Multivariate and Probabilistic Analyses of Sensory Science Problems
Jean-François Meullenet, Rui Xiong, Christopher J. Findlay

1 A Description of Sample Data Sets Used in Further Chapters

1.1. A Description of Example Data Sets

The various data sets described here are used in various chapters of the book, but we thought it would be useful to describe the methodologies in a little more detail here. The actual data can be downloaded from the book Web site at http://www.uark.edu/ua/multivariate/index.htm.

1.1.1. White Corn Tortilla Chips

1.1.1.1. Introduction

This data set is used extensively as an example in Chapters 3, 4, 5, and 7. Additional details about these studies are published in Meullenet et al. 2002 and 2003. Households in the United States are very fond of salty snacks, including tortilla chips. According to Dies (2000), 76% of U.S. households purchase tortilla chips every 32 days. In 1996, tortilla and potato chips accounted for five of the top 10 products in the salty snack category (Anonymous, 1998). In the United States, tortilla chips have a 20% market share of salty snack purchases, second only to potato chips (Lisser, 1993). In 1996, tortilla chips enjoyed their highest sales in 10 years and yellow tortilla chips gained in popularity (Wellman, 1997).

A few studies have been carried out for the evaluation of the sensory properties of tortilla chips. Buttery and Ling (1995, 1998) characterized the flavor volatiles of corn tortilla chips, whereas Hawrysh et al. (1995) examined the sensory and chemical stability of tortilla chips fried in canola oil, corn oil, and partially hydrogenated soybean oil. Stinson and Tomassetti (1995) showed that the flavor and texture acceptability of low-fat tortilla chips increased when natural corn flavor was added. However, the consumer preference pattern of white corn tortilla chips is not yet clearly defined. This study was conducted to determine the preferences for tortilla chips and to quantify the specific sensory characteristics found in the tortilla chips presently on the market.

1.1.1.2. Samples

A broad range of 25 commercially available tortilla chips were purchased at local supermarkets. The original group of tortilla chips, which included both yellow and white corn chips, was visually screened based on color, shape, and levels of salt and fat reported on the labels. Eleven commercially available toasted white corn tortilla chip products (Table 1.1) were selected for this study because white corn tortilla chips are more popular with consumers than yellow corn tortilla chips and there was a financial constraint for this project. Large bags of each of the 11 types of tortilla chips were purchased 1–2 days before testing. The samples were randomly coded with a three-digit number and stored to prevent fractioning of chips.

Table 1.1. Commercial pure white corn tortilla chip products.

Product Name	Abbreviation	Producer	Shape	Salt Content (%)[1]	Fat Content (%)[1]
Best Yet White Corn	BYW	Fleming Companies, Inc.	Triangle	4	12
Green Mountain Gringo	GMG	Green Mountain Gringo	Strip	5	13
Guy's Restaurant Rounds	GUY	Guy's Snack Foods	Round	3	9
Medallion White Corn	MED	Medallion Food Corporation	Triangle	2	11
Mission Strips	MIS	Mission Food Corporation	Strip	4	10
Mission Triangle	MIT	Mission Food Corporation	Triangle	4	10
Oak Creek Farms—White Corn	OAK	Oak Creek Farms	Round	2	11
Santita's	SAN	Frito-Lay	Triangle	5	8
Tom's White Corn	TOM	Tom's Foods Inc.	Triangle	5	10
Tostito's Bite Size	TOB	Frito-Lay	Round	5	12
Tostito's Restaurant Style	TOR	Frito-Lay	Triangle	3	9

[1]Expressed as percentage daily intake; percentage daily value is based on a 2000-calorie diet.

The coded samples were presented to panelists on white plastic plates that were 6 inches in diameter. Approximately five or six large chips or six to eight bite-size chips were placed on each plate. Each bag of chips was immediately resealed using a bag clip to preserve freshness. Chips that were excessively fractured were discarded.

1.1.1.3. Descriptive Analysis

Eleven tortilla chip samples were evaluated for appearance, flavor, and texture by a group of nine Spectrum-trained panelists. Panel orientation was conducted to develop a descriptive lexicon for the appearance, flavor, and texture attributes specific to tortilla chips, using the Spectrum method (Sensory Spectrum Inc., Chatham, NJ). References used for panel orientation and lexicon development are presented in Tables 1.2, 1.3, and 1.4. The panel orientation on tortilla chip texture, flavor, and appearance was conducted over three 3-hour sessions. The texture ballot analyzed four major categories of product texture characteristics—surface, first bite, chew down, and residual—for a total of 15 texture attributes (Table 1.2). The flavor, basic taste, aromatics, feeling factors, and aftertaste profiles consisted of 23 attributes (Table 1.3). The appearance ballot consisted of five attributes (Table 1.4).

Texture, flavor, and appearance evaluations were carried out under controlled conditions over two 3-hour sessions, two 2.5-hour sessions, and one 2-hour session, respectively. During each session, the samples were presented in a random order to each panelist (i.e., each panelists was assigned a different randomization scheme). The evaluation was performed in individual booths featuring controlled lighting and positive air pressure. Panelists were provided with a paper ballot, references, and crackers (Nabisco Premium Unsalted brand) and water for cleansing and rinsing their palates between each sample. A 10-minute break was scheduled during each session. The texture and flavor evaluations

Table 1.2. Texture vocabulary for tortilla chips.

