Preference Mapping of Domestic/Imported Jasmine Rice for U.S.-Asian Consumers

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ABSTRACT: Three domestic and 12 imported commercial Jasmine rice varieties were evaluated by a trained sensory panel and by 105 Asian families who live in the State of Arkansas. Results showed that consumers preferred imported over domestic products. According to consumers, the sensory characteristics most important to the acceptance of cooked Jasmine rice were, in order of decreasing importance, color, favor, aroma, stickiness, and hardness. Using descriptive data, we evaluated predictive models of Jasmine rice's overall acceptance. These models allowed us to identify important sensory characteristics that encouraged Asian consumers to accept Jasmine rice. Such characteristics included flavor (that is, aroma, aromatics, feeling factors, and aftertaste), texture, and visual attributes. Data collected here could be useful to the U.S. rice industry in developing an understanding of the drivers of Jasmine rice acceptance.

Keywords: Jasmine rice, Asian consumers, preference mapping, descriptive sensory analysis

Introduction

RICE (*ORYZA SATIVA L.*) IS A GOOD SOURCE of complex carbohydrates and protein and is a staple food for a large portion of the world's population. Over 100 countries, on every continent except Antarctica, grow rice (IRRI 1993). In the United States, rice production began in South Carolina in 1690 (Adair 1972). Nowadays, the U.S. rice production represents around 1.5% of the world's rice production. The major rice producing states are Arkansas, California, Louisiana, Mississippi and Texas.

Annual per capita rice consumption in the United States has risen from 10.25 lbs in 1980 to 27.1 lbs in 2000 (U.S.A. Rice Federation 2000). The U.S.A. Rice Federation has set a consumption goal of 30 lbs per capita by 2004 (U.S.A. Rice Federation 2000). The demand, in particular, has increased for whole grain foods and for processed foods using milled, brown, precooked, and specialty or aromatic rice, such as Jasmine rice imported mainly from Thailand (U.S.A. Rice Federation 1999).

Jasmine rice is mostly consumed by Asians who emigrated from Southeast Asia (Pinson 1994). Asian Americans are the fourth largest ethnic group in the United States and the fastest growing population in all regions (Campbell 1996). It is projected that this ethnic group will increase by more than 11 million by 2015. Additionally, rice consumption by Asian ethnic groups is usually 10 times more than the average for the total U.S. population (that is, consumption of 150 to 200 lbs per capita) (Goodwin and others 1992).

In the past ten y, domestic aromatic rice has accounted for less than 1% of the aromatic rice sold in the United States due to its dull off-white color and less pronounced aroma than imported aromatic rice (Rister and others 1992). The U.S.A. Rice Council's preliminary test of the market potential for domestic rice varieties among U.S.-Asian consumers suggested that visual and aromatic attributes of both uncooked and cooked rice were important to the U.S.- Asian consumers' preferences (Goodwin and others 1992). Imported Jasmine rice appearance was linked to milling practices (that is, water mist milling), which are different from those of the standard U.S. milling process. Additionally, rice breeders from the U.S. Dept of Agriculture attempted to determine the number of genes controlling the pronounced aroma of aromatic rice and developed new varieties of fragrant rice by adding the aroma gene to existing rice cultivars. The results indicated that a new aromatic rice variety, Jasmine 85, contained almost twice as much of the aromatic chemical 2-Acetyl-1-pyrroline as the other U.S. aromatic varieties (Pinson 1994). In a study reporting on Asian consumers' preferences for rice, Meullenet and others (2001) indicated that imported Jasmine rice was preferred more than any other rice, including domestic Jasmine.

Since the U.S.- Asian population can discern differences in the quality of the rice they consume, there is a need to assess the likes and dislikes of this population segment and to evaluate the key sensory differences between domestic and imported aromatic rice. The objectives of this study were to assess the acceptability of both domestic and imported Jasmine rice by U.S.- Asian consumers and to correlate the U.S.- Asian consumers' acceptance of Jasmine rice to descriptive sensory data so that the acceptance drivers could be identified.

Material and Methods

FIFTEEN DOMESTIC AND IMPORTED JASmine rices were purchased in February 2000 from either local specialty stores or producers. All imported samples purchased were labeled as the "New Crop 2000" and the "Premium Quality." According to Narainakorn (1998), these labels indicated that the imported Jasmine rices were freshly milled and packed from rice paddies harvested in 1999 and mixed with other rice varieties to a maximum of 30 % weight by weight. A list of Jasmine rice samples evaluated is given in Table 1. Three-digit random numbers were generated according to Cochran and Cox (1957) and assigned randomly for all of the 15 Jasmine rice samples. Three-lb samples were placed in plastic bags (Glad®, Ziploc® Bags) and used for both consumer testing and descriptive analysis. The coded and sealed samples were placed in

Table 1—Jasmine rice samples evaluated

Product type	Code	Product Name	Manufacturer/ Origin	Brand/Importer
Domestic	dJ	Jasmine	85	Lowell FarmTexas
	dS	Jasmine	Specialty Rice	ArkansasMarketing
	dT	Jasmati	Rice Tec	Texas
Imported	iA	Jasmine	Angel Rice	Thailand
	iB	Jasmine	Bell & Flowers	Thailand
	iK	Jasmine	BKM	Thailand
	iC	Jasmine	C.T.F.	Thailand
	iS	Jasmine	Dynasty	Thailand
	iG	Jasmine	Golden Boy	Thailand
	iM	Jasmine	Golden Camel	Thailand
	iD	Jasmine	Golden Cobra	Thailand
	iI	Jasmine	I.T.C.	Thailand
	iR	Jasmine	Riviana	Thailand
	iR1	Jasmine	Rose Rice	Thailand
	iR2	Jasmine	Rose Rice	Thailand

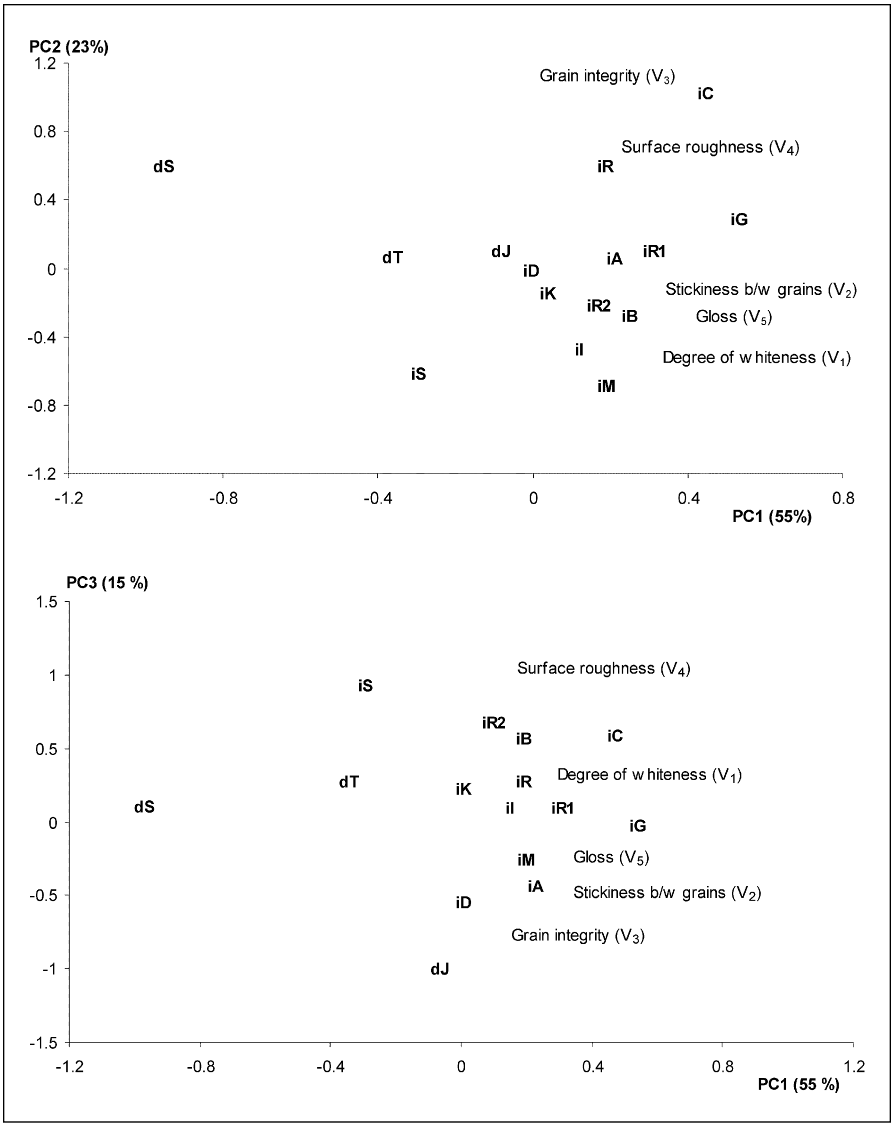

Figure 1—Sample scores and variable loadings overlay for the principal components analysis of visual sensory attributes: (a) PC1 compared with PC2; (b) PC1 compared with PC3. Score and loading plots obtained from sensory descriptive attributes using PCA model. Visual attributes data variation described was (a) 55% and 23% for PC1 and PC2, respectively; (b) 55% and 15% for PC1 and PC3 respectively. Sample name abbreviations can be found in Table 1.

plastic airtight storage buckets and stored at 4 °C in a commercial walk-in refrigerator until testing.

