DIFFERENCES IN SENSORY CHARACTERISTICS AMONG VARIOUS MANGO CULTIVARS IN THE FORM OF FRESH SLICED MANGO, MANGO PURÉE, AND MANGO SORBET

by

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Abstract

Fresh mangoes are highly perishable, and therefore, they are often processed to extend shelf-life and facilitate exportation. Studying the transformation that mango cultivars undergo throughout processing can aid in selecting appropriate varieties for products. In the 1st part of this study, the flavor and texture properties of 4 mango cultivars available in the United States (U.S.) were analyzed. Highly trained descriptive panelists in the U.S. evaluated fresh, purée, and sorbet samples prepared from each cultivar. Purées were made by pulverizing mango flesh, passing it through a china cap, and heating it to 85 °C for 15 s. For the sorbets, purées were diluted with water (1:1), sucrose was added, and the bases were frozen in a batch ice cream freezer. Much of the texture variation among cultivars was lost after fresh samples were transformed into purées, whereas much of the flavor and texture variation among cultivars was lost once fresh mangoes and mango purées were transformed into sorbets. Compared to the other cultivars, Haden and Tommy Atkins underwent greater transformations in flavor throughout sorbet preparation, and processing reduced the intensities of some unpleasant flavors in these cultivars. Tommy Atkins was the only cultivar that had flavor differences from other cultivars when it was in sorbet. Results suggest that cultivar variation is generally not detectable in mango sorbet unless the cultivar has a distinct initial flavor. In the 2nd part of this study, descriptive panelists in Thailand evaluated the flavor and texture properties of fresh samples and purées prepared from 6 cultivars grown in Thailand. Thermal processing had unique effects on the flavor of each cultivar, especially Nam Dok Mai and Chok Anun; Nam Dok Mai significantly decreased in mango identity and peach flavors after processing, whereas Chok Anun significantly increased in sweet, mango identity, and pineapple flavors. Although a slight amount of flavor variation among cultivars was lost because of thermal processing, most of the texture variation was eliminated. Because of significant changes in flavor and texture after heat treatment of mango cultivars, manufacturers should select cultivars for mango purées based on their properties after thermal processing.

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CHAPTER 1 - Literature Review

Mango Production and Distribution

World Mango Production and Distribution

Often called "The King of Fruits," mango (*Mangifera indica* L.) is one of the most popular tropical fruits worldwide. Statistics from 2008 indicate that mangoes comprised almost 40% of global tropical fruit production, which was higher than any other tropical fruit (FAO 2009). World mango production has been steadily increasing, growing at an average rate of 2.6% between 1996 and 2005 (Saúco 2004; Litz 2009) and reaching 31.5 million metric tons worldwide in 2009 (USAID 2010). The number of mango imports has also steadily increased worldwide, rising from 397,623 metric tons in 1996 to 826,584 metric tons in 2005 (Saúco 2004; Litz 2009).

Latin American countries are the primary suppliers of mangoes to North America, whereas Europe imports most of its mangoes from Asia and Latin American countries (Evans 2008). Although the Philippines and Thailand dominate the Southeast Asian mango market, the West Asian mango market is dominated by Pakistan and India (Evans 2008). Table 1.1 lists the top 10 worldwide mango producing and exporting countries that are eligible to ship to the United States (U.S.), showing quantities of mangoes produced and exported in each country in 2006. This table indicates that India and Mexico are leading producers and exporters of mangoes worldwide. China and Indonesia produce large quantities of mangoes but export only a small portion of their production (Table 1.1), and therefore these countries may have the potential to expand their mango exports in the future.

Table 1.1 Top 10 countries* for mango production and exportation.

Mango Production		Mango Exports	
Country	**Quantity†**	**Country**	**Quantity†**
India	13501	India	240.9
China	3715	Mexico	236.0
Mexico	1911	Brazil	116.3
Indonesia	1819	Peru	82.5
Thailand	1800	Netherlands	80.6
Pakistan	1719	Pakistan	62.1
Brazil	1272	Thailand	61.0
Philippines	1024	Ecuador	41.4
Bangladesh	767	Philippines	27.1
Nigeria	734	Guatemala	20.5

*Only countries eligible to ship to the U.S. are listed.
†Statistics from 2006 reported in 1,000 metric tons.
USDA 2010c

A major limitation on the exportation of fresh mango is its short shelf-life. Mangoes are subject to chilling injury during storage, but increasing storage temperatures leads to rapid decay in fruit quality (Mohammed and Brecht 2002; Nair and Singh 2009). Therefore, fresh mango is often processed to facilitate exportation and to preserve the fruit past its season. A number of products made from ripe mangoes are available on the international market, including canned mango, mango purée, mango juice, dried mango, mango leather, and mango jam (Nanjundaswamy 1991; Maneepun and Yunchalad 2004). Mango purée constitutes a large portion of processed mango production with 931,100 metric tons being produced worldwide in 2005 (Neidhart and others 2006). Although the quantity of mango purée exported globally is much less than the quantity of fresh mango exported, mango purée exports have been steadily increasing since the 1990s (USAID 2009) rising from 4,711 metric tons in 1997 to 9,500 metric tons in 2003 (Saúco 2004; Neidhart and others 2006). Mango juice is exported in slightly lower quantities than mango purée with 11,900 metric tons of mango juice being exported in 2003 (Neidhart and others 2006). Because of the growing impact of mangoes on the tropical fruit market worldwide, it is now becoming more important for producers and exporters to understand the factors that affect the demand for mangoes.

Mango Production and Distribution in the U.S. and Thailand

The U.S. is a major importer of mangoes (Evans 2008), and Thailand is a major producer and exporter of mangoes (FAOSTAT 2008; USDA 2010c); thus, each country has a large impact on the global mango market. This research focuses on cultivars available in these 2 countries.

U.S. Market

Most of the mangoes available in the U.S. are imported (Evans 2008) because U.S. production of mangoes for the commercial market is very minimal (Pegg 2011). The U.S. is the world's largest importer of fresh mangoes, accounting for 32.7% of world imports from 2003 to 2005 (Evans 2008). Mango consumption in the U.S. has doubled between 1995 and 2006, increasing from 0.5 kg per capita to 1 kg per capita (USDA 2010d). As a result of growing demand for mangoes, fresh mango imports to the U.S. have increased from 19,595 metric tons in 1980 to 297,466 metric tons in 2008 (USDA 2010b), and imports of mango purée have increased from 4,586 million metric tons in 1999 to 8,231 million metric tons in 2003 (HDC 2004). The number of countries that are able to export mangoes to the U.S. is limited because exporters must pass stringent regulations including regulations on monitoring of fruit flies (Saúco 2004). As of 2010 there are 27 countries eligible to export mangoes to the U.S. (USDA 2010e). The U.S. imports most of its fresh mangoes from Mexico, Brazil, Peru, Ecuador, and Haiti (Evans 2008), and the majority of its mango purée imports come from Latin American countries (HDC 2004). Although imports of mangoes and mango purée in the U.S. are increasing (HDC 2004; USDA 2010b), consumption of mangoes is still limited compared to other fruits (USDA 2010b) and there may be room to expand the market for mangoes in the U.S.

Thai Market

Thailand is a leading producer of mangoes following only India, China, Mexico, and Indonesia for quantity of mangoes produced (Table 1.1). In 2009 Thailand produced nearly 2.5 million metric tons of mangoes (Commodity Profile), and during that same year Thailand exported 49,700 metric tons of fresh, canned, dried, and frozen mangoes. Fresh mango constituted 24,000 metric tons of this quantity (Commodity Profile). Although Thailand is one of the top exporters of mango, only a small percentage of the mangoes grown in Thailand are actually exported. Table 1.1 shows a large discrepancy between Thai mango production and export quantities, which suggests that there is potential for increasing exports in the future.

Thailand exports most of its mangoes to Asian countries (Chomchalow and Songkhla 2008) with its major markets being Japan, Malaysia, Indonesia, Singapore, and Hong Kong, in descending order (Chomchalow and Songkhla 2008). Although Thailand is eligible to export mangoes to the U.S. (USDA 2010c), these exports are minimal; only 11 metric tons of fresh and frozen mangoes were exported from Thailand to the U.S. in 2004, and only 2 metric tons were exported in 2005 (Chomchalow and Songkhla 2008).

Processed mango products, especially mango purée, constitute a large percentage of Thai mango exports (Commodity Profile; Saúco 2004). Thailand was the number 1 worldwide exporter of mango purée almost every year from 1996 to 2006 and was the number 2 exporter every year from 1988 to 1995 (FAOSTAT 2008). Countries that Thailand exports mango purée to include Japan, Australia, England, and Germany, among others (Chomchalow and Songkhla 2008).

Nutritional Aspects

Mangoes are a rich source of vitamin C, vitamin A, and dietary fiber (Manthey and Perkins-Veazie 2009), and they contain vitamins E and K, thiamin, riboflavin, niacin, and folate (USDA 2010f). Studies show that consuming mango can be used as an effective approach to preventing vitamin A deficiency in developing countries (Drammeh and others 2002), and other research indicates that consumption of mango may reduce hypoglycemia symptoms by slowing digestion of starches and diffusion of sugars with its high dietary fiber content (Gourgue and others 1992). Out of a database containing almost 600 fruits and vegetables, mangoes were classified as having a "moderately high antioxidant content" (Carlsen and others 2010) with an estimated total ORAC value of 1,300 μmol TE/100 g (USDA 2010a). High concentrations of polyphenols are also found in mangoes (Gorinstein and others 1999) with the primary phenolic compounds being mangiferin and gallotannin (Mahattanatawee and others 2006). Some polyphenols in food have been found to reduce the risk of cancer (Agarwal and others 2000), stroke (Ness and Powles 1997), and coronary heart diseases (Tijburg and others 1997); therefore, *in vitro* studies have been conducted to examine the health effects of polyphenols in mango. Research indicates that mango juice and polyphenolic extracts from mangoes exhibit anticarcinogenic effects by inducing apoptosis of certain cancer cells without affecting normal cells (Percival and others 2006; Noratto and others 2010). Placing an emphasis on these

numerous health benefits of mangoes may increase demand for mangoes and boost global mango sales.