Term[1]	Definition	Technique	Reference
Surface Characteristics			
Roughness	The amount of irregular particles in the surface of the sample: Micro: the small crevices and irregularities on the surface of the sample. Macro: The large peaks and sloped angles detected on the surface of the sample.	Hold sample to mouth and feel the surface of the sample with tongue and lips.	Graham cracker Micro 1.0 Macro 1.5 Club cracker Micro 3.5 Macro 2.5 Cookie Micro 0.8 Macro 5.0 Pringles Micro 8.0 Macro 1.0 Twizzler Micro 0.5 Macro 7.0 Granola bar Micro 12.0 Macro 1.0 Triscuit Micro 13.0 Macro 4.0 Rye wafer Micro 15.0 Macro 0.0 Nutrageous Micro 14.0
Oily/greasy lips	The amount of oily or greasy residue (regardless of the thickness) felt on the lips after placing the sample in mouth.	Place sample between lips, compress, and release. Using the tongue to feel the surface of the lips, evaluate the amount of oily/greasy residue felt on the lips.	Club cracker 5.0 Pringles 8.0
Loose particles	The amount of particles felt on the lips.	Compress sample lightly between lips, remove sample and evaluate.	Pringles 5.0
First Bite			
Hardness	The force required to compress the sample.	Compress or bite through sample one time with molars or incisors.	Cream cheese 1.0 Egg white 2.5 American cheese 4.5 Beef frankfurter 5.5 Olive 7.0 Peanut 9.5 Almond 11.0 Carrots 11.0 LifeSavers 14.5
Crispiness	The amount of small breaks felt (perceived as having many light, airy, small breaks), and the	Compress sample with molar teeth until sample shatters, breaks or crumbles.	Granola bars 2.0 Club cracker 5.0 Graham cracker 6.5 Cheerios 7.0

(*Continued*)

Table 1.2. *Continued.*

Term[1]	Definition	Technique	Reference
	degree of pitch and sound heard when the sample is cracked, broken, or compressed once.		Bran flakes 9.5 Goldfish crackers 11.0 Cornflakes 14.0
Chew Down Characteristics			
Cohesiveness of mass	The amount that the chewed sample holds together.	Chew sample with molar teeth 8–10 times and evaluate.	Shoestring licorice 0.0 Carrots 2.0 Mushrooms 4.0 Beef frankfurter 7.5 American cheese 9.0 Brownie 13.0 Dough 15.0
Moistness of mass	The amount of wetness/ oiliness felt on the surface of the mass.	Chew sample with molar teeth 8–10 chews and evaluate. How wet does the sample feel?	Saltine crackers 4.5 Pound cake 10.5 Jell-O gelatin 14.0 Water 15.0
Roughness of mass	The amount of roughness perceived in the chewed sample.	Chew sample with molars 8–10 times and evaluate the irregularities in the sample mass.	Unchewed Jell-O gelatin 0.0 Orange peel 3.0 Cooked oats 6.5 Pringles 8.0
Moisture absorption	The amount of saliva absorbed by the sample during mastication. Pay attention to how dry your mouth is becoming, not to the sample.	Chew the sample with molar teeth 8–10 times and evaluate.	Shoestring licorice 0.0 Licorice 3.5 Popcorn 7.5 Potato chips 10.0 Pound cake 13.0 Saltine crackers 15.0
Persistence of crisp	The amount of mastication before the "crisp sound" changes.	Chew sample with molars and count the number of chews completed before the pitch or crisp sound changes.	
Residual Characteristics			
Oily/greasy film	The amount and degree of residue felt by the tongue when moved over the surface of the mouth.	Expectorate the sample and feel the surface of the mouth with tongue to evaluate.	Saltine crackers 0.5 Ritz crackers 2.5 Pringles 5.0 Oil 15.0
Toothpack	The amount of product packed into the crowns of your teeth after mastication.	Chew sample 15–20 times, expectorate and feel the surface of the crowns of the teeth to evaluate.	Captain Crunch cereal 5.0 Heath Bar 10.0
Loose particles	The amount of particles remaining in and on the surface of the mouth after swallowing.	Chew sample with molars, swallow and evaluate.	Carrot 10.0

[1]The data for roughness, hardness, cohesiveness of mass, roughness of mass, toothpack, and loose particles were from the work by Meullenet and others (1999, 2001); those for moisture of absorption was from the work by Meilgaard et al. (1999); the remaining data were from this study.

Table 1.3. Flavor vocabulary for tortilla chips.

Term	Definition	Reference	Intensity
Basic Tastes[1]			
Sweet	The basic taste, perceived on the tongue, stimulated by sugars and high-potency sweeteners.	Solutions of sucrose in spring water.	Sucrose solution 2%: 2.0 Sucrose solution 5%: 5.0 Sucrose solution 10%: 10.0 Sucrose solution 16%: 15.0
Salt	The basic taste, perceived on the tongue, stimulated by sodium salt, especially sodium chloride.	Solutions of sodium chloride in spring water.	NaCl solution 0.2%: 2.0 NaCl solution 0.35%: 5.0 NaCl solution 0.5%: 8.5 NaCl solution 0.55%: 10.0 NaCl solution 0.7%: 15.0
Sour	The basic taste, perceived on the tongue, stimulated by acids, such as citric acid.	Solutions of citric acid in spring water.	Citric acid solution 0.05%: 2.0 Citric acid solution 0.08%: 5.0 Citric acid solution 0.15%: 10.0 Citric acid solution 0.20%: 20.0
Bitter	The basic taste, perceived on the tongue, stimulated by substances such as quinine, caffeine, and certain other alkaloids.	Solutions of caffeine in spring water.	Caffeine solution 0.05%: 2.0 Caffeine solution 0.08%: 8.0 Caffeine solution 0.15%: 10.0 Caffeine solution 0.20%: 15.0
Aromatics[2]			
Grain complex	The overall grain impact.		Saltine: 3.0 Applesauce: 7.0
Raw corn	The aromatic associated with fresh or uncooked corn.	Cornmeal paste	Orange juice: 10.0 Grape juice: 14.0
Toasted corn	The aromatic associated with caramelized or browned corn meal.	Corn Chex cereal	Big Red brand gum: 16.0
Masa	The aromatic associated with alkali-treated cornmeal.	Fresh white corn tortillas; Tostitos-brand tortilla chips	
Toasted grain	A general term used to describe the aromatics of toasted grains, which can not be tied to a specific grain source.	Multiple-grain breakfast cereals	
Heated oil	The aromatic associated with fresh oil that is heated.	Fresh, heated Crisco-brand vegetable oil	
Scorched	The aromatic associated with overheating or overcooking.	Scorched popcorn	
Cardboard (papery/ packaging)	Aromatics associated with slightly oxidized fats and oils or by other sources, such as staling flours; reminiscent of wet cardboard packaging.	Wet cardboard presented in a reference jar	

(*Continued*)

Table 1.3. *Continued.*

Term	Definition	Reference	Intensity
Feeling Factors[3]			
Astringent	A chemical feeling factor felt on the tongue or other surfaces of the oral cavity, described as puckering/dry and associated with tannins or alums.	Plain yogurt	Plain yogurt: 3.5

[1]The reference and intensity for basic taste was the one used by Meilgaard et al. (1999).
[2]The reference and intensity for aromatics was a slightly modified version of the reference and intensity used by Meilgaard et al. (1999).
[3]The reference and intensity for feeling factor was the one used by Meullenet et al. (2001).