Descriptive analysis

A 9-member panel, employed by the Univ of Arkansas, Dept of Food Science, and well trained in descriptive analysis of rice (Spectrum Method®, Meilgaard and others 1999), evaluated 5 visual, 16 flavor, and 11 texture attributes for all 15 Jasmine rice samples. Visual, flavor, and texture lexicons were developed by the trained panelists during 3 orientation sessions (Meullenet and others 1998). During these orientations, a frame of reference, which represented a variety of Jasmine rice products, was presented to the panel. These reference samples assisted the panel in developing descriptors and appropriate descriptive techniques. The visual, flavor, and texture lexicons used to describe the attributes that were evaluated, their definitions, and references used are listed in Tables 2, 3, and 4.

Jasmine rice samples were retrieved from cold storage and allowed to temper for approximately 12 h before cooking. Electronic rice cookers (Rice-O-Mat, National Brand: model #SR-w10F-5 quart capacity; Panason, Cypress, Calif., U.S.A.) were used to cook all the Jasmine rice samples. All the rice samples were prepared using a 1.5:1 water:ratio ratio or 300 g of rice in 450 ml of water. The rice sample and water were emptied into the cooker holding chamber, covered with the vented lid, and the rice cooker was switched on 21 min prior to the scheduled presentation time to the trained descriptive panel. The samples remained covered throughout the cooking duration. When cooking was completed, the removable holding chamber was immediately lifted out of the heating chamber to prevent overcooking or scorching.

Regarding the presentation to the panelists, the samples were dipped into preheated (165 °F) 6-oz glass bowls. The heated glass bowls were then placed inside styrofoam cups and covered with coded watch glasses. Jasmine rice samples were presented at 160 °F, and panelists were instructed to complete their evaluations before the sample reached 140 °F; digital thermometers were provided to each panelist. The samples were unimodally (that is, one at a time) presented to the panelists in individual booths that featured controlled lighting and positive air pressure. Panelists scored all attributes on a 0 to 15 numerical scale with one significant digit. Panelists recorded the scores for

Table 2—Descriptive visual lexicon for Jasmine rice

Term	Definition	Reference
Degree of Whiteness V_1	The degree to which the sample is visually pure white.	Uncle Ben's parboiled(5.0) ThaiKitchenJasmin(11.0)
Stickiness between Grains V_2	The degree to which grains stick together. Fluff sample with fork to evaluate degree to which kernels stick together.	Thai Kitchen Jasmine (1.5). Uncle Ben's parboiled (3.0)
Grain Integrity V_3	The degree to which grain are cracked. Observe the sample and determine to which kernels are split.	Uncle Ben's parboiled (0.0). Thai Kitchen Jasmine (2.5)
Surface Roughness V_4	The degree to which kernels are rough. Observe and determine the degree of roughness.	Uncle Ben's parboiled (1.5). Thai Kitchen Jasmine (4.0)
Gloss V_5	The degree to which kernels shine. Observe and determine the degree of shine.	Thai Kitchen Jasmine (10.0). Uncle Ben's parboiled (13.0)

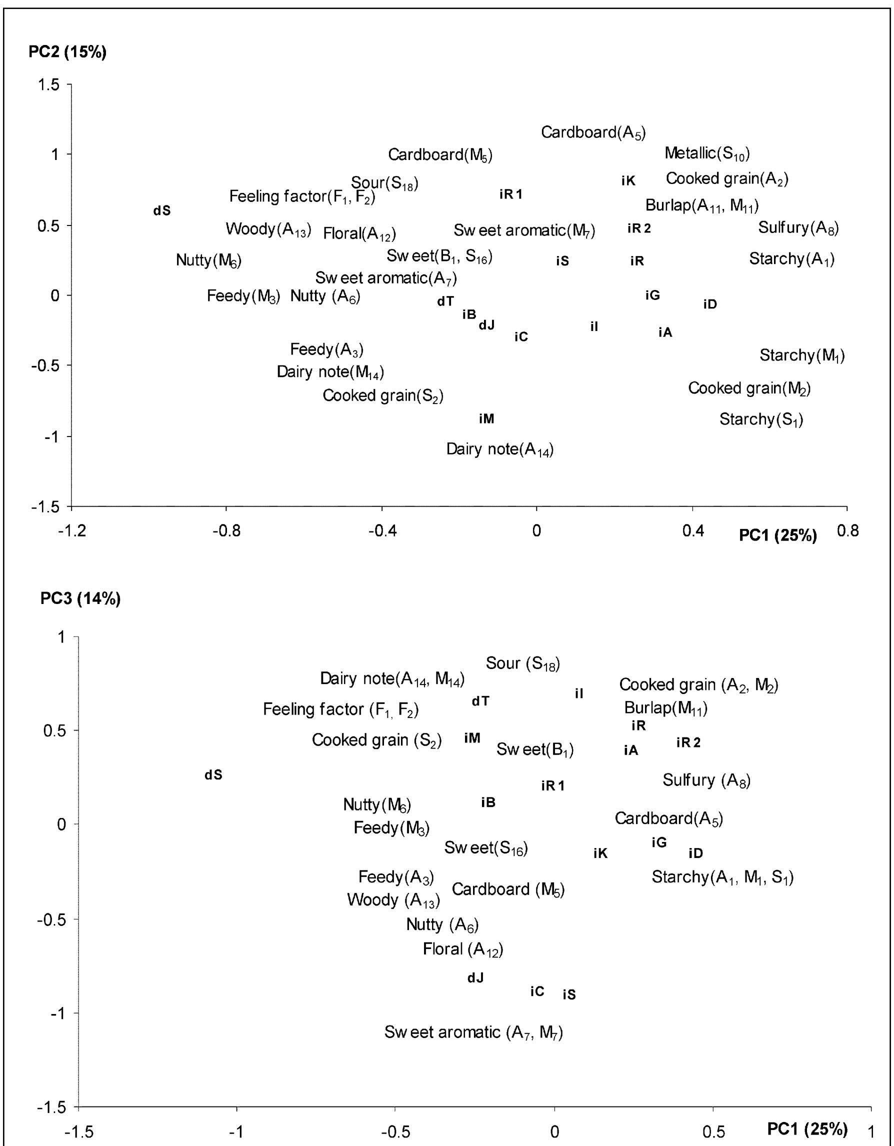

Figure 2—Sample scores and variable loadings overlay for the principal components analysis of flavor sensory attributes: (a) PC1 compared with PC2; (b) PC1 compared with PC3. Score and loading plots obtained from sensory descriptive attributes using PCA model. Flavor attributes data variation described was (a) 25% and 15% for PC1 and PC2, respectively; (b) 25 and 14% for PC1 and PC3, respectively. Sample name abbreviations can be found in Table 1.

each attribute on paper ballots. Crackers (Nabisco Premium Unsalted) and water were provided for panelists to rinse their palates between samples. Sample serving order was randomized across treatment, and all panelists evaluated each of the 15 samples in duplicate on separate testing days.