Mango Cultivars

Over 1,000 varieties of mangoes are available worldwide (Mukherjee 1953). The major cultivars from various mango growing regions are listed in Table 1.2 including cultivars from the 5 major mango producing countries: India, China, Mexico, Indonesia, and Thailand (USDA 2010c).

Table 1.2 Major mango growing regions and cultivars grown in these regions.

Continent	Country	Cultivars
Africa	Cote d'lvoire	Amelie, Kent
	Egypt	Alphonso, Bullock's Heart, Hindi be Sennara, Langra, Mabrouka, Pairie, Taimour, Zebda
	Kenya	Buobo, Ngowe, Batawi
	Mali	Amelie, Kent
	South Africa	Fascell, Haden, Keitt, Kent, Sensation, Tommy Atkins, Zill
Asia	Bangladesh	Aswina, Fazli, Gopal Bhog, Himsagar, Khirsapati, Langra
	China	Gui Fei, Tainong No. 1, Keitt, Sensation, Zill, Zihua, Jin Huang
	India	Alphonso, Banganapalli, Bombay Green, Chausa, Dashehari, Fazli, Fernandian, Himsagar, Kesar, Kishen Bhog, Langra, Mallika, Mankurad, Mulgoa, Neelum, Pairi, Samar Behisht, Suvarnarekha, Totapuri, Vanraj, Zardalu
	Indonesia	Arumanis, Dodol, Gedong, Golek, Madu, Manalagi
	Israel	Haden, Tommy Atkins, Keitt, Maya, Nimrod, Kent, Palmer
	Malaysia	Apple Rumani, Arumanis, Golek, Kuala Selangor 2, Malgoa
	Myanmar	Aug Din, Ma Chit Su, Sein Ta Lone, Shwe Hin Tha
	Pakistan	Anwar Ratol, Began Pali, Chausa, Dashehari, Gulab Khas, Langra, Siroli, Sindhri, Suvarnarekha, Zafran
	The Phillippines	Carabao, Manila Super, Pico
	Taiwan	Irwin, Jin-hwung, Keitt, Tommy Atkins, Tainong No. 1, Tsar-swain

Continent	Country	Cultivars
	Thailand	Nam Dok Mai, Ngar Charn, Ok Rong, Keow Savoey, Pimsen Mum
Australia		Calypso, Kensington Pride
North and Central America	Costa Rica	Haden, Irwin, Keitt, Mora, Tommy Atkins
	Dominican Republic	Haden, Keitt, Kent, Tommy Atkins
	Guatemala	Haden, Keitt, Kent, Tommy Atkins
	Haiti	Francine, Madame Francis
	Mexico	Ataulfo, Haden, Keitt, Kent, Manila, Palmer, Sensation, Tommy Atkins, Van Dyke
	U.S.	Keitt, Kent, Tommy Atkins
South America	Brazil	Bourbon, Coite, Coquinho, Coracao, Espada, Haden, Itamaraca, Keitt, Mamao, Palmer, Rosa, Tommy Atkins, Uba, Van Dyke
	Colombia	Vallenato
	Ecuador	Haden, Keitt, Kent, Tommy Atkins
	Peru	Haden, Keitt, Kent, Tommy Atkins
	Venezuela	Haden, Keitt, Kent, Tommy Atkins

Litz (2009)

With an increasingly international food supply, comparisons among cultivars from different countries can help determine the value and marketability of specific varieties. Studies on mango sales indicate that the market value of mangoes differs greatly based on cultivar type (Sudha and Kruijssen 2008). The current studies focus on the flavor and texture differences among the following varieties available in the U.S. and Thailand: Haden, Kent, Tommy Atkins, Manila, Nam Dok Mai, Kaew Leam Rung, Ok Rong, Nung Klang Won, Chok Anun, and Thongdam.

Flavor and Texture Variation in Cultivars

The composition of ripe mangoes varies greatly among cultivars (Table 1.3), although all mangoes are relatively high in moisture and carbohydrates, especially sugars. Compounds present in mangoes that impact flavor include sugars, organic acids, and volatile compounds (Boonbumrung and others 2001; Vásquez-Caicedo and others 2002; Suwonsichon and others

Personal Communication). Physico-chemical assessments and sensory studies have shown that mango cultivars vary greatly in both measured and perceived flavor and texture (Malundo and others 2001a; Vásquez-Caicedo and others 2002; Araiza and others 2005; Pandit and others 2009; Jha and others 2010; Suwonsichon and others *Personal Communication*), and correlating physico-chemical and sensory data suggests a complex relationship between the composition of mango cultivars and their perceived flavor and texture characteristics (Vásquez-Caicedo and others 2002; Suwonsichon and others *Personal Communication*).

Table 1.3 Composition of ripe mango.

Moisture, %	73.0 to 86.7
Carbohydrate, %	11.6 to 24.3
Protein, %	0.5 to 1.0
Fiber, %	1.1
Lipid, %	0.8 to 1.36
Total sugars, %	8.7 to 17.9
Acidity, %	0.12 to 0.38

Majumder and others (2001)

Physico-chemical and Texture Variation

Physico-chemical measurements commonly used to evaluate flavor variation among mango cultivars include total soluble solids (TSS) measurements to assess sugar content, pH and titratable acidity (TA) measurements to evaluate acidity, and gas chromatography (GC) to measure aromatic composition (Allong and others 2000; Vásquez-Caicedo and others 2004; Pandit and others 2009). The texture of mango flesh is typically assessed by firmness measurements (Chaikiattiyos and others 2000; Araiza and others 2005; Jarimopas and Kitthawee 2007), although texture variation among cultivars has been studied less extensively than physico-chemical variation.

Aromatic Composition

Analysis of volatile compounds present in mangoes and their respective intensities can be distinguished among cultivars. Mango aromatic compounds include a variety of acids, alcohols, ketones, aldehydes, lactones, esters, and hydrocarbons (Singh and others 2004), and researchers have identified more than 285 volatile compounds in various cultivars (Singh and others 2004).

Hydrocarbon monoterpenes and sesquiterpenes are the dominant volatile compounds in most cultivars (Ollé and others 1998; Quijano and others 2007; Pandit and others 2009). Hydrocarbon monoterpenes present in mangoes include pinene, camphene, sabinene, car-3-ene, myrcene, limonene, *p*-cymene, ocimene, terpinolene, β-terpinene, and phellandrene (MacLeod and Snyder 1985; Borg-Karlson and others 1993; Pandit and others 2009). Hydrocarbon sesquiterpenes found in mangoes include β-caryophyllene, humelene, guaiene, β-selinene, δ-cadanine, and germacrene (Pandit and others 2009). The perceived aromas associated with these compounds are listed in Table 1.4. A study by Pandit and others (2009) on 27 mango cultivars indicates that monoterpene hydrocarbons were the primary compounds in most cultivars with the exception of Goamankur, Gopta of Navasari, Makaram, Musharad, Pairi, Sabja, and SB Chausa, which had aromatic compositions dominated by sesquiterpene hydrocarbons. The study suggests a division between cultivars dominated by hydrocarbon monoterpenes and those dominated by sesquiterpene hydrocarbons.

Table 1.4 Concentration of select aroma compounds in various mango cultivars.

Compound	Aroma Quality	Tommy Atkins[g]	Kent[h]	Haden[g]	Manila[g]	Ok Rong[i]	Chok Anun[i]	Nam Dok Mai[i]
Aldehyde								
(*E*)-2-hexenal	green[a]	d	0.2	0.1	t	0.1	1.8	1.3
Monoterpene hydrocarbons								
δ-3-carene	mango leaf-like, sweet, green[b]	10.1	18.0	48.1	15.1	3.8	4.8	d
(*Z*)-β-ocimene	green, spicy[c]	t	1.6	t	0.5	1.4	0.2	11.3
myrcene	fresh, green grass[d]	0.4	1.3	1.1	0.4	0.8	1.8	0.1
limonene	lemon-like[d]	0.1	1.3	2.9	1.5	1.1	1.4	d
α-terpinolene	floral sweet, slightly green mango, sour[b]	0.6	d	3.1	1.1	62.5	62.7	d
α-phellandrene	estery[d]	0.1	d	0.2	0.1	0.1	t	d
α-terpinene	citrus-like[e]	0.1	d	0.4	t	0.3	0.5	d
p-cymene	herbal, minty[d]	0.2	1.4	0.1	0.5	0.1	0.1	d
sabinene	floral, fragrant[d]	d	0.5	d	d	t	0.1	d
camphene	camphor, moth balls[d]	0.1	d	d	d	t	t	d
α-pinene	pine, cedar wood[d]	0.4	0.5	0.6	t	0.5	1.0	d
Sesquiterpene hydrocarbons								
β-caryophyllene	sickly sweet, wallflower[d]	0.2	8.4	1.2	1.2	1.8	0.4	23.6
guaiene	weak woody[e]	t	d	d	d	d	d	0.1
α-humelene	fresh green, floral[d]	0.1	4.3	0.6	0.6	0.2	0.1	1.2
δ-cadanine	woody[e]	0.1	d	0.1	d	t	t	0.1
germacrene	weak spicy, earthy[e]	t	d	t	t	t	d	d
β-selinene	herbal-spicy[f]	t	4.7	t	t	d	0.4	t

Reported in mg/kg; d = not detected; t = trace (< 0.1%)
[a]Qian and Reineccius (2002)
[b]Boonbumrung and others (2001)
[c]Sawamura and others (2006)
[d]MacLeod and Snyder (1985)
[e]Jirovetz and others (2002)
[f]Jirovetz and others (2001)

[g]Quijano and others (2007)
[h]Pandit and others (2009)
[i]Tamura and others (2000)

Most studies use GC to evaluate types and concentrations of aromatic compounds present in mangoes (Boonbumrung and others 2001; Quijano and others 2007; Pandit and others 2009). GC uses an inert gas to move volatile components through a column containing an adsorbent material; this material then separates volatile compounds which are measured by a flame ionization (FID) or thermal conductivity (TCD) detector (Harris 1987). Based on GC analysis of several mango cultivars' aromatic compositions, compounds present in the highest quantities were found to be δ-3-carene, ocimene, β-myrcene, limonene, α-terpinolene, and β-caryophyllene (MacLeod and Snyder 1985; Pandit and others 2009), and the aromas associated with these compounds are listed in Table 1.4.