Table 1.4. Appearance vocabulary for tortilla chips.

Term[1]	Definition	Technique	Reference
Degree of whiteness	The amount of pure whiteness in the sample	Observe all the chips on the tray	Nacho Rounds: 0 Green Mountain Gringo: 2 Guy's Restaurant Style: 7 White plate: 15
Grain flecks	The amount (regardless of size) of dark colored particles that appear to be coarsely ground grain particles	Observe all the chips on the tray	Green Mountain Gringo: 3 Tom's White Corn: 6 Best Yet White Corn: 8
Char marks	The amount of charred markings on the surface of the sample (usually on one side) that appears to be charred from the baking surface	Observe all the chips on the tray	Tostito's Restaurant Style: 0 Mission Strips: 5 Green Mountain Gringo: 7
Micro surface particles	The amount of fine particles laying on the surface of the sample that appear to be grain dust or salt	Observe all the chips on the tray. Turn chip sideways and examine	Green Mountain Gringo: 2 Tostito's Bite Size: 5 Oak Creek Farms: 9
Amount of bubbles	The amount of surface area of the sample affected by bubbles	Observe all the chips on the tray. Estimate the proportion of the surface area of the sample affected by bubbles	None: 0 Entire surface affected: 15

[1]Degree of whiteness was from the work by Meullenet et al. (2001); the remaining scales were developed for this study.

were performed in duplicate during two sessions held on different days. The evaluation of product appearance was performed by presenting 10 chips during a single session. The panelists were asked to evaluate the appearance of all the chips and to give an average score for each attribute. This method was used because of the large variation in appearance within each product.

1.1.1.4. Consumer Testing

Based on the work of Dies (2000), who reported that 76% of U.S. households purchase tortilla chips every 32 days, we assumed that 75% of the population in Northwest Arkansas consumes tortilla chip products on a regular basis. The minimum sample size necessary to obtain a representative sample of the population was calculated to be 73 consumers, using the formula $Z_\alpha p(1-p)/C_p^2$ (Rea and Parker, 1992; in this case, $Z_\alpha = 1.96$, associated with 95% confidence level, the proportion $p = 0.75$, and the confidence interval $C_p^2 \leq 10\%$). Because the consumer test was performed over a 2-day period, 80 consumers were selected in anticipation of second-day no shows.

The consumer panel was recruited by posting advertisements at local restaurants, grocery stores, supermarkets, and the university campus, requesting participation in a salty snack consumer taste. Consumers of these snack products between the ages of 18 and 35 years who were interested in participating were asked to call a number given on the advertisements. A phone screener was used to determine whether the caller consumed tortilla chips on a regular basis, which was considered to be every 2 weeks, or twice a month. Eighty tortilla chip consumers were selected and scheduled for the 2-day test. A $20 gift card was offered as an incentive and was paid on completion of the test.

A completely randomized design was used across the 11 samples for the 80 consumers (Meilgaard et al., 1999). The 2-day consumer test was carried out at the University of Arkansas Sensory Laboratories. Each consumer was seated in an individual testing booth with controlled lighting and positive airflow and was presented with five and six tortilla chip samples on the first and second days of the test, respectively. The consumers were provided with five or six large chips or from six to eight bite-size chips for each sample, presented on 6-inch-diameter coded white plastic plates. Each sample was assigned a three-digit code to be entered by consumers on the ballot as a means of identifying the sample. Each consumer was asked to evaluate the appearance, overall impression, flavor, and texture of each sample on a 9-point hedonic scale with 9 being "like extremely" and 1 being "dislike extremely" (Table 1.5). Consumers were also asked to rate the amount of saltiness on a 5-point Just About Right scale with Just About Right being a score of 3 (1 = "much too low" and 5 = "much too high"; Table 1.6). Demographic data including gender, age group, consumption frequency, and preference for brands and shapes of tortilla chips were also gathered.

1.1.1.5. Appearance Measurements

The color of the samples was instrumentally evaluated using a Minolta CR-300 colorimeter (Minolta Co., Ltd., Osaka, Japan). The hunter color values (L, a, and b) were used. The color value "L," measuring whiteness, is quantified on a scale from 0 to 100. The color value "a" quantifies red (positive values) to green (negative values), and the color value "b" quantifies yellow (positive values) to blue (negative values).