Home-use testing

Home-use testing was conducted in the State of Arkansas in the towns of Fayetteville, Springdale, and Fort Smith. To represent a true cross-section of the population, Asian consumers living in these 3 areas were recruited via a survey distributed to local oriental supermarkets and restaurants. The main criterion considered in selecting the subjects was whether or not the consumer and the family consumed Jasmine rice. This consumer group was represented by 15% Islanders (Filipinos and Indonesian), 13% Laotian, 12% Malaysian, 23% Thai, 12% Continental (Sri Lanka, Bangladesh, and Burma), and 25% Chinese (Mainland China and Taiwan). Based on the survey results, the respondents were classified into 3 groups: light users (1 to 9 meals per wk, 27%), medium users (10 to 13 meals per wk, 30%), and heavy users (14 to 21 meals per wk, 43%). According to the census of population and housing survey by the Census State Data (Bell 1998), the approximate number of Asian families living in these 3 areas was 3,000 households. Therefore, the minimum number of respondents required to achieve the 95 percent level of confidence with an error that did not exceed ±10 percent was estimated to be 94 households (Rea and Parker 1992). Since, it was logistically difficult to have all families evaluating all 15 samples, the experiment was planned according to a balanced incomplete block design arranged in a Latin

Table 3—Descriptive aromatics and basic tastes lexicon – Jasmine rice

Term	Definition	Reference
Starchy A_1, M_1, S_1	The aromatics associated with the starch	Rice flour paste;
	of a particular grain source.	Rice flour in water.
		Mixing ratio is 1:1.
Cooked Grain A_2, M_2, S_2	A general term used to describe the aromatics of raw	Cereal grain: Bran Buds,
	or cooked grains, which cannot be tied to a special grain.	Air popped popcorn,
		Cream of Wheat
Feedy A_3, M_3, S_3	The aromatics associated with a mixture of grains	Chicken feed; Bran buds
	reminiscent of animal feed (dusty, musty, sharp).	
Scorched A4, M_4, S_4	The aromatic associated with scorching.	Scorched popcorn
Wet Cardboard/Papery A_5, M_5, S_5	The aromatics associated with early stages of oxidation.	Place wet cardboard in a
		reference jar and sniff.
Nutty A_6, M_6, S_6	The aromatics associated with nuts or nutmeats,	
	which cannot be tied to a specific origin.	Toasted Wheat Germ
Sweet Aromatic A_7, M_7, S_7	The aromatic associated with materials that also have	
sweet tastes, such as molasses, caramelized sugar,		1-Vanilla; 1-Maltol
cotton candy, maple syrup, maltol.		
Sulfury $A_{8,}$,, M_8, S_8	The aromatics associated with hydrogen sulfide,	Boiled eggs,Struckmatch,
boiled or rotten eggs.	Sewer gas,	
	Cooked cabbage	Heated Oil A_9, M_9, S_9
The aromatics associated with fresh oil that has been		Heated vegetable oil
heated: not indicative of any oxidized or "off" notes.		Heated cottonseed oil
Metallic A_{10}, M_{10}, F_1, S_{10}	The aromatics associated with metals, tinny, or irony.	Pineapple can (for
A flat chemical feeling factor stimulated on the		sniffing)
tongue and teeth by metal (coin, tin foil).		Tin foil (bite down on it
	several times)	Burlap A_{11}, M_{11}, S_{11} The
aromatics associated with burlap.	Burlap rice bag	
Floral/Mint A_{12}, M_{12}, S_{12}	The aromatics associated with a non-specific floral note	
and sometimes described as mint.	Jasmine scent	
Woody A_{13}, M_{13}, S_{13}	The aromatics associated with dry fresh cut wood;	Wood chips, Beta ionone,
balsamic or bark-like	Toothpicks	Dairy Note A_{14},
M_{14}, S_{14}	The aromatics associated with an off or negative note	
reminiscent of soured or old dairy	products.	Texmati rice
Hot Plastic A_{15}, M_{15}, S_{15}	The aromatics reminiscent of hot rubbers, vinyl or plastic.	–-
Astringency F_2	The chemical feeling factor associated with the shrinking	Grape juice (Welch's);
and puckering of the tongue caused by substances such		Tea bag / 1- hourh soak
as tannins or alum.		
Sweet B_1, S_{16}	The basic taste on the tongue stimulated by sugar and high	Solutions of sucrose in
potency of sweeteners.	spring water	
Salt B_2, S_{17}	The basic taste on the tongue stimulated by sodium chloride.	Solutions of sodium
	chloride in spring water	
Sour B_3, S_{18}	The basic taste on the tongue stimulated by acids.	Solutions of citric acid in
	spring water	
Bitter B_4, S_{19}	The basic taste on the tongue stimulated by solutions or	Solutions of caffeine in
	substances such as quinine and certain other alkaloids	springwate

Abbreviations: A= Aroma B = Basic tastes, M =Aromatics F= Feeling Factors, S= Aftertaste

Square (Cochran and Cox 1957; Kuehl 1994). Thus, to obtain a data set that would be planned according to the chosen design, 105 households (that is, 15 blocks ´ 7 replicates) were recruited (Rea and Parker 1992; Cochran and Cox 1957). In this design, the number of Jasmine rice samples per block was less than the total number of samples (15 samples). In this case, a subset of 7 from 15 samples was arranged and the order in which each household would receive the rice sample was completely randomized among the households. All 15 Jasmine rice samples were equally replicated (n = 49), and each sample pair occurred altogether in the same block 3 times. Therefore, homogeneous set of the samples and precise sample comparisons would be obtained (Kuehl 1994).

A Jasmine rice sample was delivered weekly to the respondents' homes from 1 March 2000 to 17 April 2000. The respondents received 800 g of the various Jasmine rice samples during 7 consecutive wk. Each Jasmine rice sample was accompanied by a cooking instruction as well as an evaluation form. The questionnaire was designed to assess the acceptance of each sample by the respondents. A 9-point verbal hedonic scale (Meilgaard and others 1999) anchored from "dislike extremely" to "like extremely" was used to assess the acceptance of the various products (that is, overall acceptance, appearance, aroma, flavor, and texture). A 5-point "just right" scale was used to assess the appropriateness of the intensity of more specific attributes (that is, color, aroma, flavor, stickiness, and hardness) from "much too little" to "much too much" (Meilgaard and others 1999).

Data analysis

Descriptive analysis data were averaged by using the PROC MEANS procedure of SASâ (1999) across panelists and replications and Fisher's Least Square Dif-

Table 4—Descriptive oral texture lexicon for Jasmine rice

Term	Definition	Technique
Initial		
Manual Stickiness T_1	The force required separating the fingers after compressing sample between the thumb and forefinger.	Compress 5 kernels between thumb and forefinger and evaluate the force required to separate your fingers. (easy………………………difficult)
Initial Cohesion T_2	The degree to which the unchewed sample holds or sticks together.	Place 1/2 teaspoon of sample in mouth. Feel mass with tongue and quickly evaluate how tightly the mass is sticking and holding together. (loose……………………….tight)
Partial Compression		
Adhesion to Lips T_3	The degree to which the sample adheres to the lips.	Compress sample between lips, release and evaluate the degree to which the product remains on the lips. (fall…………………………sticks)
First Bitr Chew		
Hardness T_4	The amount that the chewed sample holds together.	Chew sample with molar teeth up to 15 times and evaluate. (loosemass……………….tight mass)
Macro Roughness of Mass T_7	The amount of roughness perceived on the surface of the chewed sample. Hint: You are looking for the large lumps, bumps, hills and valleys, etc.	Chew sample with molars and evaluate the irregularities on the surface of the sample mass. (smooth…………………………rough)
Toothpull T_8	The force required separating the jaws during mastication.	Chew sample 2-3 times and evaluate the force required to pull your jaw apart. (easy…………………….difficult)
Residul		
Number of Chews T_9	The number of chews required to prepare the sample for swallowing.	Place 1 teaspoon of sample in the mouth and count the number ofchews required to prepare sample for swallowing.
Toothpack T_{10}	The amount of product packed into the crowns of the teeth after mastication	Chew sample 10-15 times, expectorate and feel the surface of the crowns of the teeth to evaluate. (none……………………….much)
Residual Film T_{11}	The amount and degree of residue felt by the tongue when moves over the surface of the mouth.	Swallow the sample and feel the surface of the mouth with the tongue to evaluate. (none………………………..much)

ference (LSD) tests (a = 0.05) performed to determine significant differences between samples. Principal component analysis (PCA) (Unscramblerâ, version 7.5, Camo, Norway) was used so that all complex multidimensional data sets (that is, descriptive variables) were visualized. The PCA can be translated as finding the linear combination of the initial variables that contribute most to making the samples different from each other (Camo 1999). The sensory attributes were standardized prior to the analysis by weighing variables by their standard deviations. For interpretation of the results, the optimal number of the principal components that explained most of the information in the data was determined (that is, model with a total residual variance close to 0 or a large total explained variance).

