caucasian or white, 0 = other	0.88	0.32

Table 3. Summary statistics for strawberry consumer demographic background information.

Variable	Description	Mean (SD)	U.S. census
Age	Participant's age in years 1 = 18–24, 2 = 25–34, 3 = 35–44, 4 = 45–54, 5 = 55–64, 6 = 65 or over	3.11 (1.55)	3.22
Gender	Gender of participant, 1 = female, 2 = male	1.32 (0.47)	1.49
Education	The highest level of education	3.04 (1.06)	3.39
	1 = Less than high school	2.97	
	2 = High school degree	34.48	
	3 = 2-yr college or technical/other degree	29.10	
	4 = 4-yr college degree	22.52	
	5 = Advanced college degree	10.94	
Income	Annual household income of participants	3.26 (1.65)	3.05
	1 = Less than $25,000	19.74%	
	2 = $25,000–$34,999	17.61%	
	3 = $35,000–$49,999	17.15%	
	4 = $50,000–$74,999	21.13%	
	5 = $75,000–$99,999	11.58%	
	6 = More than $100,000	12.79%	
Race	Participant's race		
	1 = Caucasian or white, 0 = other	0.72 (0.45)	0.74
Frequency	The frequency at which participant eats fresh strawberries	3.24 (1.46)	—
	1 = Daily	11.39%	
	2 = More than once a week	26.02%	
	3 = Once a week	17.69%	
	4 = 2–3 times a mo.	25.37%	
	5 = Once a mo.	10.93%	
	6 = Less than once a mo.	8.43%	
	7 = Never	0.19%	
Pounds of strawberries	The pounds of strawberries the participant bought at one time 1 = 1 pound, 2 = 2, 3 = 3, 4 = 4, 5 = 5, 6 = 6, 7 = 7 or more	2.21 (1.28)	—

Table 4. Mixed logit model estimation results for strawberry consumer and producer choice experiment data.

	Mixed logit estimation results		WTP estimates ($/lb) [95% confidence intervals]	
	Producer	Consumer	Producer	Consumer
Mean coefficients				
External color	0.689***	0.602***	0.710	1.069
	(5.87)	(11.82)	[0.466, 0.955]	[0.178, 1.961]
Internal color	0.539***	1.050***	0.556	1.866
	(0.09)	(16.94)	[0.365, 0.747]	[0.262, 3.468]
Firmness	0.782***	0.318***	0.807	0.564
	(4.78)	(4.00)	[0.489, 1.124]	[0.251, 0.877]
Flavor	1.336***	0.619***	1.378	1.099
	(7.43)	(12.47)	[0.966, 1.790]	[0.027, 2.172]
Size	0.264***	0.181***	0.272	0.321
	(3.30)	(4.32)	[0.111, 0.433]	[–0.064, 0.707]
Shelf life	0.536***	0.427***	0.552	0.759
	(3.69)	(9.48)	[0.264, 0.841]	[–0.006, 1.524]
Cost	–0.969***			
	(–5.99)			
Price		–0.563**		
		(–2.18)		
Standard deviation coefficients				
External color	0.635***	0.891***		
	(4.22)	(14.02)		
Internal color	–0.132	1.244***		
	(–0.92)	(17.78)		
Firmness	0.619***	0.949***		
	(3.61)	(14.63)		
Flavor	1.288***	0.859***		
	(6.62)	(13.66)		
Size	–0.139	0.375***		
	(–0.75)	(4.78)		
Shelf life	0.574***	0.648***		
	(3.77)	(10.27)		
Number of observations	2,016	15,916		
X^2	87.11***	430.75***		

t statistics in parentheses.
*P < 0.10, **P < 0.05, ***P < 0.01.

individual producer and consumer's WTP can be calculated using the individual estimated coefficients for the attributes using Eqs. [10] and [11]. Column (3) of Table 4 shows the mean values of producers' WTP for growing strawberries with different attributes. The highest mean WTP value was for *Flavor*, $1.378/lb. The second and third highest mean WTP values were for *Firmness*

($0.807/lb) and *External color* ($0.710/lb), respectively. The lowest average WTP value was $0.272/lb for *Size*. Consumer WTP values were shown in Column (4) of Table 4. The highest mean WTP value for consumers was for *Internal color*, $1.866/lb, followed by *Flavor* ($1.099/lb), and then *External color* ($1.069/lb). The lowest WTP value for strawberry consumers was $0.321/lb for *Size*.

