Mandarin Market Segments Based on Consumer Sensory Evaluations

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Ninety-five consumers in seven grocery stores tasted unidentified peeled sections of three mandarins (a tangerine, a satsuma, and a clementine), and provided demographic and purchase information. Forty-four percent of the respondents preferred tangerines, 34 percent satsumas, and 22 percent clementines. The probability of preferring each of type of mandarin was estimated from internal quality analysis of paired samples, as well as from demographic and purchase responses. Model simulations were used to recommend harvest standards for satsumas based on Brix-to-acid ratios.

In just a decade, U.S. per-capita consumption of mandarins increased by almost 16 percent, from an average of 0.93 kg in 1996 to 1.07 kg in 2005. Over the same period, while U.S. production of mandarins decreased three percent, imports increased 376 percent; the total U.S. market supply in 2005 was 355,000 metric tons, up 24 percent from 1996 (Economic Research Service 2007). Increased consumption and availability of popular mandarin varieties (clementines and tangerines) have led to increasing interest in novel mandarin varieties and the reemergence of once-popular types such as satsumas, which are becoming re-established throughout the U.S., most notably in California, Texas, Louisiana, and Alabama.

Currently, most of the whole satsumas distributed through grocery stores in the U.S. are produced in California. However, satsuma production along the Gulf Coast is beginning to expand after a 50-year hiatus because the region offers an ideal climate for producing satsumas (Ebel et al. 2004). Rapid increases in production have quickly saturated local markets, so Gulf Coast satsuma producers now need to expand into new markets. But in order for the fledgling Gulf Coast industry to be able to compete with the larger domestic and foreign suppliers of clementines and tangerines, Gulf Coast satsuma growers must better understand consumer preferences for mandarin attributes in order to market their products more effectively.

Consumer acceptance of most food products is determined primarily by flavor, texture, and appearance (Moskowitz and Krieger 1995). Appearance of mandarins has been examined by Campbell et al. (2004, 2006), who evaluated consumer preferences for skin color, fruit size, seeds, blemishes, and packaging in two studies of consumers who purchased their citrus fruit in retail grocery chain stores. However, little is known about consumer preferences for flavor attributes of mandarins. The current study segments consumers based on their combined perceptions of flavor and texture in satsumas, tangerines, and clementines, and relates those preferences to two readily-measured internal quality attributes that are known to influence flavor perceptions: soluble solids ("Brix") and titratable acidity ("acids"). Brix and acids are major contributors to perceived internal fruit quality, and the ratio of Brix to acid is a criterion used by regulatory bodies in the citrus industry to establish minimum harvest-quality standards (Fellers 1991; Poole and Gray 2002; Ting and Rouseff 1986). For example, Louisiana requires that satsumas reach a 10:1 Brix-to-acid ratio before they can be marketed (Ebel et al. 2004).

Originally our intent was to use the results of this study to recommend optimal harvest times for satsumas and to construct consumer profiles of the satsuma-preferring segment in order to position them competitively with tangerines and clementines. However, it is possible that these three types

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This project was funded in part by the Alabama Department of Agriculture and Industries, a grant from the USDA Federal-State Marketing Improvement Program, and the Alabama Agricultural Experiment Station. We thank Oral Capps, Jr. and John L. Park for reviewing an earlier version of the manuscript, and Bruno's Supermarkets, Inc. for their cooperation in conducting the survey.

of mandarins could avoid competition altogether by staggering their harvests based on consumer preferences for changing ratios.

Materials and Methods

Fruit Samples

A revealing test of the future success of a new product is to allow a sample of potential consumers to compare the new product to its closest competitors (Saguy and Moskowitz 1999). To this end, Alabama-grown satsumas were tested against two mandarin competitors popular in the marketplace: clementines and tangerines. The satsuma variety chosen for sensory evaluation was "Owari," the most common variety currently produced along the Gulf Coast. Satsumas used in the study were harvested from the Gulf Coast Research and Extension Center in Fairhope, Alabama one week prior to the start of the sensory evaluation. After harvest, fruit were stored at 4^{o}C until the day before testing, at which point they were brought to room temperature.

The clementines and tangerines were purchased from local grocery stores the day before testing and kept at room temperature. The clementines were a product of Spain, while the tangerines were from Florida. The specific varieties of clementine and tangerine available for the test were not known due to the lack of variety information on the package, but they were considered to be representative of the quality typically available to consumers during the testing period. All the fruit chosen for tasting were visually inspected to eliminate any that were blemished.