Consumer scores were averaged using the PROC MEANS procedure of SASâ (1999) for each of the 15 samples (n = 49). Consumer overall acceptance was predicted from consumer attribute data (that is, 5-point “just right” scales) using Partial Least Squares (PLS) regression (Unscramblerâ). In a similar manner, overall acceptance was predicted from sensory descriptive attributes, and acceptance of the appearance, flavor and texture predicted from the corresponding descriptive panel data (for example, appearance acceptance from visual descriptors evaluated by the trained panel). Data was centered prior to PLS regression so that all results were interpreted in terms of variation around the mean. Predictive variables were standardized by weighting with the standard deviation, so that all variables were given the same chance to influence the prediction of the consumer data, regardless of differences in variable magnitude. The full cross-validation method was used so that the same samples were used for both calibration and validation of the models. With full cross-validation, each sample is removed one at a time from the sample set, a new calibration is performed, and a predicted score is calculated for the sample that has been removed. The Root

Mean Square Error of Prediction (RMSEP) is subsequently calculated. The predictive models were optimized using the Jack-knifing method available as an option of the Unscramblerâ. Jack-knifing is a procedure that is designed to test the significance of the model parameters and is performed during cross-validation. During cross-validation, if a perturbed segment differs greatly from the common model (that is, with all samples), it indicates that the sample or samples removed have seriously affected the common model. The approximate uncertainty variance of the regression coefficients can then be estimated, and a t-test can then be performed for each element relative to its estimated uncertainty variance, giving a significant level for each parameter. All parameters for which $p < 0.05$ were kept in the model. This allowed for removal of predictive variables either not influencing the prediction or creating noise in the model. This procedure reduced "the uncertainty in the prediction models" (Camo 1999) and, in most cases, improved the validation statistics.

Overall consumer acceptance was also predicted with similar modeling methods using consumer acceptance of color, aroma, flavor, and texture as predictors. Finally, consumer acceptance of aroma, flavor, and texture was predicted using the corresponding descriptive analysis attributes. Similarly to work published by Meullenet and others (2001), the weighted regression coefficients expressed numerically the relationship between the predictors (that is, descriptive attributes) and the consumer responses. Weighted regression coefficients (that is, coefficient weighted by the variable mean value) were used toe-express their relative influence independently of differences in intensities of descriptive attributes.

Table 5—Means of descriptive visual attributes

Visual Attributes					
Sample Code	V1	V2	V3	V4	V5
dJ	7.64	6.34	2.11	3.12	8.67
dS	6.32	2.54	2.00	3.24	2.90
dT	8.51	3.90	1.91	3.26	7.42
iA	9.83	5.94	2.14	3.24	10.33
iC	9.76	5.75	2.28	4.02	10.66
iD	9.61	4.71	2.12	3.06	10.17
iG	10.68	6.47	2.18	3.56	11.51
iI	10.01	5.66	1.91	3.30	10.01
iK	10.07	4.82	1.98	3.28	9.20
iM	10.12	6.02	1.86	3.07	11.27
iR	9.91	5.07	2.19	3.64	9.10
iR1	10.01	5.81	2.08	3.49	11.11
iR2	9.99	5.25	1.79	3.53	9.50
iS	9.74	4.61	1.64	3.33	5.99
LSD[3]	0.47	0.99	0.44	0.61	1.09

[1]Definitions are presented in Table 2.
[2]Jasmine descriptions are found in Table 1.
[3]Least Significant Difference (a = 0.05)

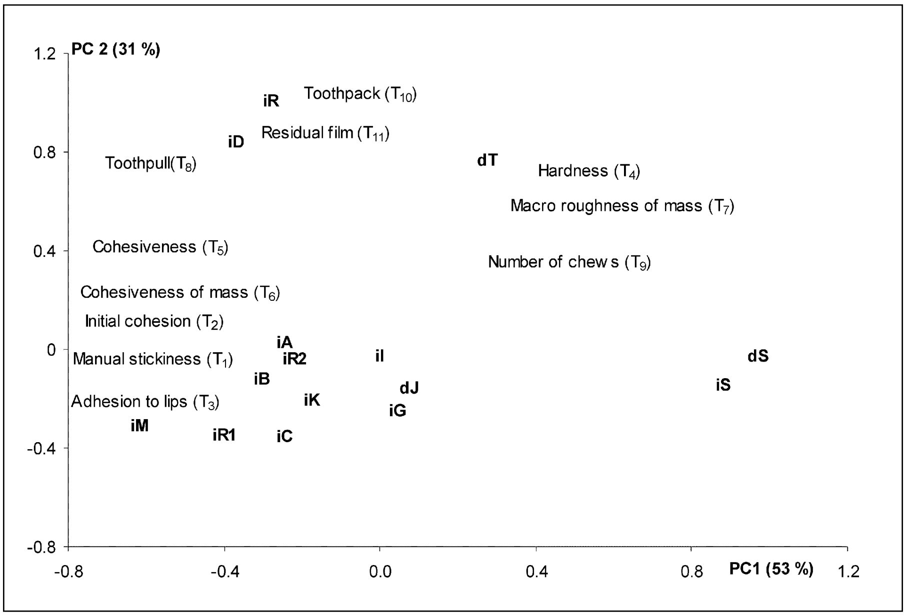

Figure 3—Sample scores and variable loadings overlay for the principal components analysis of texture sensory attributes: PC1 compared with PC2. Score and loading plots obtained from sensory descriptive attributes using PCA model. Texture attributes data variation described was 53% and 31% for PC1 and PC2, respectively. Sample name abbreviations can be found in Table 1.

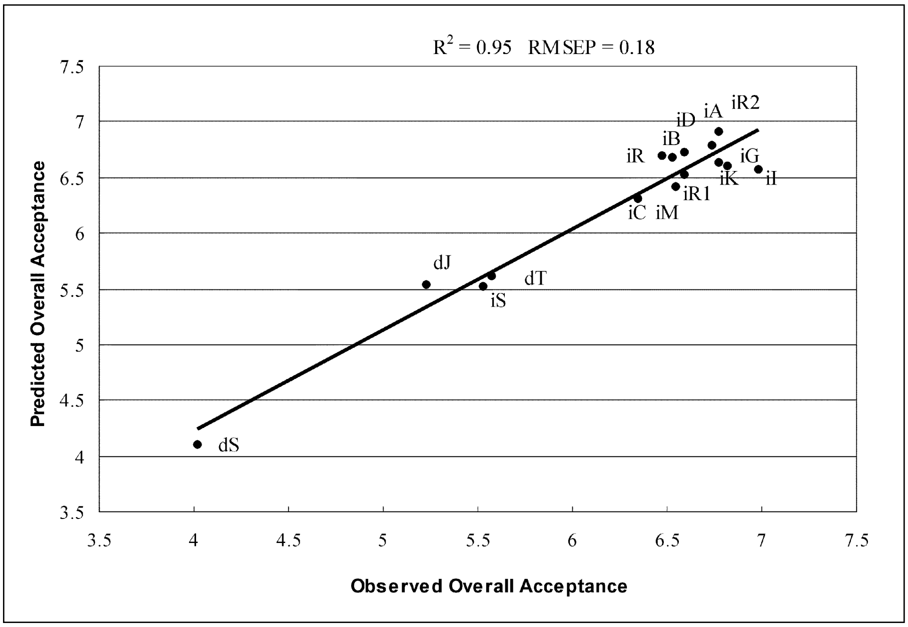

Figure 4—Predicted compared to observed overall acceptance by Asian consumers. Predicted scored obtained from sensory descriptive attributes using partial least squares regression. Sample name abbreviations can be found in Table 1.