1.1.1.6. Summary Results

The frequency (percentage) of the consumer overall acceptance and acceptance of appearance, flavor, texture, and amount of salt is presented in Table 1.6. It was evident that the Tostito's Restaurant Style chips had the highest overall acceptance frequency of "Like extremely" responses, followed by the Tostito's Bite Size chips. Both Tostito's Bite Size and Tostito's Restaurant Style tortilla chips, together with Santita's chips, from the same manufacturer (Frito-Lay), appeared to have the highest percentages (57.6%, 47.5%, and

Table 1.5. Means of descriptive and /or instrumental attributes for appearance, flavor and texture

	White Corn Tortilla Chips[1]										
Attribute	**BYW**	**GMG**	**GUY**	**MED**	**MIS**	**MIT**	**OAK**	**SAN**	**TOB**	**TOM**	**TOR**
Appearance											
Instrumental color L	95.9	92.7	93.7	84.9	68.9	69.6	96.5	93.1	95.9	92.9	92.7
Instrumental color a	–0.1	–0.3	–0.6	0.4	0.4	0.3	0.6	–0.8	–0.4	–0.3	–0.8
Instrumental color b	12.1	22.1	2.6	9.5	23.5	23.6	7.4	8.8	13	8.7	4.9
Degree of whiteness	6	2	7	6.5	5	3	6	6	6	7	6
Grain flecks	8	3	6	3.5	4	3	6	8	6	6	8
Char marks	2	7	7	3	5	4.5	2	1.5	0	6	0
Micro surface particles	2	0.5	1	2	2.5	2	2	1	2.5	3.5	2
Amount of bubbles	6	6	6	6	5	5	6	7	7.5	7	5
Flavor											
Sweet	0.5	0.5	0.5	0.4	0.6	0.4	0.7	0.6	0.4	0.4	0.6
Salt	8.8	7.2	7.8	6.9	9.4	9.9	7.3	9	8.9	8.5	8
Grain complex	6.9	7.2	6.6	6.5	7.1	6.9	6.8	7	6.9	7	6.9
Toasted corn	2.7	2.3	1.6	2.3	3.8	2.8	1.3	3.4	2.6	2.5	2.6
Raw corn	0	0.2	0	0	0	0	0.3	0	0	0	0
Masa	3.7	3.7	3.8	3.8	3.1	3.2	4.2	3.7	4	4.1	3.4
Toasted grain	1.4	2.2	2.2	1.5	1.2	2	1.8	0.8	1	1.4	2.3
Sweet	0.5	0.5	0.5	0.4	0.6	0.4	0.7	0.6	0.4	0.4	0.6
Heated oil	4.4	4.4	4.5	4.3	4.5	4.4	4.2	4.3	4.5	4.6	4.3
Scorched	0	0.5	0.6	0	2.7	0.6	0	0	0.2	0	0
Cardboard	2.4	2	2.8	3.3	2.7	2.6	2.6	2.1	1.9	2.4	2.4
Astringent	2.6	2.5	2.5	2.5	2.7	2.6	2.6	2.6	2.6	2.6	2.5
Aftertaste: toasted corn	1.4	1.1	0.7	1.1	2.2	1.8	0.5	2.4	1.7	1.1	1.5
Aftertaste: toasted grain	1	1.4	1.2	1.2	0.8	0.9	1.2	0.4	0.4	1.1	1.4
Aftertaste: toasted masa	2	1.6	2	1.5	1.3	1.7	1.5	1.6	1.3	1.7	1.2
Aftertaste: raw masa	0.2	0.9	0.6	0.7	0.2	0	1.3	0.2	0.4	1.1	0.6
Aftertaste: heated oil	2.5	2.8	2.8	2.7	3.1	2.7	2.4	2.8	3.1	2.8	2.9
Aftertaste: salt	3.6	3.1	3.3	2.9	3.9	4.1	3.3	3.8	4.1	3.5	3.7
Aftertaste: sweet	0.4	0.4	0.5	0.3	0.4	0.4	0.5	0.4	0.3	0.3	0.4
Texture											
Micro roughness	8.8	7.6	8.6	8.3	8.1	8.7	8.2	7.6	7.8	6.9	7.7
Macro roughness	3.2	3.1	2.8	4.4	4.1	4.3	3.2	4.1	3.8	5.5	4.4
Oily/greasy lips	6.7	4.4	5	6	5.3	5.8	6	5.8	5.8	5.9	5.3
Loose particles	6.7	4.4	5	6	5.8	5.3	6	5.8	5.8	5.9	5.3
Hardness	8.8	9.6	8.6	9	8.7	8.8	8.7	8.8	8.2	8.5	8
Crispness	10.4	9.6	9.9	10.6	10.2	10.2	9.5	10.7	11.1	10.7	11.5
Fracturability	7.4	7.2	7.8	7.9	7.5	7.7	7.1	7.7	8	7.5	7.9
Cohesiveness of mass	2.7	3.3	3.2	3.1	2.9	3	3.5	3	3.2	3.1	3.4
Roughness of mass	7.6	7.2	7.4	7.5	7.3	7.5	7.5	7.6	7.3	7.7	7.6
Moistness of mass	7.3	7.6	7.1	7.2	7.3	6.9	7.7	7.4	7.3	7.7	7.2
Moisture absorption	9.1	9.2	9.5	9.1	9.6	9.7	9.1	9.5	9.1	9	9.3
Persistence of crisp	6	5.2	5.1	5.5	4.9	5.3	5.1	5.7	5.7	5.4	5.4
Toothpack	5.2	5.2	5.1	5.2	5.4	5.8	5.4	5.3	5.3	5.2	5.1
Loose particles	7.2	7.2	6.9	7	7.3	7	7.1	7.5	7.3	7.3	6.9
Oily/greasy film	4	3.8	3.9	4.3	3.9	3.9	3.8	3.8	3.9	4.5	3.8

[1]Sample name abbreviations can be found in Table 1.1.

Table 1.6. Frequency (%) of consumer overall acceptance and consumer acceptance of appearance, flavor, texture and saltiness for 11 tortilla chip products[1].