Sensory Evaluation

Since only three products were to be evaluated, a treatments-by-subjects design was used (Stone and Sidel 2004). Samples were served using a balanced-block design in order to minimize the effect of time-order bias. Sensory evaluations were administered during the week prior to Christmas in several grocery store chains located in various demographic areas in and around Montgomery and Birmingham, Alabama.

Store patrons passing the survey table were asked if they would like to participate in a sensory-evaluation survey. Those agreeing to participate were first familiarized with the testing procedure, and then were shown one section of each of the three types of fruit and asked to taste each section. Since product name and external characteristics can bias sensory evaluations (Wansink 2003), consumers were told only that the taste samples were from mandarins of the quality available in a grocery store. Each product was identified only by a three-digit number assigned randomly to each fruit prior to the testing session. After a product sample was evaluated, respondents sipped water to cleanse their taste receptors before evaluating the next product sample. Upon finishing the three samples, respondents were asked to identify which mandarin they preferred and, based on this response, were assigned either to the satsuma, clementine, or tangerine market segment. A single fruit yielded enough peeled sections for as many as five respondents plus the matching samples needed for laboratory testing. Excessively small or large sections were eliminated from the evaluation, in order to standardize the volume of fruit tasted.

Consumer preference for flavor depends on past purchase experience and is related to socioeconomic attributes of the respondents (Baldwin 2002). For example, in a study of apples by Richards (2000), the preferred type and variety of apple were related to past purchase behavior including rate of consumption and purchasing habits. Therefore, in our study, consumers were also asked to complete a set of questions relating to demographic characteristics (age, gender, race, education, household size, family structure, and income), and purchasing behavior (citrus consumption rate, location of purchases, and special purchase occasions).

Internal Quality Measurements

In order to get an objective measure of fruit quality, each whole fruit used in the study was divided in half. One half was further pulled apart and sections of approximately equal size were used in the sensory evaluation, while the other half was saved for subsequent laboratory analysis of its soluble solids (Brix) and titratable acidity (acids). Each sample saved for analysis was assigned the same three-digit code as its tasted counterpart, so that consumers' preferences and internal fruit characteristics could later be matched.

Each fruit half was juiced using a Hamilton

Beach Type CJ09 HealthSmart Juice Extractor and filtered through cheesecloth. A drop of juice was applied to a Leica Microsystems Model 10494 hand-held, temperature-compensated refractometer to determine Brix content. Acid content was measured by titrating 10 ml of juice to a pH of 8.1 with 0.1 N KOH solution using a Metrohm Titrino model 751 GPD automated titrimeter and a Metrohm sample changer and associated Titrino Worcell 4.4 computer software from Brinkmann Corp. After determining the Brix and acid measurements, the ratio for each fruit sample was calculated simply as the quotient of the two.

Theoretical Model

A fundamental assumption of choice theory is that market behavior such as product choice is generated by the maximization of preferences, and these preferences can be influenced by many factors including habit, experience, attitude, and demographics (McFadden 1986). Since preferences are contingent on a consumer's satisfaction with a product or product attribute, we can derive a specific utility for each consumer given product and consumer determinants.

In order to measure the effect of the demographic and socio-economic variables on the probability of choosing a particular mandarin variety, a multinomial logit (MNL) model was specified and marginal effects calculated. This MNL model incorporates random utility theory, which assumes that each choice has a utility associated with it and that the consumer's preferred choice represents the maximum utility of all choices considered (Greene 2002, p.719). In our case, each mandarin variety (satsuma, clementine, and tangerine) has a separate utility, U^S, U^C, and U^T, made up of both fruit quality and respondent characteristics, with the respondent's final choice representing the variety with the maximum utility. $U^S > U^C$ implies satsuma is preferred to clementine. The MNL model can be written as:

$$(1) \quad \Pr(Y_i = j) = \frac{e^{\beta'_j x_i}}{\sum_{i=1}^{j} e^{\beta'_k x_i}} ,$$

where j = 1, 2, or 3 represents variety choice and the x_i are relevant explanatory variables to be included in the model, such as demographic and purchase-behavior variables, along with the internal quality measures of Brix, acid, and Brix-to-acid ratio.

Brix, acid, and their ratio are predominantly used as industry standards to measure ripeness and as an indicator of acceptance (Fellers, Carter, and de Jager 1988; Ebel et al. 2004). However, it should be noted that these may not be the only variables that influence a respondent's choice. Other factors such as color, texture, seediness, bitterness, and inherited or acquired sensory dispositions—not to mention the complex volatile organic compounds that characterize flavors and aromas—may all play a role in the taste experience, and thereby influence choices. To a greater or lesser extent these were controlled or randomized in the study, or were difficult if not impossible to measure. The absence of relevant variables in the model does not compromise its use in prediction, but it does warrant caution in the interpretation of coefficients.