The individual producers' WTP values were adjusted by adding the retail margin to obtain the retail supply price. Specifically, using the retail margin data from the USDA (2013), we multiplied the individual producer's WTP values by 2.45 to get the retail supply prices. Using these producer and consumer WTP values, we approximated the corresponding quantities for the attributes using Eqs. [12] and [13]. After getting the supply and demand retail prices and quantities supplied/demanded, we derived supply and demand curves for each attribute (Fig. 1). The red dotted lines in Fig. 1 are the demand curves, and the blue dotted lines are the supply curves for the strawberry attributes.

The consumers' demand curve for strawberry *Flavor* can be interpreted as how the quantity demanded for strawberries with full/intense flavor (compared with strawberries with weak/mild flavor) changed when the price of strawberries with full/intense flavor changed, assuming other attributes of the strawberries were the same. Similarly, the supply curve for *Flavor* represented how producers' quantity supplied for strawberries with intense/full flavor changed when the retail price of strawberries with intense/full flavor changed, assuming other attributes stayed the same. The unit for the X-axis is billion pounds, and the unit for the Y-axis is U.S. dollars.

The highest equilibrium price was for *Internal color* ($1.36), followed by *Flavor* ($1.13), *Firmness* ($1.08), and *External color* ($0.90). The highest equilibrium quantity was for *Internal color* (1.18 billion pounds), followed by *External color* (0.98 billion pounds), *Flavor* (0.93 billion pounds), and *Shelf life* (0.81 billion pounds).

We computed the total revenue by multiplying the equilibrium quantity with equilibrium price. In addition, to evaluate the social welfare, we estimated the producer surplus (PS) as well as consumer surplus (CS). The Riemann sum integral approach is a useful tool to compute the CS and PS (Pope et al.,