	White Corn Tortilla Chips[3]										
Scale[2]	**BYW**	**GMG**	**GUY**	**MED**	**MIS**	**MIT**	**OAK**	**SAN**	**TOB**	**TOM**	**TOR**
Overall acceptance											
Dislike extremely (1)	0.0	5.0	1.3	3.8	1.3	0.0	6.3	0.0	0.0	5.0	0.0
Dislike very much (2)	0.0	5.0	2.5	7.5	2.5	3.8	3.8	0.0	0.0	1.3	2.5
Dislike moderately (3)	3.8	8.8	6.3	7.5	6.3	2.5	6.3	0.0	3.8	3.8	1.3
Dislike slightly (4)	11.3	13.8	17.5	18.8	12.5	10.0	17.7	7.5	3.8	6.3	2.5
Neither dislike nor like (5)	13.8	10.0	7.5	8.8	3.8	5.0	7.6	6.3	3.8	12.5	5.0
Like slightly (6)	13.8	23.8	21.3	20.0	18.8	8.8	16.5	7.5	12.5	12.5	15.0
Like moderately (7)	30.0	16.3	22.5	25.0	26.3	36.3	27.8	33.8	18.8	30.0	26.3
Like very much (8)	26.3	13.8	20.0	6.3	22.5	25.0	10.1	38.8	43.8	21.3	30.0
Like extremely (9)	1.3	3.8	1.3	2.5	6.3	8.8	3.8	6.3	13.8	7.5	17.5
Appearance											
Dislike extremely (1)	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0
Dislike very much (2)	0.0	0.0	1.0	4.0	3.0	0.0	2.0	0.0	1.0	1.0	2.0
Dislike moderately (3)	3.0	4.0	5.0	2.0	6.0	4.0	1.0	0.0	2.0	0.0	1.0
Dislike slightly (4)	16.0	11.0	10.0	13.0	15.0	7.0	6.0	2.0	6.0	6.0	7.0
Neither dislike nor like (5)	4.0	11.0	6.0	8.0	6.0	5.0	11.0	5.0	4.0	6.0	3.0
Like slightly (6)	13.0	12.0	14.0	9.0	13.0	12.0	10.0	8.0	6.0	13.0	9.0
Like moderately (7)	21.0	19.0	22.0	27.0	12.0	20.0	27.0	26.0	16.0	19.0	19.0
Like very much (8)	21.0	17.0	18.0	13.0	15.0	24.0	12.0	32.0	29.0	27.0	27.0
Like extremely (9)	2.0	4.0	4.0	4.0	10.0	8.0	9.0	7.0	16.0	7.0	12.0
Flavor											
Dislike extremely (1)	0.0	5.1	1.3	7.5	2.5	0.0	8.9	0.0	0.0	1.3	0.0
Dislike very much (2)	0.0	7.6	1.3	10.0	3.8	1.3	11.4	0.0	0.0	5.0	2.5
Dislike moderately (3)	6.3	7.6	8.8	8.8	7.5	6.3	6.3	1.3	2.5	5.0	0.0
Dislike slightly (4)	13.8	16.5	22.5	18.8	6.3	6.3	19.0	6.3	3.8	16.3	6.3
Neither dislike nor like (5)	10.0	12.7	8.8	6.3	6.3	8.8	10.1	7.5	3.8	15.0	3.8
Like slightly (6)	13.8	17.7	21.3	22.5	23.8	15.0	13.9	8.8	17.5	12.5	18.8
Like moderately (7)	22.5	16.5	17.5	15.0	21.3	25.0	17.7	27.5	21.3	16.3	20.0
Like very much (8)	28.8	12.7	16.3	10.0	21.3	27.5	8.9	36.3	33.8	21.3	35.0
Like extremely (9)	5.0	3.8	2.5	1.3	7.5	10.0	3.8	12.5	17.5	7.5	13.8
Texture											
Dislike extremely (1)	0.0	3.8	0.0	1.3	0.0	0.0	1.3	0.0	0.0	0.0	0.0

(*Continued*)

Table 1.6. *Continued.*

	White Corn Tortilla Chips[3]										
Scale[2]	**BYW**	**GMG**	**GUY**	**MED**	**MIS**	**MIT**	**OAK**	**SAN**	**TOB**	**TOM**	**TOR**
Dislike very much (2)	1.3	6.3	0.0	7.5	1.3	1.3	2.6	0.0	0.0	3.8	1.3
Dislike moderately (3)	2.5	6.3	8.8	1.3	3.8	5.0	5.1	0.0	0.0	2.5	1.3
Dislike slightly (4)	12.5	26.6	16.3	18.8	5.0	15.0	7.7	3.8	2.5	11.4	0.0
Neither dislike nor like (5)	1.3	8.9	11.3	8.8	8.8	5.0	9.0	7.5	5.1	15.2	6.3
Like slightly (6)	12.5	15.2	13.8	15.0	17.5	15.0	19.2	13.8	16.5	11.4	8.8
Like moderately (7)	28.8	21.5	27.5	27.5	22.5	25.0	28.2	23.8	17.7	21.5	23.8
Like very much (8)	31.3	10.1	20.0	17.5	31.3	25.0	21.8	35.0	38.0	27.8	38.8
Like extremely (9)	10.0	1.3	2.5	2.5	10.0	8.8	5.1	16.3	20.3	6.3	20.0
Amount of Salt											
Much too low (1)	3.8	20.0	8.8	31.3	1.3	5.0	10.1	0.0	2.5	8.8	3.8
Low (2)	31.3	46.3	41.3	41.3	10.1	10.0	44.3	12.5	22.5	32.5	23.8
Just right (3)	48.8	32.5	36.3	15.0	63.3	60.0	38.0	62.5	62.5	46.3	65.0
High (4)	13.8	1.3	13.8	12.5	20.3	18.8	6.3	22.5	12.5	11.3	7.5
Much too high (5)	2.5	0.0	0.0	0.0	5.1	6.3	1.3	2.5	0.0	1.3	0.0

[1]Total observations (n = 80 consumers) for each tortilla chip sample.
[2]A 9-point hedonic scale for consumer overall acceptance and acceptance of appearance, flavor, and texture; a 5-point Just About Right scale for the amount of salt (saltiness).
[3]Sample name abbreviations can be found in Table 1.1.