Data Analysis

Respondents were grouped into market segments based on which type of mandarin was represented by the taste sample they said they preferred. Consumer characteristics for each segment then were evaluated using a MNL model estimated with LIMDEP (Greene 1995). The MNL model was used to determine the probability of choosing a mandarin type based on internal quality measures and respondent characteristics such as demographics and purchasing behavior. Since one goal of the study was to construct a general profile of the consumers who prefer each type of mandarin, model coefficients with p-values up to 0.11 were considered.

Simulation

An extension of the MNL model was also used to simulate the probability of choosing each of the three mandarin types based on varying Brix, acid, and Brix-to-acid ratios, *ceteris paribus*. To predict these probabilities over a wide range of values, the relation between acid levels and ratio for each type of mandarin was first estimated with an exponential regression using the data from the samples of the three mandarin types that were tasted (n = 95 samples per fruit). Then, for each integer value of ratio from seven to 25, the acid value was predicted from the regression and the Brix value was simply calculated as the product of the acid and ratio. For each of the 19 integer ratios of interest, the nine corresponding internal quality values were inserted into the MNL model and the new probabilities were predicted for each of the three mandarin segments, holding the other 18 variables in the MNL model constant at their mean values (Liao 1994).

Results and Discussion

Internal Quality of Fruit Samples

Even though the study was conducted over just a few days in mid-December, the fruit samples nevertheless provided a wide range of flavor sensations, helping to make subsequent analyses more generalizable. For example, the range of the ratio of Brix to acid varied by as much as 65 percent above the mean and 48 percent below (Table 1).

The average Brix-to-acid ratio observed during the study period (Table 1) was significantly different among the three mandarins ($p < 0.05$). This ratio is the factor that most influences our perception of the sweetness or tartness of citrus: a higher ratio is associated with a sweeter flavor, while a lower ratio is associated with a tarter flavor (Ting and Rouseff 1986). While Brix primarily measures the sugar content of a sample, Brix alone can be a misleading measure of sweetness. For instance, the tangerine samples had the highest average Brix (10.9 percent), but they also had the highest average acid (0.83 percent), which, in this combination, gave them the lowest average ratio and therefore made them the most tart of the samples. A comparison of the means in Table 1 showed that the clementine samples had the sweetest average ratios (17.1), followed by the satsumas (16.0) and the tangerines (13.5).

Segment Demographics

Ninety-five usable sensory-evaluation surveys were collected during the surveying process. After segmenting consumers by their stated preferences, results showed that 44 percent of respondents preferred the tangerine, 34 percent the satsuma, and 22 percent the clementine (Table 2).

There were few significant differences in demographics among segments (Table 2). Certain stores had disproportionate representations of segments. For example, Store 1, with higher-average-income respondents, had significantly more consumers in the satsuma segment than in the tangerine segment, while Store 5, with lower-average-income respondents, had significantly more representation in the tangerine segment than in the other two. Members of the satsuma segment also had significantly higher education and income levels compared to the tangerine segment.

Multinomial Logit Modeling

Table 3 presents a series of progressively more inclusive sets of independent variables that improved the fit of the model, using several criteria to measure performance. By the McKelvey-Zavoina pseudo-R^2 criterion, the three basic sources of improvements to fit—stores, demographics, and internal quality—contributed nine percent, 17 percent, and 20 percent respectively, which combined to approximate that of the full model (45 percent). Demographics alone did well in predicting satsuma and tangerine membership, but only the full model assigned clementine members with any accuracy. Of the internal-quality sub-models, most predicted well for tangerine segment membership but poorly for the other two segments.

The full 27-variable multinomial logit model was capable of a relatively high degree of accuracy in predicting segment membership, placing respondents in the correct segment 79 percent, 71 percent, and 88 percent of the time for the satsuma, clementine, and tangerine segments, respectively. Respondents assigned by the model to an incorrect segment were about equally distributed to the other two segments.

Table 4 shows the sign, magnitude, significance, and elasticity of each of the marginal probabilities from the full model of segment membership. Within the satsuma segment there were seven variables that met our subjective criterion for the chance of making a Type-I error ($p < 0.11$). These included the ratio for the satsuma sample tasted, purchase frequency, location of purchase, Christmas purchasing, age, gender, and education.