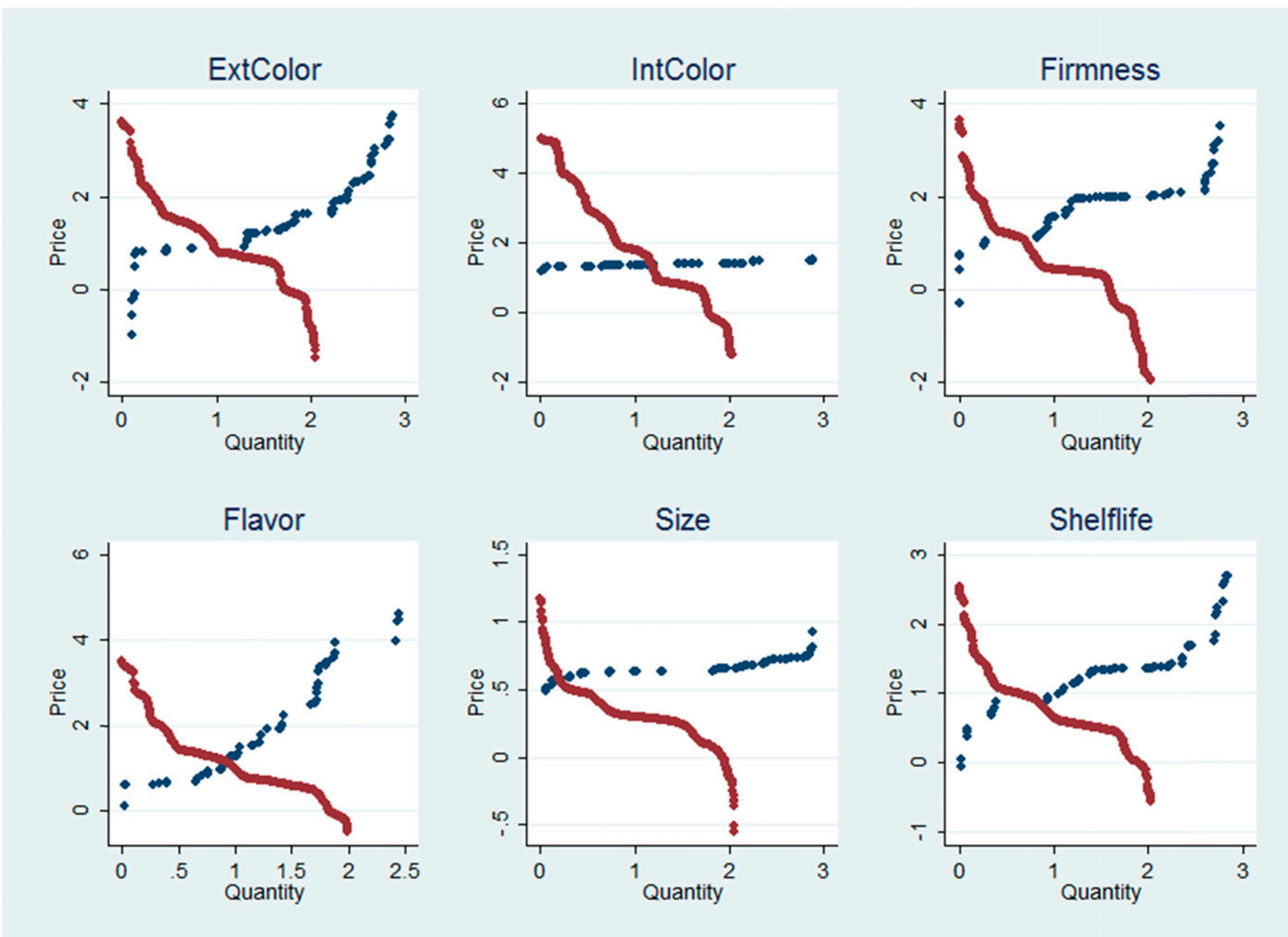

Fig. 1. Supply and demand curves for each strawberry attribute. The unit for the X-axis is billion pounds, and the unit for the Y-axis is U.S. dollars. Blue dots represent supply curves and red dots represent demand curves.

Table 5. Welfare analysis results for strawberry attributes.

Strawberry	Price ($)	Quantity (billion)	Total revenue (billion$)	Consumer surplus (billion$)	Producer surplus (billion$)	Total surplus (billion$)
External color	0.9	0.98	0.88	0.89	0.22	1.11
Internal color	1.36	1.18	1.60	1.84	0.05	1.89
Firmness	1.08	0.67	0.72	0.40	0.09	0.49
Flavor	1.13	0.93	1.05	0.73	0.37	1.10
Size	0.59	0.20	0.12	0.03	0.01	0.04
Shelf life	0.90	0.81	0.73	0.31	0.16	0.47

1983). This approach adds up the area of every rectangle between the corresponding curve and equilibrium (Stewart, 2008). The total surplus was computed as the sum of CS and PS. Table 5 shows the estimated welfare results for each strawberry attribute. As shown in Table 5, the ranking of total revenue results was similar to that of total surplus for strawberry attributes.

The simulated strawberry's total revenue was $5.1 billion and was computed by summing up the equilibrium revenue for every studied attribute of the fruit. According to the USDA (2015), for fresh strawberry, the actual market revenue in 2012 was about $5.98 billion. Our simulated total revenue for strawberry was lower compared with the actual market value. Nevertheless, only six most significant strawberry attributes were included in our estimated results. Other attributes that were not included in our study might cause the discrepancy between the USDA reported revenue and our estimated revenue.

Discussion and Conclusions

To our knowledge, this study was the first attempt to investigate the equilibrium quantities and prices for key strawberry attributes by integrating the analysis of consumers' and producers' WTP values. In addition, we also conducted a welfare analysis based on these attributes' simulated demand and supply curves.