45.1%, respectively) of "Like" to "Like extremely," whereas the Medallion White Corn, Green Mountain Gringo, and Oak Creek Farms—White Corn chips had the lowest percentages of these responses (8.8%, 17.6%, and 13.9%, respectively). The acceptance of the appearance, flavor, and texture of Tostito's Bite Size chips was rated as "Like extremely" by 16.0%, 17.5%, and 20.3% of the consumers, respectively. In contrast, the acceptance of the appearance, flavor, and texture of the Medallion White Corn chips was rated as "Like extremely" only by 4.0%, 1.4%, and 2.5% of the consumers, respectively. In terms of the amount of salt, 60%–65% of the consumers rated five products (Mission Strips, Mission Triangle, Santita's, Tostito's Bite Size, and Tostito's Restaurant Style chips) as Just About Right, whereas Medallion White Corn chips had the lowest rate of approval (i.e., 15%). It was found that the Just About Right rates were associated with the salt content (Table 1.6). A salt content of 4% was found to be Just About Right for the consumer saltiness acceptance.

Descriptive intensity means for the attributes of visual appearance, flavor, and texture and the means of instrumental color values ("L," "a," and "b") are presented in Table 1.5, illustrating some of the sensory differences observed among the 11 products.

1.1.2. Muscadine Grape Juices

1.1.2.1. Introduction

These data are used in Chapter 3 on preference mapping and in Chapter 6 on consumer segmentation. Muscadine grapes (*Vitis rotundifolia*) are native to the southeastern United

States and have been produced commercially in Arkansas since 1972 (Lanier and Morris, 1979). Recent economic analysis indicates that muscadine grape production can be a profitable enterprise for growers (Noguera et al., 2005). Interest in production of muscadines has increased since muscadines and products from muscadines were identified as a source of vitamins, minerals, fiber, antioxidants, and phenolic compounds (Ector, 2001; Ector et al., 1996; Lee and Talcott, 2004; Pastrana-Bonilla et al., 2003; Striegler et al., 2005; Talcott and Lee, 2002; Threlfall et al., 2005; Yilmaz and Toledo, 2004).

The increase in consumer interest in a healthier lifestyle provides an opportunity for the muscadine industry to capture a section of the nutraceutical market that is projected to reach $28 billion in the United States by 2006 (Green, 2003). The muscadine grape juice used to study the acceptability and sensory properties of the product was hand-harvested from black and bronze cultivars from the University of Arkansas Southwest Research and Extension Center. The cultivars included Black Beauty (Brooks and Olmo, 1991), Carlos (Brooks and Olmo, 1970), Granny Val (Brooks and Olmo, 1991), Nesbitt (Goldy and Nesbitt, 1985), Southern Home (Mortensen et al., 1994), Summit (Lane, 1977), and Supreme (Brooks and Olmo, 1991).

1.1.2.2. Samples

Thirty-six kilograms of each grape cultivar were used for juice processing. The grapes were crushed twice and placed in a plastic container with a food-grade polyethylene liner. After being processed, the juice was placed in cold storage overnight and then stabilized for 2 weeks at 2°C. The juice was then pasteurized and sealed in glass bottles and stored again at the same temperature.

Each muscadine juice was assigned a random three-digit number for identification. Two commercial muscadine juices were also included, one red juice and one white juice.

1.1.2.3. Descriptive Analysis

The 10 muscadine juices were examined for aroma, basic tastes, aromatics, feeling factors, and aftertaste by a group of nine Spectrum-trained panelists. Panel orientation was held over a 2-day period during two 3-hour sessions to develop a descriptive lexicon. The lexicon and references used to describe the sensory properties of muscadine grape juice can be found in Table 1.7.

Flavor, aroma, feeling factors, and aftertaste were evaluated under controlled conditions over two sessions of 3 hours each. The samples were replicated and presented to each panelist according to different randomized schemes so that the order of presentation was balanced. Panelists were provided with appropriate references and paper ballots, and they used a numerical scale from 0 to 15, with one significant digit (Meilgaard et al., 1999). The panelists were also given crackers (Nabisco Premium Unsalted) and water for cleansing and rinsing their palates between each sample.

1.1.2.4. Consumer Testing

Sixty-one individuals were recruited from a database of over 2000 local consumers. Consumers were recruited on the basis of the frequency of their muscadine and muscadine juice consumption. They were also chosen on the basis of their level of liking for muscadine grapes. The 10 juices were tested over the course of 2 days.

A completely randomized serving order was used across the 10 juices for the 61 consumers (Meilgaard et al., 1999). Each consumer saw the first five juices the first day of

Table 1.7. Sensory lexicon used to describe muscadine grape juice.

Term	Definition	Reference	Intensity
Basic tastes			
Sweet	The basic taste sensation on the tongue stimulated by high-potency sweeteners.	Sucrose solutions in spring water.	2.0% solution: 2.0 5.0% solution: 5.0 10.0% solution: 10.0 16.0% solution: 15.0
Sour	The basic taste sensation on the tongue stimulated by acids.	Citric acid solutions in spring water.	0.05% solution: 2.0 0.08% solution: 5.0 0.15% solution: 10.0 0.20% solution: 15.0
Bitter	The basic taste sensation on the tongue stimulated by solutions of caffeine, quinine, and other alkaloids.	Caffeine solutions in spring water.	0.05% solution: 2.0 0.08% solution: 5.0 0.15% solution: 10.0 0.20% solution: 15.0
Aromatics			
Cooked muscadine	The aromatic associated with processed or cooked muscadine grapes.	Post-brand muscadine grape juice	Intensities based on the Universal Aromatic Scale
Cooked grape	The aromatic associated with cooked, processed, or heated grapes but not specifically identifiable.	A mixture of Sunbelt-brand Thompson seedless red grapes cooked and blended together	Same
Musty	The aromatic characteristic of damp/wet basements or turned soil.	2-methyl isoborneol	Same
Green/unripe	Aromatic characteristic of certain green fruits and under ripe fruits in general.	Cis-3-hexenol, Granny Smith apples, underripe fruits	Same
Caramelized/ sweet aromatic	The aromatics associated with substances that also have a sweet basic taste such as caramelized sugar, vanillin, maltol, and so on	1) Vanillin, 2) ethyl maltol, 3) caramelized sugar	Same
Floral	A sweet, fragrant aromatic associated with flowers.	Heliotropine	Same
Fermented	Aromatic associated with fermented fruits or grains.	Fermented apple juice, overripe pineapple, cantaloupe, orange juice	Same
Apple/pear	The aromatic associated with different cooked or processed apples or pears.	Gerber-brand apple–pear juice	Same
Metallic	1) The aromatic associated with metal, tin, or iron; 2) the flat chemical feeling factor stimulated on the tongue and teeth.	Dole-brand pineapple juice (canned)	Same
Feeling Factors			
Astringent	The chemical feeling factor on the tongue or other surfaces of the oral cavity described as puckering/dry and associated with tannins or alum.	Alum solutions in spring water.	0.025% solution: 3.0 0.033% solution: 5.0 0.050% solution: 9.0