Results and Discussion

Descriptive analytical results

Descriptive attribute means are presented in Tables 5, 6a to 6c, and 7 for visual, flavor, and texture attributes, respectively. Fisher's LSD tests were performed for each attribute to evaluate significant differences (a = 0.05) between samples. Mean scores of the sensory at-

Table 6a—Means of descriptive flavor attributes (Aroma)

Sample Code[1]	A1	A2	A3	A5	A6	A7	A8	A9	A11	A12	A13	A14		
	Aroma Attributes[1]													
dJ	2.47	1.83	0.87	0.33	0.84	1.26	0.00	0.00	1.81	1.24	0.51	0.00		
dS	0.79	1.98	1.80	0.67	0.50	0.96	0.00	0.00	1.66	1.36	0.62	0.38		
dT	1.57	2.18	1.14	0.31	0.28	0.47	0.18	0.00	2.51	0.24	0.38	2.56		
iA	2.52	2.44	0.36	0.28	0.00	0.56	0.87	0.18	2.33	0.20	0.00	0.77		
iB	2.27	1.54	2.37	0.23	0.61	0.19	0.16	0.00	2.87	0.00	0.00	0.38		
iC	2.08	0.63	2.54	0.32	0.21	1.61	0.27	0.00	2.13	1.25	0.00	0.21		
iD	3.12	2.32	0.39	0.53	0.00	0.68	0.28	0.00	2.42	0.46	0.00	0.17		
iG	2.87	2.74	0.93	0.57	0.17	0.28	0.22	0.00	1.60	0.00	0.00	0.57		
iI	2.30	2.06	1.78	0.26	0.00	0.42	0.52	0.00	2.55	0.38	0.00	1.33		
iK	3.11	2.05	1.09	0.56	0.00	1.12	0.56	0.00	2.68	0.41	0.00	0.00		
iM	1.79	1.23	1.41	0.11	0.00	0.61	0.00	0.00	1.19	0.51	0.00	4.18		
iR	2.46	2.34	0.37	0.79	0.00	0.61	0.48	0.00	3.72	0.18	0.00	0.41		
iR1	2.77	2.33	0.87	0.25	0.00	0.53								
iR2	2.71	3.04	0.38	1.19	0.42	0.33	0.78	0.00	3.37	0.41	0.00	0.47	0.80	0.50
iS	2.14	1.26	0.22	1.27	0.39	0.00	3.87	0.95	0.39	0.18				
LSD[3]	0.81	1.09	1.02	0.54	0.54	0.62	0.50	0.13	1.25	0.74	0.25	0.74		

[1]Definitions are presented in Table 3.
[2]Jasmine descriptions are found in Table 1.
[3]Least Significant Difference (a = 0.05)

Table 6b—Means of descriptive flavor attributes (Aromatics)

Sample Code[2]	M1	M2	M3	M5	M6	M7	M10	M11	M12	M13	M14
	Aromatic Attributes[1]										
dJ	3.73	2.35	0.77	1.40	0.14	0.19	5.09	2.08	0.56	0.43	0.25
dS	1.58	1.98	1.95	1.80	0.88	0.00	3.81	2.10	0.72	0.54	0.83
dT	2.88	2.63	1.53	0.92	0.00	0.00	4.73	2.88	0.00	0.38	1.04
iA	3.27	2.75	0.19	1.40	0.00	0.00	4.42	2.38	0.28	0.00	0.51
iB	3.61	2.32	1.51	1.46	0.39	0.22	5.02	3.02	0.00	0.00	0.61
iC	3.46	2.54	0.67	1.53	0.00	0.38	4.51	1.93	0.50	0.00	0.50
iD	3.59	3.10	0.19	0.93	0.00	0.00	5.12	2.64	0.00	0.00	0.17
iG	4.07	2.58	0.49	1.87	0.00	0.00	5.07	1.24	0.00	0.00	0.28
iI	3.41	2.92	0.58	1.01	0.00	0.00	4.42	3.94	0.22	0.00	0.48
iK	3.60	2.05	0.94	1.46	0.00	0.19	5.29	3.69	0.00	0.00	0.00
iM	3.48	2.35	0.91	0.96	0.00	0.00	4.80	2.35	0.28	0.00	1.61
iR	3.28	2.42	0.23	1.36	0.00	0.00	4.79	3.70	0.00	0.00	0.83
iR1	3.29	1.98	0.38	1.38	0.00	0.18	5.56	3.57	0.41	0.00	0.77
iR2	3.57	2.47	0.22	1.61	0.00	0.19	5.01	4.16	0.00	0.00	0.50
iS	3.46	2.01	0.67	1.16	0.00	0.98	4.27	3.15	0.00	0.71	0.00
LSD[3]	0.64	1.00	0.90	0.76	0.23	0.41	0.62	1.11	0.62	0.13	0.83

[1]Definitions are presented in Table 3.
[2]Jasmine descriptions are found in Table 1.
[3]Least Significant Difference (a = 0.05)
Only detectable attributes are listed

Table 6c—Means of descriptive flavor attributes (basic tastes, feeling factors, and aftertaste)

Sample Code [2]	B1	B3	F1	F2	S1	S2	S5	S10	S11	S16	S18
	Basic Tastes, Feeling Factors, and Aftertaste Attributes [1]										
DJ	0.86	0.38	1.44	3.01	2.70	1.36	0.88	2.39	0.13	0.81	0.24
DS	1.04	0.92	1.92	3.12	1.71	1.01	1.08	2.46	0.21	1.06	0.83
DT	1.12	0.83	1.40	3.07	1.94	0.81	0.58	2.85	0.24	0.89	0.75
IA	0.73	0.79	1.12	3.00	2.63	1.22	0.53	2.38	0.50	0.85	0.47
IB	1.40	0.56	1.57	2.96	2.84	1.01	0.58	2.42	0.29	1.15	0.64
IC	0.95	0.52	1.21	2.97	2.81	0.91	0.64	2.70	0.31	1.06	0.43
ID	1.02	0.59	1.37	2.92	2.73	0.71	0.62	3.03	0.14	1.02	0.54
IG	0.86	0.55	1.57	3.01	2.82	0.39	0.62	2.89	0.24	0.98	0.36
II	1.13	0.74	1.47	3.11	2.79	1.22	0.58	2.46	0.48	0.81	0.71
IK	0.99	0.56	1.68	2.99	2.48	0.48	0.79	3.02	0.32	0.96	0.59
IM	1.06	0.59	1.72	3.03	2.91	1.12	0.73	2.12	0.31	1.02	0.30
IR	1.15	0.94	1.33	3.13	2.76	1.03	0.79	2.77	0.32	1.07	0.59
iR1	0.91	0.78	2.02	3.05	2.39	0.62	0.60	3.24	0.52	1.03	0.75
iR2	1.27	0.56	1.52	3.06	2.66	0.88	0.57	2.73	0.55	0.87	0.42
IS	1.14	0.37	1.17	3.03	2.31	0.84	0.80	2.71	0.92	1.01	0.21
LSD [3]	0.52	0.41	0.62	0.22	0.44	0.63	0.32	0.68	0.43	0.40	0.36

[1] Definitions are presented in Table 3.
[2] Jasmine descriptions are found in Table 1.
[3] Least Significant Difference (a = 0.05)

Table 7—Means of descriptive texture attributes

Sample Code[2]	Texture Attributes[1] T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
dJ	6.89	6.46	9.71	4.86	6.39	5.39	6.22	2.86	17.00	2.28	1.98
dS	5.76	4.22	7.05	5.46	5.58	4.39	6.52	3.35	18.00	3.10	3.30
iA	7.17	6.94	10.74	4.99	6.68	5.76	6.31	3.03	17.39	2.36	2.12
iB	7.63	7.18	11.34	4.54	6.33	5.76	6.23	3.08	16.89	2.58	2.16
iC	7.12	6.74	11.21	4.51	6.60	5.72	6.02	2.87	17.22	2.09	1.91
iD	7.16	6.96	10.91	5.23	6.63	6.17	6.32	3.81	17.77	4.10	3.64
iG	7.17	6.41	11.23	4.88	5.76	5.39	6.12	3.01	17.78	2.21	2.03
iI	6.72	6.59	10.41	4.82	6.30	5.62	6.31	3.04	16.94	2.38	2.12
iK	7.17	6.72	11.28	4.93	6.13	5.68	6.08	3.09	17.61	2.08	1.82
iM	7.56	7.19	11.75	4.04	6.42	6.33	6.17	3.11	16.44	2.14	2.01
iR	7.24	7.25	9.77	5.65	6.49	5.91	6.37	3.64	17.53	4.95	3.86
iR1	7.52	7.01	11.77	4.43	6.37	6.05	5.98	3.02	17.94	2.03	1.99
iR2	6.85	6.82	10.81	4.61	6.64	5.31	6.32	3.26	16.78	2.43	2.03
iS	6.33	4.99	7.78	5.79	5.41	4.48	6.54	2.36	18.50	1.99	1.72
LSD[3]	0.41	0.45	0.91	0.48	0.55	0.59	0.32	0.28	1.10	0.49	0.25

[1]Definitions are presented in Table 4.
[2]Jasmine descriptions are found in Table 1.
[3]Least Significant Difference (a = 0.05)

tributes that were found to be likely undetectable (that is, mean < 0.7 or detected only by 1 panelist), heated oil (A_9), hot plastic (A_{15}, M_{15}), sulfur note (M_8), and floral note (M_{12})) were excluded from the data set prior to PCA. The overlaid score and loading plots are presented in Figure 1a and 1b, Figure 2a and 2b, and Figure 3, for appearance, flavor, and texture attributes, respectively.