Research focusing on consumer strawberry attributes' preference has shown that consumers prefer a strawberry fruit that is sweeter, with complex flavor, and firmer (Colquhoun et al., 2012; Keutgen and Pawelzik, 2007; Lado et al., 2010). Our results have shown that in addition to flavor, both internal color and external color of strawberries are important to consumers. The results of producer WTP were in line with Yue et al. (2014) that concluded firmness and flavor are more important attributes for producers. After we synthesized consumer and producer WTP values in market equilibrium, we found flavor and internal color had the highest market value, which is different from those previous studies that only focused on either consumer or producer preferences.

According to our results, strawberry's breeder from private sectors who measures returns in terms of the total revenue should give the highest priority to flavor, followed by internal and external color. Breeders from the public sector who care more about the total welfare should give the highest priority to internal color, followed by external color and flavor.

The choice experiments we employed make it possible to estimate the economic values of not only existing traits but also prospective traits. The model we used does not require the IIA assumption, which enables the taste parameters to randomly vary across individuals. This allows us to simulate the demand and supply curves for each product attribute. The limitation of this study was that we only focused on the return side of breeding strawberry with improved attributes and did not consider the cost factors. For different attributes, research and development costs could differ considerably, which might lead breeders to change their breeding targets. Future research can also consider cost factors to give a holistic picture on the return on investment when breeders make decisions about the breeding targets.

Literature Cited

Bhat, C.R. 2001. Quasi-random maximum simulated likelihood estimation of the mixed multinomial logit model. Transp. Res. Part B: Methodol. 35:677–693.

Brownstone, D. and K. Train. 1999. Forecasting new product penetration with flexible substitution patterns. J. Econom. 89:109–129.

Capocasa, F., J. Scalzo, B. Mezzetti, and M. Battino. 2008. Combining quality and antioxidant attributes in the strawberry. The role of genotype. Food Chem. 111:872–878.

Colquhoun, T.A., L.A. Levin, H.R. Moskowitz, V.M. Whitaker, D.G. Clark, and K.M. Folta. 2012. Framing the perfect strawberry: An exercise in consumer-assisted selection of fruit crops. Journal of Berry Research 2:45–61.

Darby, K., M.T. Batte, S. Ernst, and B. Roe. 2008. Decomposing local: A conjoint analysis of locally produced foods. Amer. J. Agr. Econ. 90(2):476–486.

Ford, A., K. Hansen, M. Herrington, J. Moisander, S. Nottingham, S. Prytz, and M. Zorin. 1996. Subjective and objective determination of strawberry quality. Acta Hort. 439:319–323.

Gallardo, R.K., H. Li, V. McCracken, C. Yue, J. Luby, and J. McFerson. 2014. Market intermediaries' willingness to pay for apple, peach, cherry, and strawberry quality traits. Agribusiness 31(2): 259–280.

Gallardo, R.K., D. Nguyen, V. McCracken, C.Y. Yue, J. Luby, and J.R. McFerson. 2012. An investigation of trait prioritization in rosaceous fruit breeding programs. HortScience 47:771–776.

Hancock, J.F., T.M. Sjulin, and G.A. Lobos. 2008. Strawberries, p. 393–438. In: J.F. Hancock (ed.). Temperate fruit crop breeding: Germplasm to genomics. Springer, New York, NY.

He, C., Z. Gao, C.A. Sims, and X. Zhao. 2015. Does local label bias consumer taste bud and preference: Evidence of a strawberry sensory experiment. 2015 Annu. Mtg., Atlanta, GA, Jan. 31–Feb. 3 2015. (Southern Agricultural Economics Association).

Jacobs, H.L., H.D. Khan, K.A. Stralka, and D.B. Phan. 1998. Estimates of per capita fish consumption in the U.S. based on the continuing survey of food intake by individuals (CSF2). Risk Analysis 18(3):283–291.

Khanizadeh, S., M. Lareau, and D. Buszard. 1992. Evaluation of advanced strawberry selections in Quebec. Fruit Var. J. 46:53–57.