Universal Aromatic Scale

Intensities for aromatics and aromas are based on the following reference standards: soda note in a saltine cracker = 3.0; cooked apple note in applesauce = 7.0; cooked orange note in orange juice = 10.0; cooked grape note in grape juice = 14.0, cinnamon note in cinnamon gum = 16.0.

testing and the remaining five juices the second day of testing. Consumers received their samples in individual testing booths under controlled lighting and positive airflow. They were provided with a 4-ounce sample of each juice to evaluate overall impression, color, and flavor on a 9-point hedonic scale (9 = "like extremely" and 1 = "dislike extremely"). Aroma, color, overall flavor, muscadine grape flavor, sweetness, and tartness were evaluated on a 5-point Just About Right scale (1 = "much too low," 3 = "just about right," and 5 = "much too high"). Consumers also were asked questions regarding gender, age group, consumption, and purchasing preferences.

1.1.2.5. Summary Results

Table 1.8 provides a summary of the hedonic scores for the 61 consumers. Mean overall liking scores ranged from 6.3 to 7.0 on the 9-point hedonic scale, which is rather small. Without further analysis, it could be concluded that all products were of high quality. However, the use of this data set in Chapters 3 and 6 will clearly demonstrate that segments of consumers with varying preferences exist in this data.

1.1.3. Fried Mozzarella Cheese Stick Appetizers

1.1.3.1. Introduction

This data set is being used in Chapters 8, 9, and 10. Little details are given about the actual samples, as the data are subject to confidentiality agreements. However, the coded data are available for download from http//:www.uark.edu/ua/multivariate/index.htm.

1.1.3.2. Samples

The sample set consisted of eight commercial cheese stick products (P1, P2, P3, P4, P5, P6, P7, and P8). These products were obtained from a food manufacturer and stored in a freezer until evaluation. The samples were fried according to the manufacturers' cooking instructions before serving. On each of two testing days, each product was cooked at each scheduled time according to each product's own cooking instruction using two Red Hots Fryer (Model EF10-120 Deep Fat Fryer, The Eagle Group, Metal Masters Food Service Equipment Co. Inc., Clayton, DE). After cooking, the cooked samples were held under two 250-W infrared bulk lamps (NEMCO Incorporated Food Equipment, Hicksville, Ohio) for no more than 20 minutes. The lamps were used to keep the samples' temperature within the range of 140°–160°F.

1.1.3.3. Consumer Testing

A screening questionnaire was sent via e-mail to potential cheese stick users from a consumer database. Eighty regular cheese stick users (those who ate cheese sticks at least once every 2 weeks) were selected at each of the two testing sites (i.e., the University of Arkansas and Oregon State). A completely randomized design was used across the eight branded samples for all the consumers (Meilgaard et al., 1999). The 2-day consumer tests were carried out at two university sensory laboratories on the same day, using the same computerized ballot. Each consumer was seated in an individual testing booth with controlled lighting and positive airflow and was presented with four samples on each of two consecutive test days. The consumers were served the samples on three-digit coded white plastic plates. Each consumer was asked to evaluate the overall acceptance and acceptance of appearance, flavor, and texture of each sample on a 9-point hedonic scale with 1

Table 1.8. Hedonic and diagnostic means for 10 muscadine grape juices.

	Hedonic						JAR			
Type of juice	**Overall**	**Appearance**	**Aroma**	**Color**	**Flavor**	**Aroma**	**Color**	**Overall flavor**	**Muscadine flavor**	**Sweetness**	**Tartness**
Black Beauty	6.9a	6.7cd	6.6abc	6.5cd	6.7a	2.6de	2.7de	2.8d	2.7d	3.3a	2.7d
Carlos	6.8ab	6.7cd	6.7abc	6.5cd	6.7a	2.8bcd	2.4f	3.2ab	3.2a	2.9cde	3.2b
Granny Val	7.0a	6.9cd	6.8abc	6.6cd	6.9a	2.8abc	2.6ef	3.0cd	2.9bcd	3.0cd	3.0c
Ison	6.9a	7.5a	7.0a	7.4a	6.8a	2.7cde	3.0abc	3.1abc	2.8cd	2.9cde	3.3b
Nestitt	6.6ab	7.3ab	6.5bcd	7.2ab	6.5ab	2.7cde	3.1ab	3.1abc	2.8cd	2.8de	3.4ab
Post Red	6.3b	7.3ab	6.4cd	7.3a	6.0b	2.5e	3.1a	3.2ab	2.9bcd	2.7e	3.5a
Post White	6.3b	6.4d	6.1d	6.1d	6.0b	2.5de	3.2a	3.0bcd	3.0abc	2.8cde	3.3b
Southern Home	6.9a	7.0bc	7.0a	6.6cd	6.9a	3.0ab	3.1ab	3.3a	3.2a	3.0bc	3.0c
Summit	7.0a	7.0abc	6.9ab	6.9abc	6.9a	3.0a	2.8cde	3.1abc	3.1ab	3.2ab	2.8cd
Supreme	6.6ab	7.0bc	6.7abc	6.8bc	6.3ab	2.6cde	2.9bcd	3.0cd	2.8cd	2.8de	3.4ab

Note: Means with the different letters for each attribute are significantly different ($p < 0.05$), using the Least Significance Difference method.