In interpreting marginal probabilities, if the variable is continuous the coefficient approximates the change in the probability of being in the segment given a one-unit change in the explanatory variable, holding the other variables constant (Liao 1994, p. 20). For example, a one-year increase

Table 1. Internal Fruit Quality Measures.

	Satsumas tasted			Clementines tasted			Tangerines tasted		
Statistic	Brix	acid	ratio	Brix	acid	ratio	Brix	acid	ratio
Mean	8.83	0.58	15.96	9.13	0.57	17.13	10.92	0.83	13.49
Median	9.10	0.55	15.59	8.90	0.55	17.13	11.20	0.82	14.05
Minimum	6.30	0.31	8.25	7.60	0.35	10.17	8.20	0.56	9.24
Maximum	11.10	1.02	23.27	11.50	0.95	28.25	12.80	1.11	22.28
Coeff. of variation	13%	27%	22%	11%	26%	26%	12%	18%	19%
Distribution:									
6.1 to 8	27			10					
8.1 to 10	56		7	66			23		7
10.1 to 12	12		2	19		7	52		23
12.1 to 14			14			11	20		15
14.1 to 16			31			29			37
16.1 to 18			23			11			12
18.1 to 20			5			14			0
20.1 to 22			2			13			0
22.1 to 24			11			5			1
24.1 to 26						0			
26.1 to 28						1			
28.1 to 30						4			

Table 2. Average Demographics by Segment.

Demographic variable	Satsuma segment	Clementine segment	Tangerine segment	Overall
Market share (% of total sample)	34%	22%	44%	100%
Survey site (% of segment)				
Store 4 - Chain A (mean income = $86,580)	9^{a}	5^{a}	10^{a}	8
Store 1 - Chain A (mean income = $82,024)	27^{a}	14^{ab}	7^{b}	16
Store 6 - Chain B (mean income = $45,714)	15^{a}	29^{a}	12^{a}	17
Store 3 - Chain B (mean income = $44,215)	27^{a}	38^{a}	29^{a}	30
Store 2 - Chain B (mean income = $38,010)	12^{a}	5^{a}	5^{a}	7
Store 5 - Chain C (mean income = $24,230)	6^{b}	5^{b}	26^{a}	15
Store 7 - Chain C (mean income = $19,285)	3^{a}	5^{a}	12^{a}	7
Times purchase sweet citrus per month	3.23^{a}	2.1^{a}	3.02^{a}	2.89
Amount purchased (kg/purchase)	1.12^{a}	1.07^{a}	1.47^{a}	1.26
Buy citrus at grocery store (% yes)	85^{a}	90^{a}	79^{a}	83
Purchase for Christmas (% yes)	45^{a}	40^{a}	57^{a}	49
Age (years)	49.2^{a}	44.3^{a}	42.3^{a}	45.1
Gender (% female)	73^{a}	75^{a}	69^{a}	72
Ethnicity (% white)	76^{a}	80^{a}	55^{a}	67
Education (years)	15.7^{a}	14.5^{ab}	13^{b}	14.2
Average family size (persons)	2.9^{a}	2.9^{a}	3^{a}	3
Average income category (5 = $35–50K)	6.3^{a}	5.49^{ab}	4.89^{b}	5.51
Average income ($)	$57{,}590^{a}$	$42{,}321^{ab}$	$33{,}939^{b}$	42,949
Parents with children <9 years old (%)	15^{a}	25^{a}	26^{a}	22

[a, b] Different letters represent significant differences between means in a row ($p < 0.05$), using Duncan's multiple range test.

Table 3. Performance of Various Multinomial Logit Models and Sub-Models.

Model	Number of parameters in model	Pseudo R^2	Prob of X^2 > value	Percent of segment members correctly predicted		
				Satsuma	Clementine	Tangerine
Internal quality sub-models:						
Brix-only	3	0.05	0.1470	24%	24%	79%
acid-only	3	0.06	0.0479	39%	19%	74%
ratio-only	3	0.06	0.0512	39%	0%	83%
Brix + acid	6	0.10	0.0478	30%	19%	79%
Brix + ratio	6	0.10	0.0492	48%	24%	67%
acid + ratio	6	0.15	0.0023	30%	38%	86%
Brix + acid + ratio	9	0.20	0.0019	39%	38%	79%
Store only	6	0.09	0.0914	39%	29%	76%
Demographics only	11	0.17	0.0406	82%	5%	86%
Store + demographics	17	0.22	0.0901	70%	29%	76%
Brix + acid + ratio + store	15	0.25	0.0084	55%	48%	69%
Brix + acid + ratio + demographics	20	0.36	0.0010	64%	38%	83%
Brix + acid + ratio + store + demographics	26	0.45	0.0006	79%	71%	88%

Table 4. Marginal Probabilities and Elasticities by Consumer Segment.