Table 1.4 also shows the concentrations of select aromatic compounds for 7 of the 10 U.S. and Thai cultivars evaluated in this research. For the 4 U.S. cultivars evaluated in this research (Manila, Tommy Atkins, Haden, and Kent) the primary aromatic compound is δ-3-carene, which has a mango leaf-like, sweet, and green scent (Boonbumrung and others 2001; Quijano and others 2007; Pandit and others 2009). Kent has a high concentration of β-caryophyllene, described as having a sickly sweet, wallflower odor (MacLeod and Snyder 1985; Pandit and others 2009). Manila is high in limonene, contributing a lemon-like scent (MacLeod and Snyder 1985), and Haden has a high concentration of terpinolene, described as having a floral sweet, slightly green mango, and sour scent (Boonbumrung and others 2001; Quijano and others 2007). Researchers have analyzed the volatile compositions for the common Thai varieties evaluated in this research, Nam Dok Mai, Chok Anun, and Ok Rong. The primary aromatic compound in Ok Rong and Nam Dok Mai is terpinolene (Tamura and others 2000), and although Chok Anun also has a high concentration of terpinolene (Tamura and others 2000), its major aromatic compound is ethanol, described as having a sweet alcohol aroma (Tamura and others 2000; Boonbumrung and others 2001).

GC provides complex data, and one way to easily compare the aromatic compositions of different cultivars is to compare total concentrations of volatiles. Although this does not show differences among specific aromas, it indicates which cultivars have higher intensities of scent. A compilation of data for 15 cultivars shows that total volatile concentrations range from 19.8 μg/g for Van Dyke to 2,495 μg/g for Langra (Quijano and others 2007; Pandit and others 2009), suggesting that aroma intensities vary greatly depending on the cultivar. Of the 4 U.S. cultivars evaluated in this research previous studies indicate that Manila has the highest total volatiles

content, Haden has the 2nd highest, Tommy Atkins has the 3rd highest, and Kent has the lowest (Pino and others 2005; Quijano and others 2007).

A less common alternative to GC for measuring volatile composition is using the electronic nose. This device was designed to imitate the human olfactory system, and it uses a series of sensors to detect patterns in aromatic composition (Persaud and Dodd 1982). Unlike GC the electronic nose cannot detect and quantify individual compounds; instead it only detects patterns in overall aromatic composition (Persaud and Dodd 1982). Although the main use of the electronic nose is to monitor fruit maturity level and shelf-life (Lebrun and others 2008; Wilson and Baietto 2009), it can also distinguish among mango varieties; a study by Lebrun and others (2008) indicated that the cultivars Kent and Keitt had different aromatic composition patterns based on electronic nose data.

Olfactometry and determination of threshold intensities are methods that directly relate volatile composition to human perception. For olfactometry a sniff port attached to the GC exposes each volatile compound exiting the column, which human assessors smell and describe (Ulrich and Grosch 1987). Their descriptions provide a detailed picture of how volatile composition affects the aroma of a product, whereas threshold intensities show the minimum concentration of volatiles that can be detected by the human nose. Odor recognition thresholds are based on minimum concentrations that can be recognized and described, whereas odor detection thresholds are based on minimum concentrations that can be detected but not described (Lawless and Heymann 1999). Pairing threshold intensity data with GC data shows which compounds in mango are present at high enough concentrations to be detected.

Studies on odor detection thresholds indicate that only a small percentage of aroma compounds present in mangoes impact perceived aroma (Boonbumrung and others 2001; Pino and Mesa 2006). Boonbumrung and others (2001) used the limited odor unit (Lod) method to determine which compounds in mango significantly influence perceived aroma. In this study, judges assessed the odor detection and recognition thresholds of 80 different compounds present in Keaw mango. Lod values were calculated based on odor thresholds, and mixtures of the top 5, 10, and 15 compounds with the highest Lod values were assessed by sensory panelists. The mixture of the top 15 chemicals was most easily recognized as characteristic of Keaw mango, and the compounds in this mixture are listed in Table 1.5 with their associated Lod values for Kaew mango. In another study on 20 different cultivars, ethyl-2-methylpropanoate, ethyl

butanoate, (*E*,*Z*)-2,6-nonadienal, (*E*)-2-nonenal, methyl benzoate, (*E*)-β-ionone, decanal and 2,5-dimethyl-4-methoxy-3(2*H*)-furanone were determined to be present in mangoes in concentrations sufficiently over their odor detection thresholds to impact mango aroma (Pino and Mesa 2006).

Table 1.5 Aromatic compounds that significantly contribute to the aroma of Kaew mango based on Lod values.

Compound	Aroma Quality	Lod
β-damascenone	sweet, fruity	14.40
terpinolene	floral sweet, slightly green mango, sour	1.39
ethyl hexanoate	fruity	0.67
(*E*,*Z*)-2,6-nonadienal	waxy, fatty, cucumber-like	0.32
2,5-dimethyl-4-methoxy-3(2*H*)-furanone	sweet, candy-like, caramel-like	0.25
(3*R*)-(−)-linalool	floral, woody	0.24
ethyl butyrate	sweet, fragrant, estery	0.15
ethyl octanoate	fruity	0.10
ethanol	sweet alcohol	0.09
(1*S*)-(+)-3-carene	mango leaf-like, sweet, green	0.07
(1*S*,5*S*)-(−)-α-pinene	terpene-like	0.04
trans-linalool oxide	sweet, fruity	0.03
(3*S*)-(+)-linalool	fresh flowery, sweet	0.03
butyric acid	sweat, rancid	0.02
p-methylacetophenone	intense green	0.02

Boonbumrung and others (2001)

Certain fatty acids and amino acids may be precursors to volatile compounds in mango. A study by Gholap and Bandyopadhyay (1975) suggests that the palmitic and palmitoleic acid content of mango influences its aroma; in this study, mangoes that developed stronger aromas throughout ripening had a lower ratio of palmitic to palmitoleic acid at the fully ripe stage. However, it is unknown how the ratio of these fatty acids impacts mango aroma. Some fatty acids in fruit have been found to be converted to ketones, esters, and alcohols during ripening (Tressel and Drawert 1973), and this transformation may occur in mangoes. Studies have shown that fatty acid content in mangoes ranges based on cultivar (Gholap and Bandyopadhyay 1975; Selvaraj and others 1989), and this may lead to the development of different aroma profiles during ripening. Like fatty acids, certain amino acids may be precursors to aromatic compounds in mangoes. Amino acids such as leucine, valine, and phenylalanine have been found to be

converted to volatile compounds during ripening of fruit (Tressl and Drawert 1973), and a study on strawberries suggests that changes in free amino acid levels during ripening may be related to ester biosynthesis (Pérez and others 1992). As in other fruits, amino acids may play a role in generating aromatic compounds in mangoes, and the varying amino acid compositions of mango cultivars (Elahi and Khan 1973) may lead to the development of different aroma profiles. More research is needed on the biosynthesis of aromatic compounds in mango cultivars to understand the influence of fatty acids and amino acids on mango flavor.

Sugar Composition

Sweetness level is a distinguishing physico-chemical property among mango cultivars. A study on 7 Indian cultivars showed that glucose composition ranged from 4.48 to 8.06%, whereas fructose composition ranged from 2.74 to 5.80%, and sucrose composition ranged from 1.55 to 5.13% (Selvaraj and others 1989). The study showed that the glucose to fructose ratio varied significantly among mango cultivars, ranging from 1.03 for Langra to 2.68 for Totapuri. Also, the pattern of change in the glucose to fructose ratio during ripening varied among cultivars; the ratio decreased during ripening for Alphonso, Fazli, Langra, and Totapuri, whereas it increased for Banganapalli, Dasheri, and Suvarnarekha (1989).

Many studies report total soluble solids (TSS) content of mangoes (Khurdiya and Roy 1988; Donadio 1995; Allong and others 2000; Vásquez-Caicedo and others 2004), which estimates the sugar content in foods by measuring the concentration of dissolved solids. Although some studies evaluate the total sugar content of cultivars (Kurdiya and Roy 1988), TSS is more common because it is easier to measure. For ripe mangoes, TSS ranges from 12.0 to 23.0% (Jha and others 2010). Table 1.6 shows TSS data for mango cultivars grown in various regions; varieties with low TSS include the Cuban variety Bullocks Heart and the Egyptian varieties Hindi Bisinnara, and Hindi Khassa, whereas varieties with high TSS include Indian cultivars Langra, Chaunsa, and Mulgoa.

Table 1.6 TSS and TA data for major mango cultivars from various growing regions.