PCA applied to visual descriptive attributes of 15 Jasmine rice samples indicated that 3 components explained a total of 93% of the variation. The map of Jasmine rice samples (that is, score plot) andthe first 2 components is shown in Figure 1a. Principal component 1 (PC1) was found to account for 55% of the variation in the data, while PC2 accounted for 23% of the variation. Most of imported samples, except Dynasty (iS), Golden Cobra (iD), and BMK (iK), laid close to each other along the X-axis and were similar for all visual attributes (Table 5). The highest degree of whiteness, stickiness between grains, and gloss were found in Golden Boy (iG), and the highest degree of grain integrity and surface roughness was found for C.T.F. (iC). Dynasty (iS) and 2 domestic samples (that is, Specialty rice, dS, and Rice Tec, dT) laid farthest away from the other samples. It was also found that replicated samples (Rose Rice: iR1 and iR2) were identical in their visual atvisual attributes (that is, loading plot) for the first 2 components is shown in Figure 1a. Principal component 1 (PC1) was found to account for 55% of the variation in the data, while PC2 accounted for 23% of the variation. Most of imported samples, except Dynasty (iS), Golden Cobra along the X-axis and were similar for all visual attributes (Table 5). The highest degree of whiteness, stickiness between grains, and gloss were found in Golden Boy (iG), and the highest degree of grain integrity and surface roughness was found for C.T.F. (iC). Dynasty (iS) and 2 domestic samples (that is, Specialty rice, dS, and Rice Tec, dT) laid farthest away from the other samples. It was also found that replicated samples (Rose Rice: iR1 and iR2) were identical in their visual at tributes. However, Fisher's LSD test at a = 0.05 (Table 5) indicated that panelists perceived these 2 samples (iR1 and iR2) differently for glossiness. Along the second component, degree of whiteness (V_1),

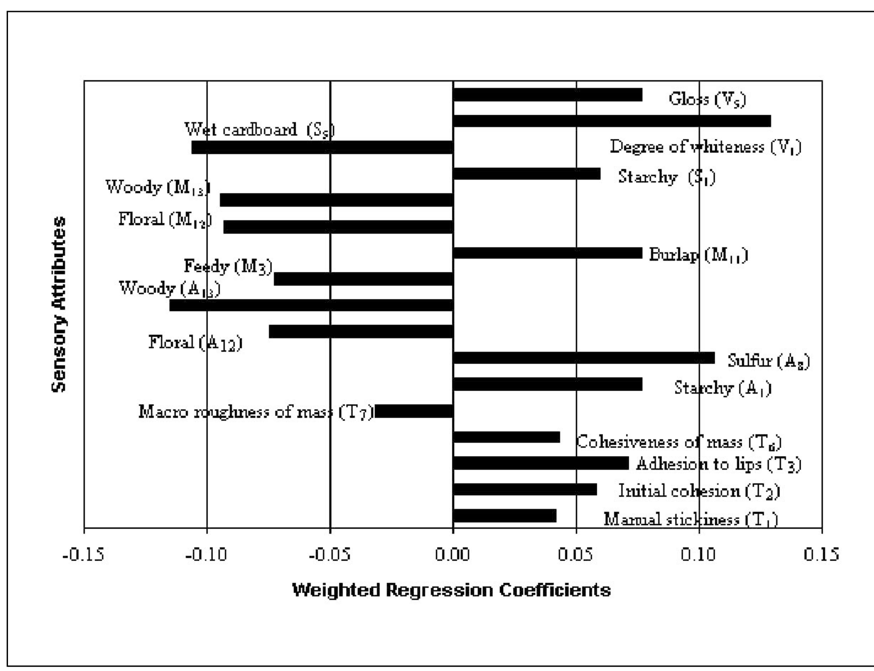

Figure 5—Weighted regression coefficients for the partial least squares regression model predicting overall acceptance from visual, flavor, and texture descriptors. Descriptor name abbreviations are defined in Tables 2, 3, and 4 respectively.

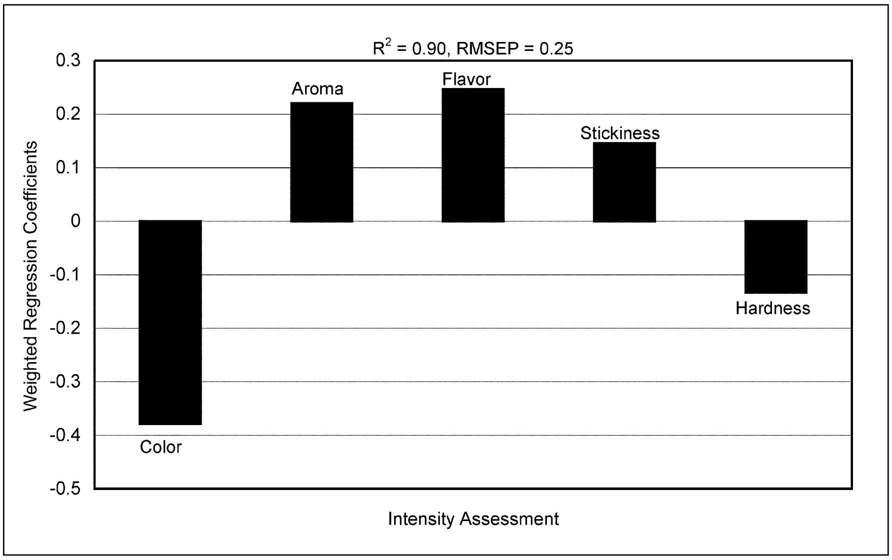

Figure 6—Weighted regression coefficients for the partial least squares regression model predicting overall acceptance from the "just right" intensity assessment scores for color, aroma, flavor, stickiness, and hardness.

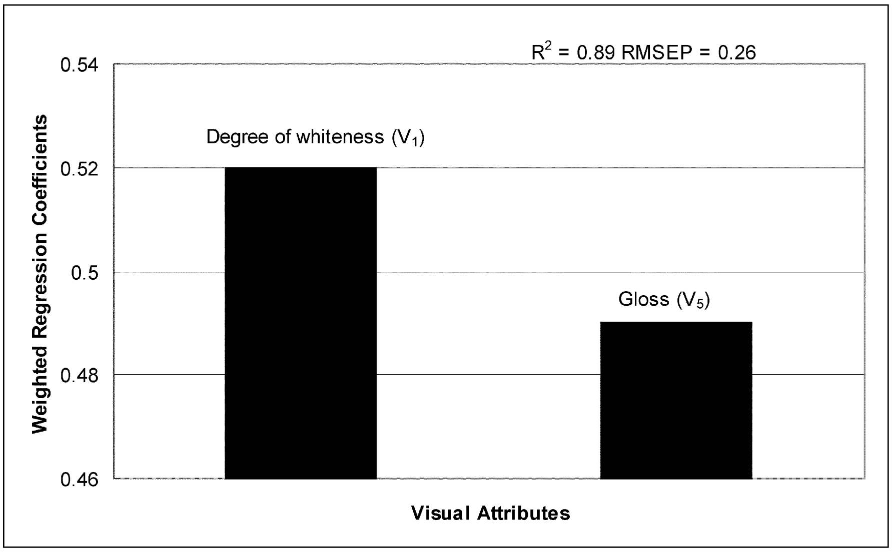

Figure 7—Weighted regression coefficients for the partial least squares regression model predicting the acceptance of Jasmine rice appearance form the visual attributes evaluated by a descriptive panel. Descriptors name abbreviations are defined in Table 2.

stickiness between grains (V_2), and gloss (V_5) loaded negatively, whereas grain integrity (V_3) and surface roughness (V_4) loaded positively. Two imported samples (C.T.F., iC, and Riviana, iR) exhibited more grain integrity and surface roughness than the other samples. The plots of PC1 compared with PC3 (Figure 1b) showed that Jasmine 85 (dJ) scored similarly to some imported samples (Golden Cobra, iD, and Angel Rice, iA) in terms of grain integrity. The mean score also showed that this domestic sample (dJ) exhibited higher grain integrity than the other 2 domestic products (Table 5).