	Prob[Satsuma]			Prob[Clementine]			Prob[Tangerine]		
Variable	Coeff.	p-val.	Elas.	Coeff.	p-val.	Elas.	Coeff.	p-val.	Elas.
Intercept	-3.6993	0.59	0.1186	0.59	3.5807	0.60			
Satsuma brix	-0.1605	0.31	-4.68†	-0.0102	0.50	-2.89†	0.1708	0.22	2.23†
Satsuma acid	2.8372	0.19	5.17†	-0.3590	0.51	-6.32†	-2.4782	0.11	-2.03†
Satsuma ratio	-0.0286	0.05	--[a]	0.1435	0.52	--[a]	-0.1150	0.03	--[a]
Clementine brix	-0.3073	0.34	-9.35†	-0.0279	0.81	-8.19†	0.3351	0.34	4.58†
Clementine acid	3.2018	0.31	5.69†	0.5998	0.67	10.31†	-3.8016	0.31	-3.04†
Clementine ratio	0.0842	0.58	--[a]	0.0025	0.98	--[a]	-0.0867	0.58	--[a]
Tangerine brix	-0.0635	0.67	-2.31†	-0.0401	0.55	-14.09†	0.1036	0.63	1.69†
Tangerine acid	0.8382	0.63	2.26†	0.4124	0.55	10.76†	-1.2506	0.59	-1.52†
Tangerine ratio	0.1367	0.70	--[a]	0.1415	0.55	--[a]	-0.2782	0.65	--[a]
Store 4	-0.3068	0.62	-0.09	0.1591	0.57	0.43	0.1477	0.65	0.02
Store 1	-0.8231	0.15	-0.43	-0.2706	0.58	-1.36	1.0937	0.14	0.26
Store 3	0.2089	0.82	0.12	-0.1546	0.54	-0.83	-0.0543	0.85	-0.01
Store 6	-0.2886	0.58	-0.07	-0.0506	0.73	-0.12	0.3392	0.57	0.04
Store 5	0.0810	0.91	0.04	-0.0407	0.70	-0.19	-0.0403	0.92	-0.01
Store 7	-0.7530	0.20	-0.18	-0.0153	0.92	-0.04	0.7682	0.20	0.08

Multinomial logit model likelihood ratio statistic significant at $p<0.001$.

[a]Elasticity omitted, since changes in ratio cannot be evaluated while simultaneously holding Brix and acid constant

†Complex elasticity -- accounts for interaction of Brix with ratio (with acid held constant), and acid with ratio (with Brix held constant).

Table 4. Marginal Probabilities and Elasticities by Consumer Segment (Continued).

	Prob[Satsuma]			Prob[Clementine]			Prob[Tangerine]		
Variable	Coeff.	p-val.	Elas.	Coeff.	p-val.	Elas.	Coeff.	p-val.	Elas.
Purchase frequency (times/mo)	0.0687	0.11	0.66	-0.0190	0.54	-1.77	-0.0497	0.14	-0.21
Purchase amount (kg/time)	-0.0515	0.64	-0.22	-0.0389	0.60	-1.58	0.0904	0.61	0.17
Buy citrus at grocery store? (1 yes)	0.4286	0.07	1.19	0.0325	0.75	0.87	-0.4611	0.06	-0.57
Buy citrus for Christmas? (1=yes)	-0.3875	0.03	-0.63	-0.0970	0.56	-1.53	0.4845	0.03	0.35
Age (years)	0.0235	0.01	3.54	0.0025	0.60	3.66	-0.0261	0.01	-1.76
Gender (1=female)	0.3195	0.11	0.76	0.0226	0.77	0.52	-0.3421	0.11	-0.37
Ethnicity (1=white)	-0.2159	0.39	-0.48	0.0050	0.78	0.11	0.2109	0.40	0.21
Education (years)	0.1169	0.01	5.53	0.0012	0.71	0.53	-0.1181	0.01	-2.51
Family size (persons)	-0.0157	0.75	-0.15	-0.0126	0.59	-1.20	0.0283	0.72	0.13
Income category (5=$35-50K/yr)	0.0606	0.24	1.11	0.0127	0.60	2.25	-0.0733	0.23	-0.60
Parents with kids <9 years old (1=yes)	0.1346	0.55	0.10	0.0967	0.56	0.68	-0.2313	0.51	-0.08
Percentage correctly predicted		79%			71%			88%	
Probabilities at the mean vector		0.3003			0.0311			0.6686	