Cultivar	Region	TSS	TA
Alampur Baneshan	India	12.7[a]	0.34[a]
Alfonso	India	20.5[b]	0.40[b]
Alpha	Brazil	16.0[c]	0.23[c]
Amelie	West Africa	13.1[d]	-
Amrapali	India	19.0[e]	0.03[e]
Anmol	India	21.0[b]	0.35[b]
Anwar-retaul	India	24.5[b]	0.32[b]
Ataulfo	Mexico	16.6[f]	0.62[f]
Baganpali	India	23.0[b]	0.50[b]
Bennet Alphonso	India	20.1[a]	0.67[a]
Beta	Brazil	24.8[c]	0.16[c]
Bullocks Heart	Cuba	7.8[g]	-
Burma-surkha	India	20.0[b]	0.30[b]
Carabao	Philippines	19.0[h]	0.30[p]
Chaunsa	India	25.0[b]	0.30[b]
Cherukkurasam	India	13.1[a]	0.73[a]
Chinnarasam	India	24.0[a]	0.21[a]
Chittor	India	14.5[a]	0.73[a]
Chok Anun	Thailand	12.8[i]	0.32[m]
Dashehari	India	23.0[e]	0.14[e]
Dusehri	India	24.7[b]	0.31[b]
Ewais	Egypt	10.4[g]	-
Fajri	Pakistan	21.0[b]	0.40[b]
Ghulabkhas	Pakistan	22.8[b]	0.60[b]
Glenn	Florida	17.0[j]	0.10[j]
Graham	Florida	15.7[k]	0.56[k]
Haden	Florida	17.4[j]	0.83[q]
Himayuddin	India	18.5[a]	0.28[a]
Hindi Bisinnara	Egypt	9.6[g]	-
Hindi Khassa	Egypt	8.0[g]	-
Irwin	Florida	14.1[j]	0.16[j]
Julie	West Indies	15.1[k]	0.50[k]
Kalapady	India	24.7[a]	0.94[a]
Keitt	Florida	21.4[b]	0.40[b]
Kensington	Australia	20.5[b]	0.62[b]
Kent	Florida	18.9[l]	0.45[l]
Kiew Sawoei	Thailand	17.0[i]	0.16[m]
Langra	India	26.0[b]	0.34[b]

Cultivar	Region	TSS	TA
Maha Chanok	Thailand	16.7[m]	0.35[m]
Malda	Pakistan	18.0[b]	0.32[b]
Mallika	India	24.0[e]	0.10[e]
M'Bingue	West Africa	16.6[d]	-
Momi-K	Pakistan	22.3[b]	0.60[b]
Mon Duen Gao	Thailand	14.8[i]	0.16[m]
Mulgoa	India	25.2[a]	0.52[a]
Mundappa	India	18.5[a]	0.37[a]
Nam Dok Mai	Thailand	17.0[i]	0.32[m]
Neelum	India	20.0[b]	0.55[b]
Okrong Kiew	Thailand	15.6[m]	0.30[m]
Okrong Thong	Thailand	18.7[m]	0.16[m]
Osteen	Florida	15.0[n]	-
Palmer	Florida	17.2[d]	-
Phirangiladuva	India	22.0[a]	0.33[a]
Pimsen	Thailand	13.6[o]	0.36[o]
Pope	Florida	21.0[b]	0.65[b]
Prior	India	17.7[a]	0.32[a]
Rad	Thailand	14.4[o]	0.35[o]
Saleh-bhai	Pakistan	20.5[b]	0.33[b]
Sanglakhi	India	21.0[b]	0.35[b]
Sensation	Florida	19.5[b]	0.40[b]
Shahpasand	India	22.0[b]	0.30[b]
Sindhri	Pakistan	19.0[b]	0.40[b]
Spring-fels	Florida	21.8[b]	0.48[b]
Suvarnarekha	India	16.7[a]	0.60[a]
Swarnareeka	Pakistan	23.2[b]	0.68[b]
Tete de Chat	West Africa	16.3[d]	-
Tommy Atkins	Florida	13.6[j]	0.54[q]
Totapuri	India	20.8[b]	0.36[b]
Van Dyke	Florida	18.2[j]	0.22[j]
Yakta	Pakistan	20.5[b]	0.55[b]
Zafran	Pakistan	24.0[b]	0.50[b]
Zard-alu	India	20.5[b]	0.35[b]
Zil	South Africa	19.5[b]	0.52[b]

[a]Pradeepkumar and others (2006)
[b]Syed (2009)
[c]Litz (2009)
[d]Ollé and others (1996)
[e]Khurdiya and Roy (1988)

[f]Montalvo and others (2007)
[g]Shaban and Ibrahim (2009)
[h]Siriphanich (2002)
[i]Suwonsichon and others (*Personal Communication*)
[j]Donadio (1995)
[k]Allong and others (2000)
[l]Avena and Luh (1983)
[m]Vásquez-Caicedo and others (2004)
[n]Araiza and others (2005)
[o]Maneepun and Yunchalad (2004)
[q]Bender and others (2000)
[p]Kitma and Esguerra (2009)

Acidity

Acidity is another major source of physico-chemical variation among mango cultivars. Many studies report the ratio of sugar to acid for providing an indication of ripeness and flavor (Selvaraj and others 1989; Ollé and others 1996; Vásquez-Caicedo and others 2002). As mangoes ripen acidity decreases and soluble sugars increase in concentration, showing a significant rise in the sugar to acid ratio (Selvaraj and others 1989). The sugar to acid ratio has been found to be a good indicator of perceived sweetness and sourness, and in a study on 9 Thai cultivars the ratio ranged from 47.6 to 114.1 (Vásquez-Caicedo and others 2002).

Citric acid is the primary organic acid in most mango cultivars (Selvaraj and others 1989). A study on 7 different cultivars showed that citric acid composition ranged from 80.4 to 123.0 % mg, malic acid composition ranged from 23.4 to 49.5 % mg, and the ratio of citric to malic acid ranged from 1.67 to 3.02 (Selvaraj and others 1989). Several studies report titratable acidity (TA) and pH of mango varieties (Allong and others 2000; Vásquez-Caicedo and others 2004). TA is measured by titrating acid in a solution with a strong base, whereas pH measures hydrogen ion activity in a solution using an ion-selective electrode. For ripe mangoes, literature reports that acidity ranges from 0.12 to 0.38% TA (Jha and others 2010). A study on 9 Thai mango cultivars showed that the pH ranged from 3.98 to 5.08 (Vásquez-Caicedo and others 2002), and a study on 6 Indian cultivars showed that the pH ranged from 4.15 to 4.86 (Gowda and Huddar 2004). Table 1.6 lists TA values for various cultivars grown in different regions; varieties with low TA include the Floridian cultivar Glenn and the Indian cultivars Amrapali and Mallika, whereas varieties with high TA include the Floridian variety Haden and the Indian varieties Cherukkurasam, Chittor, and Kalapady.

Texture

Most studies on mango texture report firmness of the flesh, and the most common instrumental measurements to assess firmness are compression and hardness tests (Yoneya and others 1990; Valente and Ferrandis 2003; Vásquez-Caicedo and others 2004). To determine the firmness of whole mangoes with the peel still on, studies have measured force to rupture, stiffness, and toughness (Valente and Ferrandis 2003; Moreno and others 2006). A study conducted on 6 Indian varieties showed that firmness ranged from 14.75 lb/in^2 for Alphonso to 20.50 lb/in^2 for Totapuri (Gowda and Huddar 2004). Firmness reduction during ripening has also

been found to vary among cultivars (Araiza and others 2005; Jarimopas and Kitthawee 2007). Using a penetrometer to measure firmness, Araiza and others (2005) determined that Ataulfo, Gouveia, and Osteen softened faster than Tommy Atkins and Kent, whereas Jarimopas and Kitthawee (2007) used compression and impact tests to show that Chok Anun became firmer than Nam Dok Mai throughout ripening, although softening rates were similar for both cultivars.

Studies have related mango firmness to the activity of enzymes pectinesterase (PE), polygalacturonase (PG), and β-galactosidase (Aina and Oladunjoye 1993; Ali and others 1995; Ketsa and others 1998). PG and β-galactosidase have been found to decrease firmness of fruits and vegetables (Serrano and others 2002; Smith and others 2002), whereas PE has been found to increase firmness (Alonso and others 1995; Villarreal-Alba and others 2004). Studies on ripening mangoes indicate that throughout the ripening process PE activity decreases and PG and β-galactosidase activity increases (Aina and Oladunjoye 1993; Ali and others 1995; Ketsa and others 1998). These changes occur subsequently with increasing pectin solubility and decreasing firmness, which suggests that the activities of these enzymes are linked with the softening of mangoes during ripening (Ketsa and others 1998).

In addition to firmness, fibrousness is a texture property that varies based on cultivar. Most studies on mango fiber content use a method published by the Association of Official Analytical Chemists (AOAC) that applies a combination of enzymatic and gravimetric methods to analyze total dietary fiber content (Vásquez-Caicedo and others 2004; Mahattanatawee and others 2006). A study on 8 Egyptian mango varieties showed that the dietary fiber composition ranged from 2.03% for Alphonso to 5.97% for Langra (Zaied and others 2007).

Differences in Sensory Properties among Mango Cultivars

Sensory analysis, as opposed to physico-chemical analysis, can be used to analyze the perceptible properties of mangoes. Two types of sensory analysis are used in detecting differences among cultivars: 1) descriptive analysis in which trained panelists describe and rate intensities of attributes perceived in a product, and 2) consumer testing, which evaluates consumer preferences and opinions. Descriptive studies provide detailed information on the flavor and texture properties of mango cultivars, whereas consumer studies on mango show preferences for certain cultivars.

Descriptive Analysis

Few studies use descriptive analysis to evaluate differences among fresh ripe mangoes of various cultivars. Malundo and others (1996b) developed a language to describe mango flavor, aroma, and chemical feeling attributes, and using this language differences among mango cultivars were evaluated (Malundo and others 2001a). In another study Vásquez-Caicedo and others (2002) used terms to describe basic tastes, aroma, feeling factors, aftertaste, and texture of mango cultivars. Suwonsichon and others (*Personal Communication*) later expanded the mango lexicon using flavor, texture, and chemical feeling attributes to analyze cultivars. Table 1.7 compiles the terminology used in past descriptive studies on mangoes.

Table 1.7 Descriptive terms used in defining mango flavor and texture attributes.