Keutgen, A. and E. Pawelzik. 2007. Modifications of taste-relevant compounds in strawberry fruit under NaCl salinity. Food Chem. 105:1487–1494.

Lado, J., E. Vicente, A. Manzzioini, and G. Ares. 2010. Application of a check-all-that-apply question for the evaluation of strawberry cultivars from a breeding program. J. Sci. Food Agr. 90:2268–2275.

Lancaster, K. 1966. A new approach to consumer theory. J. Polit. Econ. 74:217–231.

Louviere, J.J., D.A. Hensher, and J.D. Swait. 2000. Stated choice methods: Analysis and application. Cambridge University Press, Cambridge.

Lusk, J.L. and D. Hudson. 2004. Willingness-to-pay estimates and their relevance to agribusiness decision making. Appl. Econ. Perspect. Policy 26(2):152–169.

Lusk, J.L. and T.C. Schroeder. 2004. Are choice experiments incentive compatible? A test with quality differentiated beef steaks. Amer. J. Agr. Econ. 86(2):467–482.

Pope, R., J.P. Chavas, and R.E. Just. 1983. Economic welfare evaluations for producers under uncertainty. Amer. J. Agr. Econ. 65(1): 98107.

Qin, Y., J.A. Teixeira da Silva, L. Zhang, and S. Zhang. 2008. Transgenic strawberry: State of the art for improved traits. Biotechnol. Adv. 26(3):219–232.

Safley, C.D., M.K. Wohlgenant, and R.E. Suter. 1999. Factors affecting consumers purchases direct market strawberries, *ARE Report* 22. North Carolina State Unviersity.

Stewart, J. 2008. Single variable calculus. vol. 1, 6th ed. Cengage Learning, Boston, MA.

Tonsor, G.T., N. Olynk, and C. Wolf. 2009. Consumer preferences for animal welfare attributes: The case of gestation crates. J. Agr. Appl. Econ. 41(3):713–730.

U.S. Department of Agriculture (USDA). 2013. Retail Price [Data file]. 26 June 2015. <http://www.ers.usda.gov/data-products/fruit-and-tree-nut-data/yearbook-tables.aspx#.UqPUU_RDvNc>.

U.S. Department of Agriculture (USDA). 2015a. Fruit and Tree Nut Yearbook [Data file]. 26 June 2015. <http://usda.mannlib.cornell.edu/usda/ers/89022/2015-Fruitand-TreeNutYearbook.pdf>.

U.S. Department of Agriculture (USDA). 2015b. U.S. strawberry harvested acreage, yield per acre, and production, 13 states. [Data file]. 26 June 2015. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1381>.

U.S. Department of Agriculture (USDA). 2015c. Fruit and tree nuts outlook. [Data file]. 26 June 2015. <http://usda.mannlib.cornell.edu/usda/current/FTS/FTS-03-27-2015.pdf>.

U.S. Department of Commerce, Census Bureau. 2014. National Characteristics: Vintage 2013. [Data file]. 15 July 2015. <http://www.census.gov/popest/data/national/asrh/2013/index.html>.

U.S. Department of Commerce, Patent and Trademark Office. 2015. *Patent full text-and image database* [Data file]. 26 June 2015. <http://patft.uspto.gov/netahtml/PTO/search-bool.html>.

Wang, Q., J. Sun, and R. Parsons. 2010. Consumer preferences and willingness to pay for locally grown organic apples: Evidence from a conjoint study. HortScience 45:376–381.

Whitaker, V., T. Hasing, and C.K. Chandler. 2011. Historical Trends in strawberry fruit quality revealed by a trial of University of Florida Cultivars and advanced selections. HortScience 46:553–557.

Yue, C., R.K. Gallardo, J. Luby, A. Rihn, J.R. McFerson, V. McCracken, V.M. Whitaker, C.E. Finn, J.F. Hancock, C. Weebadde, A. Sebolt, and A. Iezzoni. 2014. An evaluation of U.S. strawberry producers' trait prioritization: Evidence from audience surveys. HortScience 49:188–193.