Multinomial logit model likelihood ratio statistic significant at $p<0.001$.
[a]Elasticity omitted, since changes in ratio cannot be evaluated while simultaneously holding Brix and acid constant
[†]Complex elasticity -- accounts for interaction of Brix with ratio (with acid held constant), and acid with ratio (with Brix held constant).

in the average years of education in the overall sample from 14.2 to 15.2 years would result in an 11.7 percent increase in the probability of being in the satsuma segment. Purchase frequency and age were other continuous variables that increased the probability of being in the satsuma segment. The continuous demographic variables with the largest proportional impact on segment membership—as measured by their elasticities—were education and age. One-percent increases in education or age were associated with 5.5 percent or 3.5 percent increases in the probability of being in the satsuma segment, respectively.

In discussing the marginal probabilities in the case of discrete variables (e.g. eliciting a yes or no answer), the coefficient is interpreted as the approximate change in the probability of being in the segment if the relation applies to the respondent (Liao 1994, p. 18). For example, respondents who answered yes to the question about whether they purchased mandarins for Christmas were 39 percent less likely to be in the satsuma segment. If the respondent mostly bought sweet citrus fruits at the grocery store (rather than at roadside stands or farmers markets) or was female, these substantially increased the probability of being in the satsuma segment, by about 43 percent and 32 percent, respectively.

There were no significant variables associated with the clementine segment. This result may have been due to the small size of the sample or to the wide variability in responses. Nevertheless, the lack of significant marginal effects did not appreciably limit the predictive accuracy of the MNL model associated with this segment.

The tangerine segment also had seven variables significant at the 0.11-level, including satsuma acid and ratio, purchase location, Christmas purchasing, age, gender, and education. As with the satsuma segment, education and age had the largest impacts on segment membership, but in the case of the tangerine segment they were negative impacts. A one-percent increase in education was associated with a 2.5-percent decrease in the probability of membership in the tangerine segment (inferred from the elasticity value), or a 12-percent decrease for every additional year of education above the average (inferred from the coefficient value). A one-percent increase in age led to a 1.8-percent decrease in probability of membership in the segment, or a three-percent decrease per year of increased age above the average. Female respondents and respondents buying their sweet citrus at a grocery store were 34 percent and 46 percent less likely to be in the tangerine segment, respectively, while respondents purchasing sweet citrus for Christmas were 48 percent more likely to be in the tangerine segment.

Simulations of Changes in Flavor

Variables of special interest to this study were the internal quality factors affecting the sweetness or tartness of mandarins and their subsequent effects on membership in the various segments. Brix and acid levels of all mandarins—and the specific flavor sensations associated with their ratios—change with harvest date and postharvest handling techniques, and show considerable variation from fruit to fruit, tree to tree, grove to grove, and year to year (Ebel et al. 2004). Furthermore, Brix and acid levels are not independent: Brix rises as the harvest season progresses, while acid declines, and their combined effect on the mandarins of interest in this study is a rise in the average Brix-to-acid ratio during the fall months in the northern hemisphere (Ebel et al. 2004). The probabilistic effects of small changes in Brix, holding acid constant, and vice versa can be evaluated from their elasticities in Table 4, which indicate that segment probabilities are comparatively sensitive to some of these changes. But to evaluate the effect of ratios formed from combinations of Brix and acid changing *simultaneously*, a simulation approach is required (Liao 1994).

To estimate the effects of Brix and acid and their ratios on the probabilities of segment membership, realistic values for the Brix and acid variables were estimated using internal quality data from the laboratory samples of all three mandarins and following the method described above. The multinomial logit model was used to predict new probabilities of segment membership over a range of integer values for Brix-to-acid ratios (Figure 1). Essentially, this scenario asks the question: "If all three fruits were available with the same Brix-to-acid ratio, what would be the probability of a representative consumer preferring a given mandarin type (an estimate of market share), assuming all other variables were held constant?" Figure 1 shows that in a head-to-head comparison, satsumas are the most preferred mandarin at ratios up to about 15, after which tangerines have the most preferred flavor. Clementines do not show any appreciable market share in this simulation, but do rise steadily in popularity to 13 percent as ratio increases to the highest simulated sweetness level of 25.