For the flavor descriptive attributes, 3 components accounted for only 54% of the variation in the data. The score and loading plots are shown in Fig. 2a and 2b. PC1 was found to account for 25% of variation in the data, while PC2 and PC3 were found to account for 15% and 14% of the variation, respectively. The flavor descrip- were starchy aroma/aromatic/aftertaste and sulfur aroma (A_8) (that is, positively) and woody aroma (A_{13}), feedy (M_3) and nutty (M_6) aromatics (that is, negatively) (Figure 2a). The sample score of 1 imported sample (iD) exhibited high starchy and cooked grain aromatics and metallic aftertaste. One domestic sample (dS) was significantly different from all others. It exhibited high woody aroma and nutty and feedy aromatics. Wet cardboard aroma (A_5) and metallic aftertaste (S_{10}) were most highly positively correlated to PC2, while dairy aroma (A_{14}) was most highly negatively correlated to PC2. Even though the intensity of starchy aroma (A_1) was very high in iK (Tables 6a to 6c), the sample scores along PC2 suggested that this imported sample also exhibited high wet cardboard aroma (A_5), cooked grain aroma (A_2), and metallic aftertaste (S_{10}). Another imported sample (iM) exhibited high soured dairy aroma. The other 2 domestic types (dJ and dT) did not load highly on this PC. Thus, the third component gave more details about the similarities and differences of these domestic samples with imported Jasmine rice samples. The attributes sweet aroma/aromatic (A_7, M_7)(Figure 2b) loaded most highly on PC3. One domestic (dJ) and 2 imported products (iC and iS) loaded similarly and in the vicinity of sweet aroma/aromatic (A_7, M_7) and floral aroma (A_{12}). In contrast, dT loaded close to dairy aroma/aromatic (A_{14}, M_{14}) and sour aftertaste (S_{18}).

The texture descriptive analysis results indicated that 2 components explained 84% of the variation. The sample map (that is, score plot) and texture attributes (that is, loading plot) for PC1 and PC2 are shown in Figure 3. These components described, 53% and 31% of the variation, respectively. The attributes positively correlated with PC1 were hardness (T_4), macro roughness of mass (T_7), and number of chews (T_9), and the samples whose scores were the highest were dT, iS, and dS. Negatively correlated with this PC were manual stickiness (T_1), initial cohesion (T_2), adhesion to lips (T_3), cohesiveness (T_5), cohesiveness of mass (T_6), and toothpull (T_8). For PC2, the attributes with the highest positive loads were toothpack (T_{10}) and residual film (T_{11}). The samples whose scores were the highest were iR and iD. Other imported samples scored negatively on PC2; these were samples with higher manual stickiness (T_1) and adhesion to lips (T_3).

Prediction of overall acceptance from descriptive profiles using partial least squares regression

Figure 4 is a graphical representation of the observed consumer overall acceptance of Jasmine rice samples in contrast to the predicted scores calculated using descriptive attributes as predictors in a partial least squares regression model. Visual, flavor (that is, aroma, aromatics, feeling factors, and aftertaste) and texture attributes were used in this analysis. Two principal components that explained most of variation in the sensory data were retained in the regression model. PC1 described 95% of the variation in consumer overall acceptance and 50% of the variation in descriptive attributes, whereas PC2 described only 3% and 15% of the variation in consumer overall acceptance and descriptive attributes, respectively. Results showed that this consumer group preferred most of the imported Jasmine rices. One imported sample (iS) and all domestically grown Jasmine rice were found to be less acceptable (Figure 4). Meullenet and others (2001) hypothesized that Asian consumers expected some specific sensory characteristics pertaining to imported Jasmine rice.

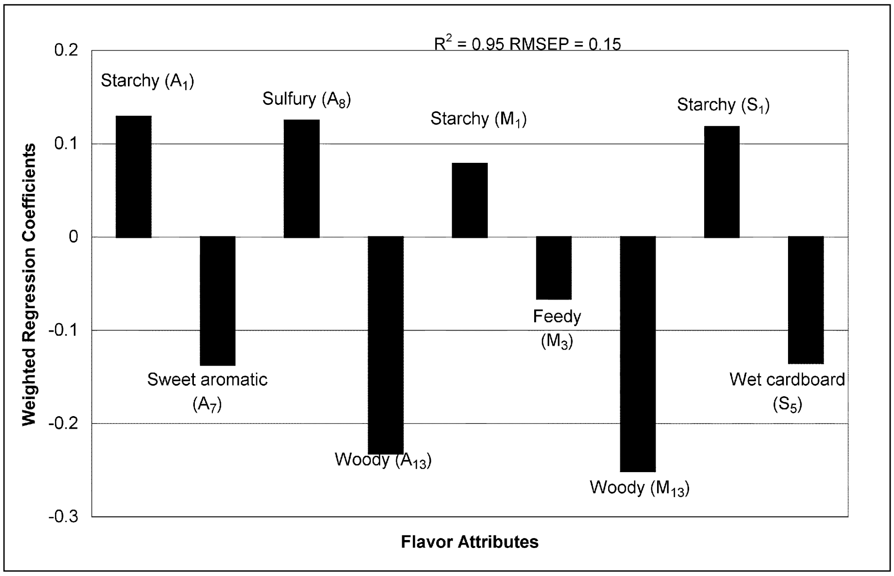

Figure 8—Weighted regression coefficients for the partial least squares regression model predicting the acceptance of Jasmine rice flavor from the flavor attributes evaluated by a descriptive panel. Descriptors name abbreviations are defined in Table 3.

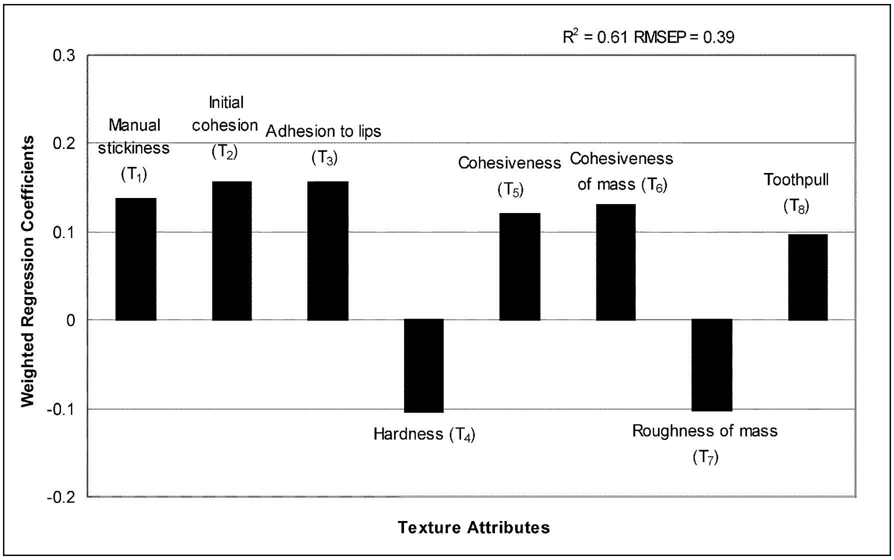

Figure 9—Weighted regression coefficients for the partial least squares regression model predicting the acceptance of Jasmine rice texture from the texture attributes evaluated by a descriptive panel. Descriptors name abbreviations are defined in Table 4.

By evaluating the weighted regression coefficients relating the response variable (that is, the overall acceptance by Asian consumers) to each predictive variable (that is, descriptive attributes), influential sensory attributes can be defined. Figure 5 is a graphical representation of the weighted regression coefficient for each of the descriptive sensory attributes retained in the model predicting overall coked rice acceptance after stepwise selection using Jackknifing.

In this study, the most important sensory attributes of Jasmine rice were defined as those with weighted regression coefficients greater than 0.1 (that is, absolute value from Figure 5) such as sulfur (A_8), woody (A_{13}), wet cardboard (S_5), and degree of whiteness (V_1). Other important attributes were defined as those with regression parameters greater than 0.03. Greater scores for adhesion to lips (T_3), starchy (A_1), sulfur aroma (A_8), burlap note (M_{11}), degree of whiteness (V_1), and glossiness (V_5) were associated with greater overall acceptance while greater macro roughness of mass (T_7), floral note (A_{12}), woody (A_{13}) and feedy aroma (M_3), and wet cardboard aftertaste (S_5) contributed to lowering acceptance scores. Contrary to previous studies (Meullenet and others 2001), cooked grain intensity, bitter, and nutty notes were not significant in determining the overall acceptance of Jasmine rice by Asian consumers. It should not be surprising since all the samples studied here were Jasmine aromatic rices, whereas non-aromatic and aromatic samples were included in previous reports (Meullenet and others 2001). An increase in intensities for floral, woody, and wet cardboard resulted in a decrease in acceptance. High intensities of floral, woody, and wet cardboard notes were exhibited in iS, dJ, dT, and dS. Consumers also commented on the foul smell when they tested any one of these samples. Although it would be hard to hypothesize the origin of the floral and woody notes, it seems that the rice samples exhibiting wet cardboard notes were slightly oxidized. This could be a result of storage, processing conditions, or inherent qualities of the cultivars. However, since the samples selected were commercial samples, this question would remain unanswered.