Reference	Flavor	Aroma	Texture	Aftertaste
Malundo and others (1996b); Malundo and others (2001a); Malundo and others (2001b)	Sweet Sour Bitter	Peachy Pine/turpentine Sweet potato Banana Grassy Orange peel Overripe grape* Green banana*	Astringent Biting	
Vásquez-Caicedo and others (2002)	Sweet Sour Bitter	Mango impact	Astringent Firm Juicy Chewy	Sour Sweet Astringent Bitter
Della Modesta and others (2004)	Mango flavor Sweet taste Unripe flavor Artificial flavor Fermented flavor Overcooked	Mango aroma Cooked aroma Sweet aroma Unripe aroma Fermented aroma	Consistency	
Suwonsichon and others (*Personal Communication*)	Chemical Overall sweet Overall sour Bitter Starchy Mango identity		Firmness Cohesiveness of mass Slimy Slickness Mealy	

Reference	Flavor	Aroma	Texture	Aftertaste
	Fruity		Astringent	
	Peaches		Grainy/Gritty	
	Pineapple		Fibers	
	Oranges		Seeds	
	Fermented		Pulpy residue	
	Floral/Perfumy			
	Piney			
	Viney			
	Peel-like			
	Spicy			
	Woody			
	Green			
	Animalic			

*Attributes were not studied in Malundo and others 1996b or Malundo and others 2001b.

Malundo and others (2001a) studied mangoes of the Tommy Atkins and Van Dyke varieties, listing 11 attributes to describe mango flavor and 2 attributes to describe chemical feeling factors (Table 1.7). Of 11 flavor attributes, sweet flavor had the widest intensity range among cultivars, and biting, sour, and peachy also varied greatly among varieties. The attributes for bitter, pine/turpentine, grassy, orange peel, and green banana flavors were not significantly different ($P < 0.05$) from each other, and panelists confused bitter and green banana attributes (Malundo and others 2001a). In future studies, researchers should eliminate or better define confusing terms, and terms that are indistinguishable from one another should be removed.

In a study by Vásquez-Caicedo and others (2002) 9 Thai cultivars were evaluated using 12 terms total to describe basic tastes, aroma, feeling factors, aftertaste, and texture (Table 1.7). Okrong Kiew was highest in sour taste and lowest in sweet taste, whereas Chok Anun was highest in firmness and chewiness. Chok Anun and Rad were perceived to be the most fibrous cultivars.

Suwonsichon and others (*Personal Communication*) expanded the mango lexicon (Table 1.7) using 19 flavor attributes and 10 texture attributes to describe 9 Thai mango cultivars consumed either in the green or ripe form. By expanding the number of terms to describe mango flavor and texture, this research can assist in making more specific distinctions among cultivars in the future. Suwonsichon and others (*Personal Communication*) found that Nam Dok Mai was

highest in mango identity, fruity, and sweet attributes, whereas Ok Rong had distinct chemical, peel-like, sour, and bitter flavors. Khiaosawoey, Raet, Nam Dok Mai, and Ok Rong had higher intensities of peach and floral/perfumy attributes than Falan, Phetbanraj, Nongsaeng, Chok Anun, and Mun Duean Kao. At certain stages of ripeness, Chok Anun and Nam Dok Mai had a spicy note, and Khiaosawoey, Raet, Mun Duean Kao, and Ok Rong had an orange note and high intensities of piney flavor.

Table 1.7 lists descriptive language used by Della Modesta and others (2004) to evaluate fresh and commercial mango juices. The study generated 12 terms to describe mango juice flavor and texture. Although the attributes overcooked flavor, overcooked aroma, consistency, and artificial flavor apply specifically to mango juice, other attributes can be used to describe fresh mango. All of these studies aid in developing terminology to describe perceptible flavor and texture attributes in mangoes, which can be used in determining differences among cultivars.

Relating Descriptive and Instrumental Data

Relating descriptive and instrumental data shows how the compositions of various mango cultivars affect their perceived properties. Some studies use olfactometry to describe the aromas of volatile compounds in mango detected by GC (MacLeod and Snyder 1985; Boonbumrung and others 2001), and descriptors for select aromatic compounds in mango cultivars are listed in Table 1.4. One study relates mango fiber content to descriptive evaluation of texture properties by analyzing correlations between fiber content of mangoes and the texture attributes firm and juicy (Vásquez-Caicedo and others 2002). Results indicate that firmness had a strong positive correlation of 0.82 with % fiber, whereas juiciness had a strong negative correlation of -0.87 with % fiber. This data suggests that mangoes with higher fiber content tend to be more firm and less juicy.

Other studies compare physico-chemical data to descriptive data for sweetness and sourness of mangoes (Malundo and others 2001b; Vásquez-Caicedo and others 2002; Suwonsichon and others *Personal Communication*). A study by Suwonsichon and others (*Personal Communication*) compared descriptive data on perceived sweetness and sourness intensities to TSS and pH measurements for 9 Thai cultivars. Fig 1.1 graphs the relationship between TSS and sweetness intensity for the cultivars at varying ripeness stages. As TSS increased, sweetness intensity did not increase consistently. The correlation between TSS content and sweet intensity is positive (0.60), but the correlation is somewhat weak. These results

suggest that although cultivars with higher sugar content tend to taste sweeter, there may be factors other than sugar composition that influence sweetness. One of these factors may be the suppression of sweetness by bitter compounds (Calvino and others 1990).

Figure 1.1 Relationship between sweetness intensity using descriptive analysis and TSS measurement for 9 Thai mango cultivars at varying ripeness stages. Samples are organized from lowest TSS content to highest. Source: Suwonsichon and others (*Personal Communication*).

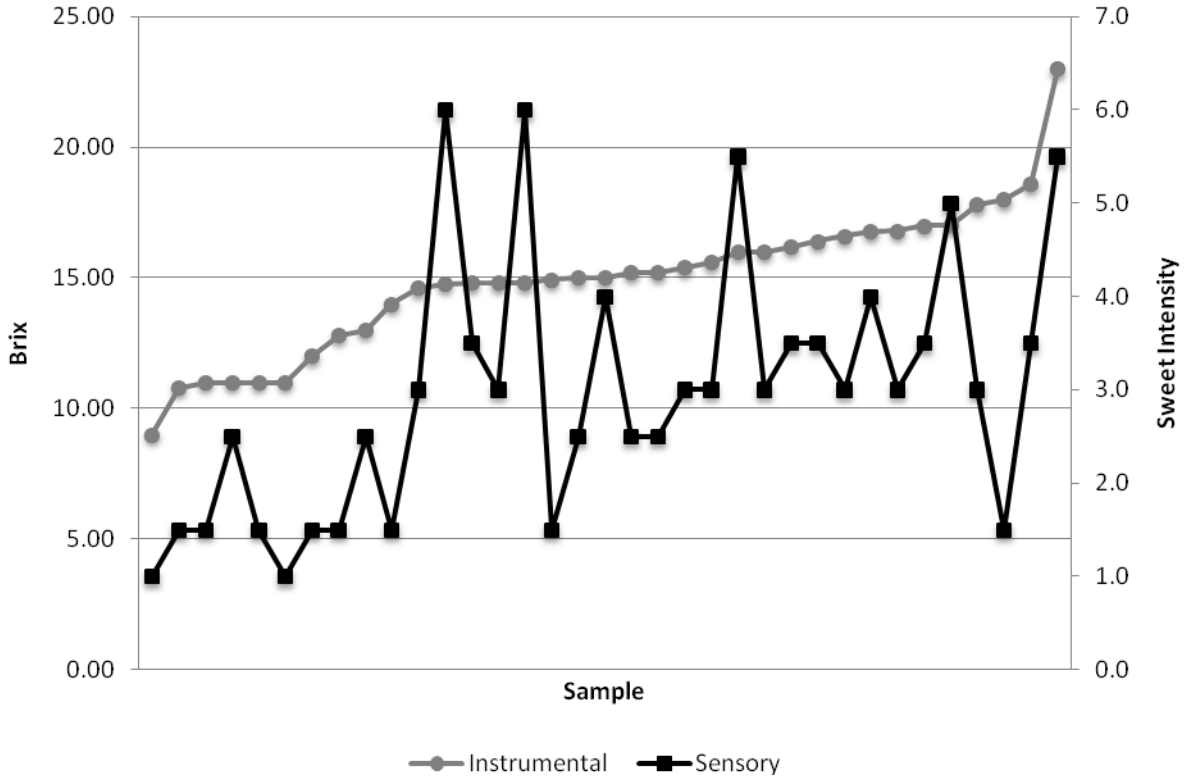
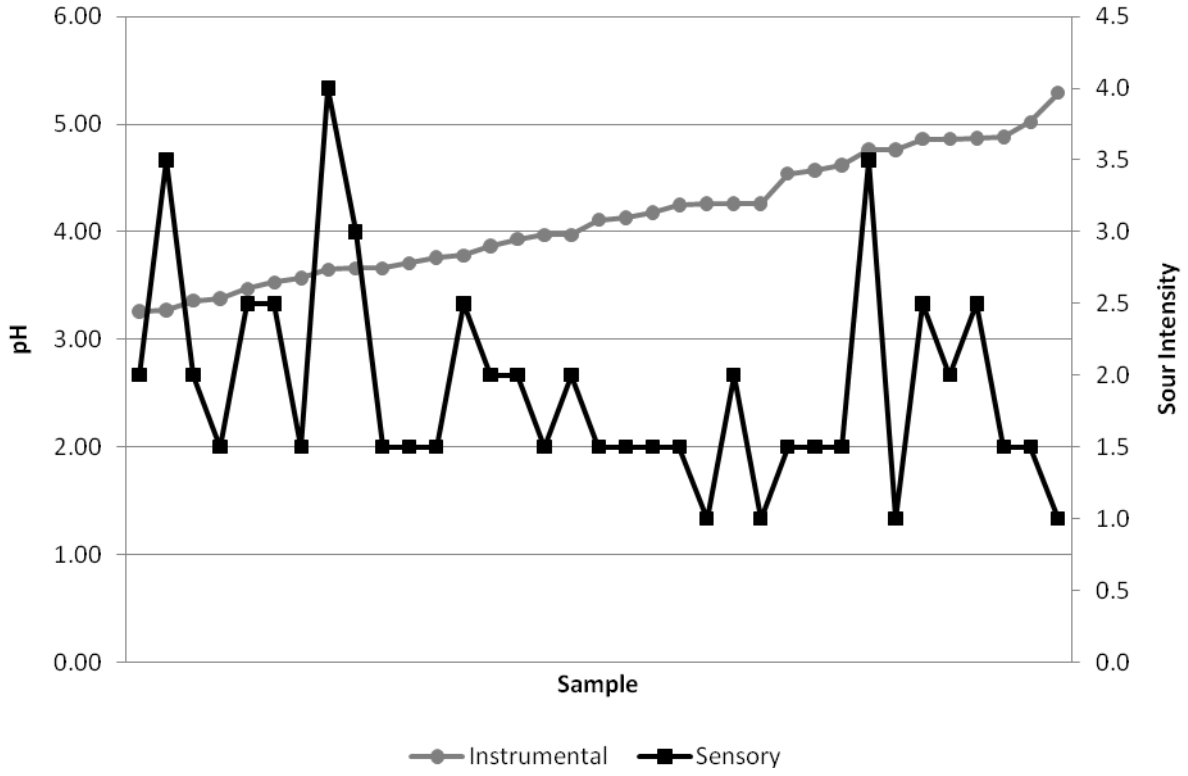