Obviously, the actual market relationship is even more complex than was simulated by holding all other variables constant and varying only Brix, acid, and ratio for the three mandarins. For one thing, during the typical fall/winter retail season, all three types are not available with identical ratios at the same time—satsumas usually appear in the market first (with lower ratios), followed by tangerines and then clementines (at the highest ratios). Because our survey was only a snapshot taken relatively late in the season, and because we did not have internal quality data throughout the whole season for the tangerines and clementines available in our sample stores, we could not simulate the effects of varying them all simultaneously over time using the different flavor ratios that consumers actually experienced throughout the season. Nevertheless, there was sufficient variability in the individual samples taken during our snapshot to simulate within a wide range of values. Furthermore, the simulation model provides a platform for evaluating a multitude of alternative scenarios other than the one we illustrate here. For example, if tangerines were *only* available at a ratio of 13.5, and clementines were *only* available at a ratio of 17.1 (their respective averages in our sample), but satsumas could be delivered at a variety of ratios, then an alternative simulation revealed that satsumas would be preferred when their ratios fell between nine and 14.

Conclusions and Marketing Implications

In the larger scope of commercial mandarin production and marketing, the results of this study provide some support for state- or industry-mandated quality standards in determining the timing of the harvest season for various mandarins. At least one of our original objectives is satisfied in that a quality standard for satsumas is suggested by the current evidence: marketing satsumas at ratios over 15 puts

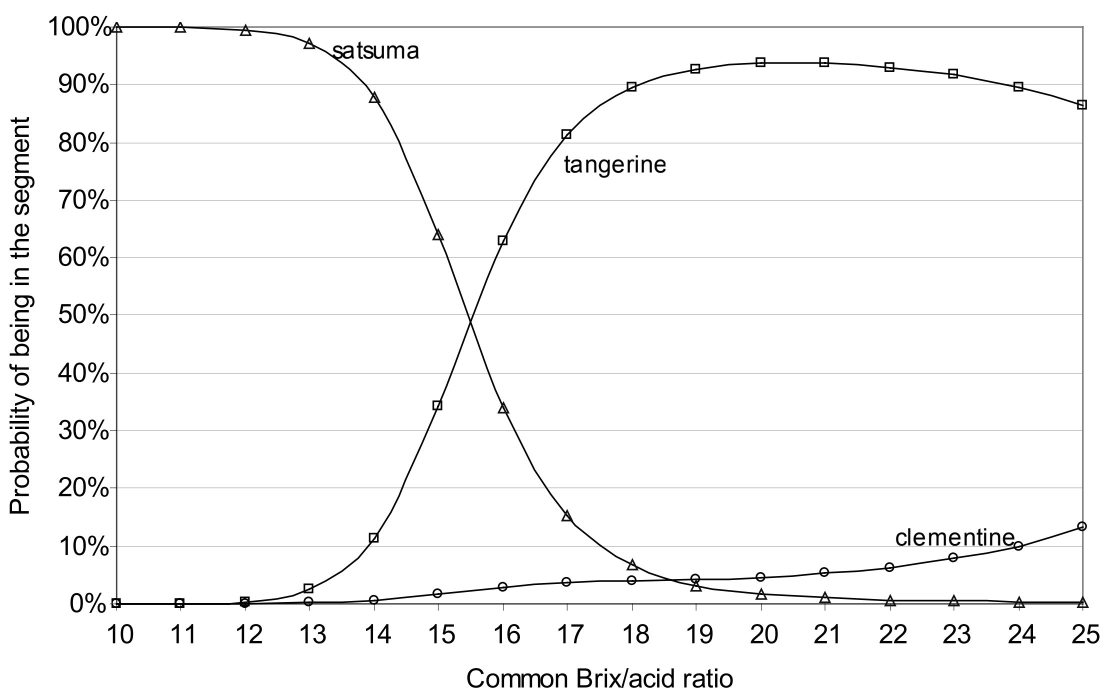

Figure 1. Predicted Changes in the Probability of Being in the Clementine, Satsuma, or Tangerine Segment (Given Identical Brix/Acid Ratios, Holding All Other Variables Constant at Their Means).

them at a disadvantage relative to tangerines and clementines. This suggests that in addition to quality standards imposed early in the season, such as Louisiana's lower limit of 10:1 (a "too-tart" rule) there should also be an upper limit of 15:1 imposed later in the harvest season (a "too-sweet" rule).

