Estimating Strawberry Attributes’ Market Equilibrium Values

Jong Woo Choi
Korea Rural Economic Institute, Naju, South Korea

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

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

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

Karina Gallardo and Vicki McCracken
School of Economics, Washington State University, Pullman, WA 99163

Jim McFerson
Washington Tree Fruit Research Commission, Wenatchee, WA 98801

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 $2.1 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 the 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
In 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, non-technical 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 after harvest” and “Will last 4 d after harvest.” 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 137 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 l alternatives (i = 1,2, ..., l). For consumer n (n = 1, 2, ..., N), the utility derived from the ith alternative can be represented as:

\[ U_{ni} = \beta_i x_{ni} + e_{ni} \]  

where: 

- \( U_{ni} \): individual n’s utility from choosing alternative i;
- \( x_{ni} \): a vector of observed variables representing the characteristics of individual n and alternative i;
- \( \beta_i \): an unobserved random coefficient vector for each n that varies in the population;
- \( e_{ni} \): 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 l 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 \( \beta_i \), the conditional probability of choosing alternative i is:

\[ Pr(Y_n = i | \beta_i) = Pr(\text{max}_{j \neq i} U_{nj} < U_{ni}) \]  

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

\[ Pr(Y_n = i | \beta_i) = \frac{e^{\beta_i x_{ni}}}{\sum_{k=1}^{M} e^{\beta_k x_{nk}}} \]  

Integrating (3) over the density of the vector, \( f(\beta_i) \), we can get the unconditional choice probability in the mixed logit model.

\[ Pr(Y_n = i) = \int Pr(Y_n = i | \beta_i) f(\beta_i) d\beta_i \]  

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.

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<th>Level 1</th>
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Here, the logit function \( Pr(Y_n = i)\) is estimated by drawing \( \beta \) from \( f(\beta|\theta) \) \( \mathbb{R} \) times, and \( \beta^r \) represents the \( r \)th draw of \( \beta \). \( SPr(Y_n = i) = \sum_{r=1}^{R} Pr(Y_n = i)(\beta^r) \) 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 \( P_n^i \) 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 \( i \)th alternative can be represented as:

\[ \pi_{mai} = \alpha_m x_{mai} + \mu_{mai} \]

Assumption 2: Fixed total quantity demanded for strawberries. We assumed that the total strawberry quantity demanded 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 demand 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.

Some individual producer’s quantity supplied was approximated as follows:

\[ \text{Quantity Supplied per acre for strawberries}(\text{lbs}) \]
\[ = \text{Average quantity(lbs)/acre in top 5 producing states} \times \text{Total acres from the survey} \]

(12)

Each individual producer’s quantity supplied was approximated as follows:

\[ \text{Quantity Supplied per acre} = \frac{\text{Average quantity(lbs)/acre in top 5 producing states} \times \text{Total acres from the survey}}{0.98} \]

(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 the retail 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).

Suppose: 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).

\[ WTP_{mk} = - \left( \frac{\beta_{mk}}{\beta_{np}} \right) \]

(10)

where \( \beta_{mk} \) is consumer \( n \)’s coefficient for the \( k \)th attribute, and \( \beta_{np} \) is producer \( n \)’s coefficient for price.
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 individual operation 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.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Participant’s age in years</td>
<td>57.2</td>
<td>12.7</td>
</tr>
<tr>
<td>Gender</td>
<td>Gender of participant, 1 = male, 2 = female</td>
<td>1.08</td>
<td>0.27</td>
</tr>
<tr>
<td>Education</td>
<td>The highest level of education</td>
<td>4.52</td>
<td>2.12</td>
</tr>
<tr>
<td>Income</td>
<td>The gross annual income from participant’s strawberries</td>
<td>2.86</td>
<td>2.42</td>
</tr>
<tr>
<td>Acre</td>
<td>Participant’s total acres of strawberries</td>
<td>2.25</td>
<td>1.57</td>
</tr>
<tr>
<td>Experience</td>
<td>Years involved in production of strawberries as a farm owner, manager, or primary decision-maker</td>
<td>20.9</td>
<td>14.6</td>
</tr>
<tr>
<td>Structure of Farms</td>
<td>Participant’s farm business structures</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Family or individual operation (excluding partnerships and corporations)</td>
<td>0.63</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>Family partnership</td>
<td>0.14</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>Family corporation</td>
<td>0.18</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>Partnership, other than family</td>
<td>0.013</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>Corporation, other than family</td>
<td>0.013</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>Educational, research, or nonprofit farm</td>
<td>0.024</td>
<td>0.15</td>
</tr>
<tr>
<td>Race</td>
<td>Participant’s race</td>
<td>0.88</td>
<td>0.32</td>
</tr>
</tbody>
</table>

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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.](image)

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