Fig 1.2 graphs the relationship between pH and sour intensity for the same samples. As pH increases sour intensity does not decrease consistently, and although the correlation between pH and sourness is negative (-0.29) as expected, it is a relatively weak correlation. These results suggest that cultivars with lower acidity levels are not always perceived to be sourer, which may result from varying levels of sucrose suppressing the perceived intensity of the primary acid in mangoes, citric acid (McBride and Johnson 1987; Selvaraj and others 1989; McBride and Finlay 1990).

Figure 1.2 Relationship between sour intensity using descriptive analysis and pH measurement for 9 Thai mango cultivars at varying ripeness stages. Samples are organized from lowest pH to highest. Source: Suwonsichon and others (*Personal Communication*).



A study by Vásquez-Caicedo and others (2002) also compared sweetness and sourness sensory evaluations with physico-chemical data. This study evaluated 9 Thai cultivars (Chok Anun, Nam Dok Mai #4, Rad, Mon Duen Gao, Kiew Sawoei, Okrong Kiew, Okrong Thong, Kaew, and Maha Chanok). Results indicate significant correlations between sour intensity and the following: pH (-0.84), TA (0.86), TSS:TA ratio (-0.85), and citric acid content (0.84); however, sour intensity was not significantly correlated with malic acid content as expected. Sweetness intensity was correlated with TSS:TA ratio (0.84), citric acid content (-0.76), and malic acid content (0.77) but was not significantly correlated with sucrose content as expected. Although sourness and sweetness intensities were relatively consistent with their associated physico-chemical measurements, results suggest that the sugar to acid ratio may be a better indicator of perceived sweetness and sourness than acidity and sugar content measurements

alone. This difference may result from acidity counterbalancing perceived sweetness (McBride and Johnson 1987; McBride and Finlay 1990).

Malundo and others (2001b) also studied the effect of acid and sugar levels on the flavor of mangoes. Using terms listed in Table 1.7 descriptive panelists evaluated Tommy Atkins purées with the addition of varying citric acid, sugar, and water concentrations. Results from regression analysis indicate that acid levels affected the intensities of sweet, sour, peachy, pine, astringent, and biting attributes, whereas sugar levels affected all attributes intensities with the exception of sour taste. Based on correlation analysis, increasing acidity led to higher intensities of the attributes sour, bitter, orange peel, astringent, and biting and led to lower intensities of sweet, sweet potato, and banana attributes. Sugar level was positively correlated with the attributes sweet, peachy, sweet potato, and banana and negatively correlated with bitter, pine/turpentine, and grassy. In opposition to results from a previous study (Vásquez-Caicedo and others 2002) the TSS:TA ratio was not significantly related to sweetness; however, the ratio was negatively correlated with sourness, which was consistent with previous research (Vásquez-Caicedo's study 2002).

The studies by Malundo and others (2001b), Vásquez-Caicedo and others (2002), and Suwonsichon and others (*Personal Communication*) show that sugar and acid compositions of mangoes generally relate to perceived sweetness and sourness, although there are some inconsistencies. These results suggest that factors other than sugar and acid content alone affect the perception of mango sweetness and acidity.

Consumer Studies

Consumer studies are useful in predicting the demand for mangoes and for specific mango cultivars. Preference tests show consumer liking of mangoes, and pairing consumer and descriptive data helps determine which attributes influence liking. Difference tests, on the other hand, help differentiate cultivars with perceptibly distinctive attributes.

A study on Spanish consumers shows that they preferred mango over banana and peach, but they preferred melon over mango (Calatrava and others 2000). During the 6 years in which data was collected consumer preference remained relatively consistent. Another consumer study reveals that Spanish consumer preference varied based on mango cultivar; out of 13 different cultivars, consumers preferred Carmen, Irwin, Osteen, Lippens, and Keitt, whereas low acceptability ratings were given to Sensation (Calatrava and others 1996). Consumer studies

were conducted to compare the acceptability of the cultivars Dusahri, Chaunsa, Ratol, and Langra, showing that Ratol rated highest and Langra rated lowest for flavor and taste (Akhtar and others 2009). Langra was also low in overall acceptability, whereas Chaunsa, Dusahri, and Ratol did not significantly differ in overall acceptability from each other (2009). Acceptability studies such as these aid in predicting the demand for specific mango varieties.

By relating consumer and descriptive data Malundo and others (2001a) developed a model to determine which flavor attributes influenced probability of purchase of the cultivars Tommy Atkins and Van Dyke. Certain terms like astringent and biting could be expressed as linear functions of the other attributes in the model, and therefore, these terms were dropped from the model. Results showed that only peachy, grassy, and green banana attributes influenced preference for specific varieties. Grassy positively influenced consumer perception, while peachy and green banana negatively influenced perception (2001a). Relating consumer studies to descriptive analysis in this way provides useful information in predicting the acceptability of mango varieties by understanding the drivers behind consumer preferences.

Although sweetness and sourness are distinguishing descriptive properties among mango cultivars, studies have not shown a clear relationship between consumer preferences for mango cultivars and sweetness or sourness intensities. In a 1996 study, U.S. consumers were found to prefer sweeter mango varieties (Malundo 1996a), but in a later study no significant relationship between sweetness and consumer preference was found (Malundo and others 2001a). A more recent study showed that Pakistani consumers preferred the least sweet variety (Faiz Kareem) out of the cultivars Faiz Kareem, Anwar Ratole, and Chaunsa (Rajwana and others 2010). Studies evaluating the taste factors that influence consumer preference for mango cultivars have not shown a significant relationship between sourness and consumer preference (Malundo and others 2001a; Rajwana and others 2010). It is unknown whether these unclear relationships between consumer preferences and sweetness and sourness levels result from varying consumer opinions or from a greater impact of other flavor and texture properties on the preference for mangoes.

Other studies have used difference testing to identify mango cultivars with perceptibly different properties. One study indicates that the Corazón variety significantly differed in aroma from 19 other cultivars studied, which may result from its high concentration of volatile compounds (Pino and others 2005). In another study Tommy Atkins, Haden, and Kent cultivars sliced and processed in sucrose syrup did not vary in color, aroma, taste, or texture (Lima and

others 2004). Difference tests like these show which cultivars are indistinguishable in flavor or texture, providing manufacturers and producers with more options when selecting mango varieties for their target markets.

Mango Processing

Effects of processing on mangoes include changes in the physico-chemical, nutritional, and sensory properties (Malundo and others 1996b; Vásquez-Caicedo and others 2007). Studying the effects of heat treatment on the flavor of mango can help establish appropriate processing methods, and it can also aid in determining various uses and markets for processed mango products.

Mango Purée

Effective heat treatment of mango purée minimizes color changes and the degradation of nutritional quality (Vásquez-Caicedo and others 2007). Mango purée should be heated enough to reduce peroxidase (POD) and polyphenyl oxidase activity (PPO), which contribute to enzymatic browning (Vásquez-Caicedo and others 2004). However, if the purée is subjected to excessive heat, carotenoid degradation causes a loss of orange color (Vásquez-Caicedo and others 2007). Heating mango purée to 85°C for 15 s has been found to inactivate enzymes while maintaining sensory quality (Isaacs 1991).

Only 1 study has evaluated the effect of thermal processing on the descriptive properties of mango. In this study diluted fresh mango purée was compared to diluted mango purée processed for 2 h in an evaporator at 40 °C (Malundo and others 1996b). Using attributes listed in Table 1.7 panelists found that the intensities of sweet, peachy, sweet potato, and banana attributes were lower after thermal treatment, whereas the intensities of sour, bitter, and orange peel were higher after processing. Some of these changes in flavor may be attributed to the degradation or loss of volatile compounds during processing (Kimura and others 1994; Malundo and others 1996b; Yen and Lin 1999). The processing methods used in this study were designed to concentrate volatile compounds through evaporation at low temperatures, and therefore these methods differed from typical thermal treatment methods to produce mango purée, which use higher temperatures (85 to 95 °C) to treat mango (Isaacs 1991; Malundo and others 1996b). Further research should be conducted to evaluate the effects of heat processing on the perceived flavor of mango during the production of purées.

One study evaluated the properties of thermally processed mango purées prepared from 6 Indian cultivars. Sensory ratings for the acceptability of color, consistency, taste, and flavor of the purées varied based on cultivar; the values for these measurements are provided in Table 1.8. Totapuri purée rated lowest in acceptability for color and taste, but it rated highest for consistency. Scores for taste and flavor were highest for Alphonso purée, whereas Banganapali rated lowest for consistency and flavor. Amrapali had the highest scores for color. These results suggest that preferences for mango purées depend on the cultivar used, although the effects of mango purée texture and chemical composition on consumer preferences are still unclear.

Table 1.8 Acceptability of canned mango pulp prepared from 6 different Indian cultivars.