Simulations can also be used to estimate the market shares for satsumas, tangerines, and clementines as the harvest season progresses. At the time of our study, the sample market share proportions were 4:3:2 for tangerines, satsumas, and clementines respectively. Questions about whether these proportions would differ at other times and whether they would respond to strategic management efforts can be addressed with further simulations. For example, for the Owari variety of satsumas in the Gulf Coast region, the harvest window for the ten-to-15 range of ratios is from about mid-November through December—the same time that tangerines and clementines are coming onto the market. Moreover, the Christmas season appears to have a significant negative effect on satsuma market share and a positive effect on tangerine shares. In order to achieve a more cooperative marketing environment, the simulation results suggest that if satsumas could be harvested earlier (for example, by introducing earlier-maturing varieties) and brought up to the 15:1 ratio faster (for example, by postharvest technologies) they could be in and out of the marketplace before tangerines reach their optimal flavor ratios of 15 to 19, which could in turn be followed by clementines at ratios from 19 to 25. This sort of non-competitive marketing strategy is probably beyond all but the largest brands and distributors, but at least it does suggest that these mandarins need not be viewed strictly as competitors in today's dynamic marketplace.

References

Baldwin, E. A. 2002. Fruit flavor, volatile metabolism and consumer perceptions, p. 89-105. In M. Knee, ed., *Fruit Quality and Its Biological Basis*. Boca Raton, FL: CRC Press.

Campbell, B. L., R. G. Nelson, R. C. Ebel, W. A. Dozier, J. L. Adrian, and B. R. Hockema. 2004. "Fruit Quality Characteristics that Affect Consumer Preferences for Satsuma Mandarins." *HortScience* 39(7):1664–1669.

Campbell, B. L., R. G. Nelson, R. C. Ebel, and W. A. Dozier. 2006. "Mandarin Attributes Preferred by Consumers in Grocery Stores." *HortScience* 41(3):664–670.

Ebel, R. C., M. Nesbitt, W. A. Dozier, B. Hockema, F. M. Woods, R. Thomas, B. S. Wilkins, and R. McDaniel. 2004. "Fruit Quality of Satsuma Mandarin Grown on the Northern Coast of the Gulf of Mexico." *HortScience* 39(5):979–982.

Economic Research Service. 2007. "Food Consumption (Per Capita) Data System. Fresh Tangerines, Tangelos, and Other Mandarins: Supply and Disappearance." <http://www.ers.usda.gov/Data/FoodConsumption/spreadsheets/fruitfr.xls#Citrus!a1 >. [Accessed 20 February 2007.]

Fellers, P. J. 1991. "The Relationship between the Ratio of Degrees Brix to Percent Acid and Sensory Flavor in Grapefruit Juice." *Food Technology* 45(7):68–75.

Feller, P. J., R. D. Carter, and G. de Jager. 1988. "Influence of the Ratio of Degrees Brix to Percent Acid on Consumer Acceptance of Processed Modified Grapefruit Juice." *Journal of Food Science* 53(2):513–515.

Greene, W. H. 2002. *Econometric Analysis, 5th ed*. Upper Saddle River, NJ: Prentice Hall.

Greene, W. H. 1995. *LIMDEP version 7.9 User's Manual*. Plainview, NY: Econometric Software.

Liao, T. F. 1994. "Interpreting Probability Models: Logit, Probit, and Other Generalized Linear Models." Sage University Paper series on Quantitative Applications in the Social Sciences, series no. 07-101. Thousand Oaks, CA.

McFadden, D. 1986. "The Choice Theory Approach to Market Research." *Marketing Science* 5(4): 275–297.

Moskowitz, H. R. and B. Krieger. 1995. "The Contribution of Sensory Liking to Overall Liking: An Analysis of Six Food Categories." *Food Quality and Preference* 6(2):83–90.

Poole, N. D. and K. Gray. 2002. "Quality in Citrus Fruit: To Degreen or Not to Degreen?" *British Food Journal* 104(7):492–505.

Richards, T. J. 2000. "A Discrete/Continuous Model of Fruit Promotion, Advertising, and Response Segmentation." *Agribusiness: An International Journal* 16:179-196.

Saguy, S. and H. R. Moskowitz. 1999. "Integrating the Consumer into New Product Development."

Food Technology 53(8):68–73.

Stone H. and J. L. Sidel. 2004. *Sensory Evaluation Practices, 3rd ed*. New York: Academic Press, Inc.

Ting, S. V. and R. L. Rouseff. 1986. *Citrus Fruits and Their Products: Analysis and Technology*. New York: Marcel Dekker, Inc.

Wansink, B. 2003. "Response to 'Measuring Consumer Response to Food Products'. Sensory Tests that Predict Consumer Acceptance." *Food*