Table 1.9. Scales used in the consumer testing of fried mozzarella cheese sticks.

Overall Acceptance and Acceptance of Appearance, Flavor, and Texture
1 = Dislike extremely
2 = Dislike very much
3 = Dislike moderately
4 = Dislike slightly
5 = Neither dislike nor like
6 = Like slightly
7 = Like moderately
8 = Like very much
9 = Like extremely
Purchase Intent
1 = Definitely would not buy
2 = Probably would not buy
3 = May or may not buy
4 = Probably would buy
5 = Definitely would buy
Product Color
1 = Much too light
2 = Somewhat too light
3 = Just about right
4 = Somewhat too dark
5 = Much too dark
Product Size
1 = Much too small
2 = Somewhat too small
3 = Just about right
4 = Somewhat too large
5 = Much too large
Amount of Breading
1 = Much too little
2 = Too little
3 = Just about right
4 = Too much
5 = Much too much
Saltiness
1 = Much too little
2 = Too little
3 = Just about right
4 = Too much
5 = Much too much
Crispness
1 = Not nearly crispy enough
2 = Not crispy enough
3 = Just about right
4 = Too crispy
5 = Much too crispy
Cheese Texture
1 = Much too soft/melted
2 = Somewhat too soft/melted
3 = Just about right
4 = Somewhat too firm/not melted
5 = Much too firm/not melted

= “dislike extremely” and 9 = “like extremely” (Table 1.9). Consumers were also asked to rate the color, the size, the amount of breading, the amount of saltiness, the crispness, and the cheese texture of each sample on a 5-point Just About Right scale, with the Just About Right score = 3 (Table 1.9). Purchase intent toward the products was rated using a 5-point scale with 1 = “definitely would not buy” and 5 = “definitely would buy.”

1.1.3.4. Descriptive Analysis

Eight cheese stick products were evaluated for appearance, flavor, and texture by a group of nine Spectrum-trained panelists. Panel orientation was conducted to develop a descriptive lexicon for appearance, flavor, and texture attributes specific to cheese sticks, using the Spectrum method and a numerical scale from 0 to 15 with one significant digit. A total of 44 descriptors (21 flavor attributes, 16 texture attributes, and 7 appearance attributes) were assessed. The list of descriptors is not given here because of confidentiality agreements between the authors and an industrial partner. Texture, flavor, and appearance evaluations were carried out under controlled conditions. During each session, the samples were randomly presented to panelists assigned to an individual booth and provided with a computerized ballot and references. Crackers and water were provided to each

Table 1.10. Consumer hedonic and diagnostic and purchase intent means for eight fried mozzarella cheese sticks.

		Hedonic					Just About Right			
Sample name	**Overall**	**Appearance**	**Flavor**	**Texture**	**Size**	**Breading**	**Color**	**Saltiness**	**Crispness**	**Texture**
P1	6.47a	6.94ab	6.63a	6.11ab	3.13a	3.09a	2.80c	3.09ab	2.63ab	3.61a
P2	6.56a	7.02ab	6.25ab	6.48a	3.03a	3.04a	3.02a	2.86c	2.61ab	3.19b
P3	5.50b	4.99d	5.61c	5.84b	2.06c	2.75b	2.31d	2.84c	2.53abc	3.47a
P4	5.70b	6.13c	5.27cd	5.91b	3.12a	2.88b	2.90bc	2.45e	2.67a	3.02c
P5	4.95c	5.07d	4.97de	5.14c	2.20b	3.04a	2.78c	2.96bc	2.08d	3.11bc
P6	4.31d	4.51e	4.76e	4.11d	1.87d	2.49c	1.81e	2.64d	1.52e	2.56d
P7	6.60a	7.25a	6.22b	6.15ab	3.04a	3.04a	2.99ab	3.13a	2.42c	3.25b
P8	6.27a	6.85b	6.32ab	5.95b	3.07a	3.12a	3.01ab	3.11a	2.49bc	3.54a

Note: Means with the same letter in the column are not significantly different ($p < 0.05$) with the Least Significance Difference method.
JAR = Just About Right scale.

panelist as a means for cleansing and rinsing their palates between each sample. A 10-minute break was scheduled at each session. The texture and flavor evaluations were performed in duplicate, whereas the appearance evaluation, because of product nonuniformity, was performed by presenting several cheese sticks on a white plate.

1.1.3.5. Summary Results

A summary of consumer testing means is provided in Table 1.10 for the eight products tested. Overall liking means ranged from 4.31 to 6.47, with products P1, P2, and P7 being most liked and products P5 and P6 being most disliked. This data set is used in Chapter 5 as an illustration of Landscape Segment Analysis, in Chapter 8 to introduce the concepts of risk analysis, and in Chapter 9 to describe the application of multivariate adaptive regression splines to identifying attributes driving liking of this type of product.

1.1.4. Data Sets for Panelist and Panel Performance Evaluation

1.1.4.1. Chocolate Chip Cookies—Simple DA

This experiment dates back to the 1980s. Chocolate chip cookies are a common product across North America. There are clear differences among commercial products that result from the use of real chocolate chips versus compound chips and the proportion of chips in the formula. In recent years, chewy biscuits have been included in this product category. It is easy to find four or five brands that are sufficiently different that a novice panel may be trained in the evaluation of a small number of key attributes in a short period of time, usually under 1 hour. This data set was created in 2002 as part of a training exercise. The attributes were familiar to most potential panelists. In this case, the Excel (Microsoft Corp., Redmond, WA) sheet held responses from 10 panelists for five attributes and five products in a single session. Because this was a training session, the samples were presented monadically in a fixed order.

1.1.4.2. White Wine Descriptive Panel

This data set was part of a major study that has been reported in the literature (Findlay et al., 2006). A total of 20 white wines were evaluated in triplicate by 10 panelists using 76 attributes. For this reduced data set, there are 10 wines, and the 27 attributes are those related to flavor and mouthfeel. The data were collected over nine sessions that provided three replicates. The design was a balanced complete block that was broken across sessions.

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