Cultivar	Color (0 to 25)	Consistency (0 to 25)	Taste (0 to 25)	Flavor (0 to 25)
Alphonso	20.70	19.50	20.10	20.00
Banganapali	14.30	14.20	17.00	14.90
Neelum	15.20	16.70	17.30	13.90
Mallika	17.00	20.70	16.40	12.20
Amrapali	22.80	16.70	19.60	18.60
Totapuri	14.10	22.40	15.90	15.10

Gowda and Huddar (2004)

Mango Sorbet

One application for mango purée is the production of sorbet. Mango is one of the most popular sorbet flavors in the U.S.; a poll by Epicurious in 2010 showed that mango was the most preferred sorbet flavor out of 10 fruits, receiving 52% of votes (Santos-Neves). There is a large market for frozen desserts in the U.S., and statistics indicate that U.S. frozen dessert sales increased 2% in 2009, reaching $25 billion at approximately 18.1 L per capita (Packaged Facts 2010; IDFA 2011). In 2009 about 4.92 L per capita of low-fat and non-fat frozen desserts were sold (IDFA 2011). Sherbet, ices, and frozen yogurt fall within the low-fat and non-fat frozen desserts category (IDFA 2011), and they are defined by the Code of Federal Regulations (CFR 2010a; CFR 2010b). However, sorbet does not yet have a standard of identity; it is very similar to sherbet but does not contain dairy ingredients (Marshall and others 2003).

Sorbet started to gain popularity in the U.S. between 1994 and 1996, and since then, the sale of sorbet has greatly increased (Shih 2005). It is dairy-free and typically fat-free, making it a

healthier alternative to ice cream (Stogo 1998). Sorbet is a frozen dessert containing a mixture of fruit purée, sugar, and water that is frozen churned to incorporate air into it (Migoya 2008). It has a low overrun of 20% or less (Arbuckle 1986). Table 1.9 displays the typical composition of fruit sorbets. The relatively high sugar content of sorbets prevents large ice crystals from forming, therefore giving sorbet a smooth texture (Migoya 2008). Citric acid may be added to enhance flavor (Marshall and others 2003), and stabilizers are often added to sorbets to inhibit crystal formation, prevent separation during storage, and reduce melting rates (Hong and Nip 1990; Higawara and Hartel 1996; Marshall and others 2003). Common stabilizers include egg white solids (2.6% total weight), pectin, or gum stabilizer (0.4% total weight) (Marshall and others 2003). Sensory studies on the effect of stabilizers show that they can increase hedonic scores for texture and overall acceptability without influencing flavor or appearance (Minhas and others 1997; Moeenfard and Therani 2008).

Table 1.9 Composition of sorbet.

Ingredient	Minimum	Maximum
Fruit purée (sweet fruit)	40% total weight	60% total weight
Fruit purée or juice (acidic fruit)	25% total weight	40% total weight
Dry extracts (fruit solids plus sugar and powdered glucose)	31%	36%
Stabilizer (if used)	0%	1% total weight
Percentage of sugar (or Brix)	25% (or 25° Brix)	32% (or 32° Brix)

Migoya (2008)

The texture of mango sorbet and ice cream differs from products made using other fruits. A study on ice cream samples produced in the U.S. and Italy evaluated differences among the descriptive properties of fruit flavored samples (Thompson and others 2009). Mango ice cream and gelato samples were relatively low in iciness and seed awareness. Most of the Italian samples containing fruit had low intensities for mouthcoating and fat feel attributes with the exception of mango, coconut, and banana. This may indicate that mango has a naturally rich and thick texture giving mango sorbet or mango ice cream the impression of fat feel and mouthcoating even in the absence of dairy.

The properties of fruit used in sorbets can affect the quality of the final product. A study on selecting suitable strawberry varieties for processing into sorbet showed that varying the

cultivar affected the quality and sensory properties of the sorbet because it changed the texture, flavor, and appearance (Avitabile-Leva and others 2006). The effect of cultivar variation on the properties of mango sorbet has not yet been studied.

Although sorbet is a popular dessert in the U.S., very little research is published on this topic. No published research exists on evaluating the descriptive properties of mango sorbet; this information would be useful, however, in helping manufacturers determine the ideal composition and properties of mango sorbet. Studying the effects of cultivar variation on mango sorbet flavor and texture would help manufacturers select the best cultivar for their product.

Conclusions

The market for fresh and processed mangoes is growing worldwide, and it is becoming increasingly important for mango producers and exporters to understand how mangoes differ from cultivar to cultivar. Studying these differences is a key step in predicting the demand for specific varieties. Although fresh mangoes dominate the world mango market, exports of mango purée are increasing worldwide, and studying the effects of processing fresh mangoes into mango purée can help determine ideal processing methods and various uses for mango purée. In addition, information about the effects of cultivar variation on the properties of mango purée can assist manufacturers in selecting varieties that will be successful in their target markets. One application for mango purée is mango sorbet, which has become a popular flavor for sorbet in the U.S. Further research on the flavor and texture properties of mango sorbet can provide manufacturers with information useful in creating a high-quality product, and researching cultivar effects on the properties of mango sorbet can assist manufacturers in selecting appropriate varieties.

A number of factors, i.e., aromatic composition, sweetness, sourness, and firmness, affect the flavor and texture properties of mango, creating a complex eating experience for consumers. Descriptive analysis is an effective way of measuring how the flavor and texture attributes of mango are perceived. Few studies have used descriptive analysis to differentiate various mango cultivars or to evaluate the effects of processing on the descriptive properties of mango. Further research on these topics is needed to better understand cultivar effects and processing effects on the properties of mango.

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CHAPTER 2 - Materials and Methods

Section 1– Changes in the Sensory Characteristics of Mango Cultivars during the Production of Mango Purée and Sorbet

Samples

Four cultivars of mangoes imported from Mexico into the U.S. (Haden, Kent, Manila, and Tommy Atkins) were supplied by Splendid Products, Burlingame, CA. These cultivars were selected because they are commonly imported to the U.S., with Tommy Atkins being the most commonly imported variety. Undamaged, ripe fruit were selected using conventional ripeness indices (soft to touch and yellowish green or yellowish red skin). Mangoes were stored at room temperature (24 ± 1 °C) until used, and they were processed within 7 d of shipping at the ripe stage.

Preparation of Purées

To evaluate the impact of thermal processing on the sensory properties of each mango cultivar, heat-treated mango purées were prepared. Individual batches of purée were made for 3 replications of each cultivar. For each batch, 4 to 6 mangoes of a single cultivar were manually peeled, and the flesh was cut from the seeds. The flesh (925 g) was combined and puréed for 3 min using an immersion blender (WSB33; Waring Products, Torrington, Conn., U.S.A.), which was then passed through a china cap with a 2.5 mm mesh size (Model CCCS-8C; Winco Industries Co., Lodi, N.J., U.S.A.) to remove large particles and create a homogenous purée. Processing methods were based on previous studies on mango purée (Gowda and Huddar 2004; Vásquez-Caicedo and others 2007).

The purée was heated rapidly in a saucepan (1.89 L; Magnalite, World Kitchen LLC, Greencastle, Pa., U.S.A.) on an electric stove (4 burner; Whirlpool, Benton Harbor, Mich., U.S.A.), with constant stirring, until it remained at 85 °C for 15 s. A study by Isaacs (1991) evaluated the quality of aseptic mango purée treated at various temperatures and holding times, and results indicated that heating mango purée to 85 °C for 15 s was sufficient to inactivate enzymes, kill microorganisms, and maintain quality parameters (color, flavor, consistency, pH,

TSS, % acid, ascorbic acid) even after 8 mo of ambient storage. Results from a study by Dougherty (1971) suggest that mango purée should be heated and cooled rapidly to inactivate enzymes and maintain quality.

After heating, each batch of mango purée was cooled immediately to 35 °C using an ice bath. Purées were packaged with a vacuum sealer (Model VS107; Seal-a-Meal®, Jarden Corp., Rye, N.Y., U.S.A.) and frozen (Jamison Built Doors, Hagerstown, Md., U.S.A.) (-17 °C) until needed. Purées were used within 2 wk of preparation. Based on a study conducted by MacLeod and Snyder (1988), freezing of mangoes has little effect on their volatile composition. The study that showed mango slices stored for 14 mo at -15 °C had very similar aromatic compositions to those of fresh mango slices.

Preparation of Sorbets

Sorbets were prepared using each mango cultivar, and individual batches were made for 3 replications of each sample. Separate batches of heat-treated purée were prepared for each sorbet batch, and the purées were refrigerated (True Manufacturing Co., St. Louis, Mo., U.S.A.) (3.5 °C) and used within 5 d of preparation. To prepare a single batch of sorbet, 350 mL of heat-treated purée was combined with 350 mL of distilled water. The proportion of purée to water was based on the typical range for fruit purée composition in sorbets, which is 40 to 60% by weight (Migoya 2008). A refractometer (Model Palette PR101α; Atago U.S.A., Inc., Bellevue, Wash., U.S.A.) was used to measure TSS, and the appropriate amount of sugar was added to increase TSS to 32 ± 2 °Brix. According to Migoya (2008), 32 °Brix is the upper limit of the typical range for sorbets (Migoya 2008). Having a sufficient amount of sugar prevents large ice crystals from forming and creates a smooth texture (Migoya 2008).

The sweetened purées were vacuum-sealed and refrigerated (3.5 °C) overnight. They were frozen churned the next day in a batch-type ice cream freezer (Model Lello Pola 5030; Lello, Musso, Italy) and were placed in a storage freezer (Jamison Built Doors, Hagerstown, Md., U.S.A.) (-17 °C) overnight. Sorbets were used within 10 d of preparation to avoid large ice crystal formation.

Instrumental Measurements

To compare the acidity and approximate sugar content of each cultivar at each processing stage, TSS and pH measurements were taken. TSS and pH were measured for all fresh mango samples the day of serving. To prepare fresh mango samples for measurement, flesh remaining after serving was passed through a china cap with a 2.5 mm mesh size (Model CCCS-8C; Winco Industries Co., Lodi, N.J., U.S.A.). Measurements were taken for TSS and pH of all purée samples after heat-treatment on the day of serving, and measurements were taken for the sorbet bases immediately after they were prepared. All measurements were performed on samples at room temperature (24 ± 1 °C). TSS was measured in °Brix with a refractometer (Model Palette PR101α; Atago U.S.A., Inc., Bellevue, Wash., U.S.A.), and pH was measured by a digital pH meter (Model Accument Portable AB 15; Thermo Fisher Scientific®, Waltham, Mass., U.S.A.).