Prediction of overall acceptance from attribute acceptance

Figure 6 is a graphical presentation of weighted regression coefficients for a model predicting overall consumer acceptance from color, aroma, flavor, stickiness, and hardness scores (5-point "just right" scale) of the Jasmine rice samples.

Consumers indicated that the most important factor in determining their overall acceptance for Jasmine rice were, in order of decreasing importance, color, flavor, aroma, stickiness, and hardness intensities (Figure 6). Greater aroma, flavor, and stickiness contributed to a greater overall acceptance, while a yellow color and hardness contributed to lower overall acceptance scores.

Most of the imported Jasmine rice samples including Rice Tec Jasmine rice (dT) were rated by 67% to 85% of this consumer group as satisfactory ("just about right") for color (n = 49). Only 22% to 44% of consumers rated the color of 2 of the domestic samples (dJ and dS) as "just about right" (n = 49). A significant proportion of respondents rated these 2 samples as "somewhat too brownish yellow" (that is, 30% to 63%). Three imported Jasmine rice samples, Golden Boy (iG) and replicates of Rose Rice (iR1and iR2), were rated as "just about right" by 61%, 61%, and 63% and 81%, 63%, and 75.5% in terms of their aroma and flavor intensities (n = 49), respectively. However, these three most acceptable Jasmine rices were rated for aroma and flavor as too low in intensity ("somewhat too little" to "much too little") by 30.5%, 26%, and 24% and 14.5%, 28.5%, and 20% of consumers, respectively. For the 3 domestic Jasmine rice samples, (Jasmine 85, dJ; Specialty Jasmine, dS; and Jasmati, dT) least preferred by consumers, their aroma and flavor intensities were not rated satisfactorily. For Aroma, only 45%, 28.5%, and 41% of consumers rated the intensity as "just about right" and 47%, 57%, and 40% as too low in intensity ("somewhat too little" to "much too little") for Jasmine 85 (dJ), Specialty Jasmine (dS), and Jasmati (dT), respectively. For Flavor, 39%, 43%, and 55% of consumers gave a rating of "just about right," while 51%, 39% and 39% rated them as too low in intensity ("somewhat too light" to "much too light"). Stickiness and hardness seemed to play a small role in determining overall acceptance of Jasmine rice by this consumer group. However, an increase in stickiness and a decrease in hardness contributed to a greater overall acceptance. More detailed information about the drivers of liking can be obtained by using descriptive attributes as predictors of the acceptance of appearance, aroma, flavor, and texture.

Prediction of Jasmine rice appearance from visual descriptors

Degree of whiteness (V_1) and gloss (V_5) were shown to be the most important parameters in determining the acceptance of Jasmine rice appearance by Asian consumers, while stickiness between grain (V_2), grain integrity (V_3), and surface roughness (V_4) were not important contributors (Figure 7). These findings confirmed results from Meullenet and others (2001) and Goodwin and others (1992). Goodwin and others (1992) conducted a study assessing the market potential for domestic rice varieties among Asian Americans and concluded that one of important attributes of cooked rice for Asian consumers was the color. Results from the present study showed that 31% and 63% of Asian consumers expressed a discontent for the appearance of dJ and dS; 2 of the domestic rice samples exhibited a dark or brownish yellow color prior and after cooking. However, 75.5% of consumers reported that one of the domestic Jasmine rices (dT) had a very acceptable appearance after cooking.

Prediction of Jasmine rice flavor acceptance from flavor descriptors

The prediction of flavor acceptance from flavor attributes suggests that starchy attributes (A_1, M_1, S_1) and sulfur note (A_8) positively impact the aroma and flavor acceptance among Asian consumers while higher sweet aromatic (A_7), woody (A_{13}, M_{13}), feedy (M_3), and wet cardboard (S_5) notes contributed to lowering acceptance (Figure 8). The starchy and sulfur notes were readily detected in most of the samples, except in Specialty rice's Jasmine (dS). This sample was found to exhibit very low intensities for starchy and undetectable sulfur notes (Tables 6a to 6c), thus, the lower overall acceptance score reported by consumers (Figure 4).

The intensity of the cooked grain note (that is, equivalent to popcorn-like aroma in our methodology) was found to be different among the Jasmine rice samples according to Fisher's LSD test at a = 0.05 (Tables 6a to 6c). Some samples exhibited significant differences in terms of starchy and sulfur notes, but did not for cooked grain intensities. This result showed that cooked grain note or popcorn-like is not the only significant flavor characteristic of Jasmine rice as previously reported (Buttery and others 1983; Pinson 1994). Furthermore, the intensity of this attribute was not significantly higher in Jasmine 85 (dJ) than in other domestic samples (that is, dS and dJ). These results are inconsistent with those of Pinson (1994), who reported that Jasmine 85 contained nearly twice as much of the aromatic chemical responsible for the popcorn-like aroma than other U.S. aromatic varieties.

Increase in intensities of attributes, such as sweet aromatic (A_7), woody (A_{13}, M_{13}), feedy (M_3), and wet cardboard (S_5) notes, resulted in a decrease in acceptance. Even though the sweet aromatic note (A_7) detected was less than 1.3 units (Table 6a), it had a significant impact on the consumer acceptance of the aroma. Woody notes (A_{13}, M_{13}) were undetectable in most imported Jasmine rice but present in all domestic Jasmine rice and one imported sample (Dynasty). Feedy (M_3) and wet cardboard (S_5) notes were detectable in both domestic and imported Jasmine rice samples. Most of these findings are in agreement with the results obtained from previous studies by Meullenet and others (2001), except for sulfur notes. Similar sulfur intensities were detected in Jasmine rice using the descriptive analysis from both studies, but the importance of this parameter was found to be much more prominent in the present study. Results from this study showed that sulfur contributed as a major determinant of flavor acceptance, opposite to the previous reports.

Prediction of Jasmine rice texture acceptance from texture descriptors

Manual stickiness (T_1), initial cohesion (T_2), adhesion to lips (T_3), cohesiveness (T_5), cohesiveness of mass (T_6), and toothpull (T_8) were found to have positive impacts, whereas hardness (T_4), and roughness of mass (T_7) had negative impacts on the acceptance of Jasmine rice texture by Asian consumers (Figure 9). These findings confirm PCA results (Figure 3) and confirmed results reported by Meullenet and others (2001), which indicated that higher sample cohesiveness contributed to increased consumer acceptance of texture, while higher sample macro roughness of mass contributed to decreased acceptance. This model (RMSEP = 0.39), however, explained only 61% of the variation in consumer acceptability for Jasmine rice texture. Further research is necessary to confirm the factors that significantly affect the acceptance of rice texture.

Conclusions

ASIAN CONSUMERS PREFERRED IMPORTed Jasmine rice more than the domestic products. The most important factors in determining the acceptance of Jasmine rice were, in decreasing order of importance, color, flavor, aroma, stickiness, and hardness, respectively. Increase intensities of yellowness, floral, woody, and wet cardboard notes resulted in a decrease in acceptance. Two domestic samples (dJ and dS) exhibited brownish yellow color prior and after cooking. High intensities of floral, woody, and wet cardboard notes were exhibited in domestic and in one imported Jasmine rice (for example dJ, dT, dS, and iS). These findings allowed the identification of sensory characteristics most important to Jasmine rice acceptance by this Asian consumer group. Data collection from this study could be useful to the U.S. rice industry, including rice breeders, to better understand the specific sensory characteristics needed for optimizing acceptance by Asian consumers. Further research should focus on correlations between consumer acceptability of Jasmine rice and analytical measurements, such as color, headspace analysis, and rheological characterization, to determine if these methods are applicable to the optimization of aromatic rice cultivars cultivated in the United States.

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