Orientation and Lexicon Development

Analysis was conducted by 6 highly-trained descriptive panelists at the Kansas State University Sensory Analysis Center in Manhattan, KS. The sensory testing facility had controlled temperature, lighting, and humidity. Each panelist completed a 120-h general training course on descriptive sensory testing and had about 2,000 h of testing experience with a variety of food products.

Prior to testing, 3 orientation sessions of 1.5 h were held. During orientation, panelists evaluated fresh sliced mango, mango purée, and mango sorbet made from each mango cultivar to develop terminology describing the flavor and texture properties of these samples. They were provided with flavor and texture attributes from a previous study on fresh mangoes as a starting point (Suwonsichon and others, *Personal Communication*). Several of the texture terms from this study were not applicable to mango sorbet, and therefore, terminology from a study by Thompson and others (2009) describing the texture of ice cream was also presented to the panelists.

Panelists evaluated each sample independently and identified all perceived flavor and texture attributes. The panel subsequently discussed all terms, clarifying confusing ones and removing repetitive ones. A final list of flavor and texture terms for each product type (fresh, purée, and sorbet) was compiled during orientation. Attributes were organized by grouping similar ones and by placing predominant attributes higher on the list. During orientation panelists

also developed detailed definitions for each attribute using definitions included in previous studies as a starting point (Thompson and others 2009; Suwonsichon and others, *Personal Communication*). They also established consistent evaluation procedures and discussed appropriate serving sizes and serving procedures.

During orientation panelists selected appropriate references for each attribute and assigned intensities to each reference. To ensure that panelists were scoring in the same way, the panelists practiced evaluating samples for testing, and they subsequently discussed how attribute intensities were scored. Panelists who were inconsistent with others in their scaling altered the way in which they scored attribute intensities. By the end of orientation all terms and definitions on the lexicon were clarified and all evaluation procedures were established.

The final lexicon for fresh sliced mango included 30 flavor attributes and 8 texture attributes. The lexicon for mango purée included 31 flavor attributes and 9 texture attributes, and the lexicon used for testing sorbets included 28 flavor attributes and 11 texture attributes. Table 2.1 lists all attributes, definitions, and references used for testing. Aside from the addition of the term cooked to the mango purée and sorbet lexicons, the flavor attributes were the same for all lexicons. The texture terms chalky mouthfeel, slimy, slickness, fiber awareness, and pulpy residue were used to describe the texture of fresh mango, mango purée, and mango sorbet. The terms firmness, particles, and cohesiveness of mass were only used to describe the texture of fresh mango, whereas the terms thickness and mealy were only included in the mango purée lexicon. Viscosity and mouthcoating were used to describe the texture of purées and sorbets, whereas density, meltdown, and iciness were used only to describe the texture of sorbets.

Table 2.1 Terms, definitions, and references used in evaluating fresh sliced mango, mango purée, and mango sorbet flavor and texture.

Attribute	Definition	References
Flavor		
Mango Identity	A sweet, fruity, green, somewhat woody and piney aromatic associated with mango that sometimes may include aromatics similar to other specific fruits, such as peach, orange, grapefruit, and/or pineapple.	Jumex Mango Nectar = 6.5 Reese Sliced Mango in Mango Juice = 7.5
Fruity	An aroma blend which is sweet and reminiscent of a variety of different fruits. When possible, specific fruits were described.	Trans-2-Hexenal (10,000 ppm) = 5.0
Grapefruit	A natural, sour, slightly sweet, fruity, somewhat musty, woody, pungent, citrus-like aromatic associated with grapefruit.	Grapefruit Essential Oil (Aura Cacia) = 6.0
Orange	A natural, sweet, fruity, floral, slightly sour and citrus-like aromatic associated with oranges.	Majestic Mountain Sage Orange Valencia Essential Oil = 6.5 Majestic Mountain Sage Orange 5-Fold Essential Oil = 8.5
Peach	Aromatic associated with ripe peach which includes floral, perfumy, sweet, sometimes woody and green notes, and can have a hint of fermented note.	Fresh Peach Pit = 8.0
Pineapple	A sweet, woody, slightly sharp, floral aromatic associated with pineapple.	Diluted Dole Canned Pineapple Juice (1:1) = 6.0
Cooked[‡]	An aromatic impression associated with a cooked fruit rather than fresh, uncooked fruit.	Jumex Mango Nectar = 6.0 Reese Sliced Mango in Mango Juice = 7.0
Animalic	Aromatic associated with sulfur compounds which exhibit skunk-like characteristic commonly associated with decaying animals.	Tincture of Civet = 6.0
Black Pepper	Spicy, pungent, musty, and woody aromatic characteristic of ground black pepper.	McCormick Ground Black Pepper = 13.0

Attribute	Definition	References
Caramelized	A round, full bodied, medium brown aromatic.	C&H golden Brown Sugar = 9.0
Clove	A pungent, brown spicy aromatic.	LorAnne Gourmet Clove Leaf Oil= 12.0
Chemical	A general term associated with many different types of compounds generally known as chemicals.	Borneol (10,000 ppm) = 2.5
Cumin	A musty, brown, sweet, slightly pungent aromatic.	McCormick Ground Cumin = 13.0
Green	Slightly sour aromatic commonly associated with under-ripe fruit.	Green Granny Smith = 7.0
Green-viney	Green, fresh aromatic associated with newly cut vines and stems. It sometimes relates to cucumber.	2-Isobutylthiazole (Givaudan; 10,000 ppm) = 9.0
Fermented	A combination of aromatics that are sweet, slightly brown, overripe and somewhat sour.	Blackberry WONF 3RA654 = 7.0
Floral/Perfumy	A sweet, heavy aromatic blend of a combination of flowers which can be somewhat chemical and perfume-like.	Geraniol (IFF; 10,000 ppm) = 7.5
Musty	An aromatic that has a damp, earthy character similar to fresh mushrooms.	Sliced White Mushroom = 10.5
Peel-like	A slightly sharp aromatic that can be described as slightly sour and bitter. It is commonly associated with citrus peel.	Lime peel = 13.0
Piney	A slightly sharp resinous aromatic that may be medicinal or chemical in character. It is associated with green pine needles or pine pitch.	Isobornyl propionate (IFF; 10,000 ppm) = 6.5
Spicy	A sweet brown, slightly musty aromatic reminiscent of cinnamon.	McCormick Ground Allspice = 9.5

Attribute	Definition	References
Starchy	A bland, cooked vegetable-like aromatic associated with the meat of a baked sweet potato or squash.	Baked Sweet potato = 8.0
Vegetable (yellow squash-like)	Sweet, musty, earthy aroma characteristic of yellow squash.	Gerber Squash Baby Food = 7.5
Woody	Flat, dark, dry, musty aromatics associated with the bark of a tree.	Oil of Cedar Wood (Aldrich; 10,000 ppm) = 6.0
Overall Sweet	Aromatics and flavor notes associated with the impression of all sweet substances.	Lorna Doone Cookie = 4.5 6% C&H Brown Sugar in water = 9.0
Overall Sour	Aromatics and flavor notes associated with the impression of all sour substances.	Highland Sour Cream = 4.5
Sweet	The fundamental taste sensation of which sucrose is typical.	2% Sucrose Solution = 2.0 4% Sucrose Solution = 4.0 6% Sucrose Solution = 6.0
Bitter	The fundamental taste sensation of which caffeine or quinine are typical.	0.02% Caffeine Solution = 3.5
Sour	The fundamental taste sensation of which citric acid is typical.	0.015% Citric Acid Solution = 1.5 0.050% Citric Acid Solution = 3.5
Metallic	The chemical feeling factor on the tongue described as flat, associated with iron, copper, and silver spoons rated after spoon has been removed.	0.10% Potassium Chloride Solution = 1.5
Astringent	The complex of drying, puckering, shrinking sensations in the oral cavity.	0.05% Alum Solution = 2.5 0.1% Alum Solution = 5.0

Attribute	Definition	References
Texture		
Chalky Mouthfeel	A dry, powdery sensation in the mouth.	10 g Argo cornstarch in 1,000 mL water = 3.0 Highland Sour Cream = 10.0
Slimy	Degree to which a thick, mucous-like substance is perceived in the mouth during mastication.	Kroger Frozen Cut Okra = 13.0
Slickness	Ease with which a product slides around in the mouth during mastication (2.46 mL of product).	Kraft Miracle Whip Light = 7.5
Fiber Awareness	The degree to which fibers are present. Evaluated during mastication after 5 to 8 chews (excludes skin).	Private Selection Frozen Whole Strawberries = 2.0
Pulpy Residue	A soft moist residue.	Del Monte Lite Peaches = 2.0
Cohesiveness of Mass*	Degree to which the mass holds together after 7 chews.	Oscar Mayer Wieners = 6.5 Sweet potato = 9.0
Particles*	The amount of small pieces of sample remaining in mouth just after swallowing. This does not incorporate toothpacking and refers only to particulate matter on mouth surface other than in and between the molar teeth. Evaluate 3 pieces at a time.	Cheerios = 3.0
Firmness*	The force required to compress the sample between the tongue and palate.	Highland Sour Cream = 5.5 Philadelphia Light Cream Cheese (tub) = 7.0 Philadelphia Cream Cheese (tub) = 10.0 Philadelphia Cream Cheese (block) = 14.0
Thickness**	A measure of the consistency of a product when manipulating a sample on the roof of the mouth with the tongue.	Diluted Contadina Tomato Paste (1:1) = 7.5† Contadina Tomato Paste = 14.0†
Mealy**	The perception of fine, soft particles distributed within the product.	Gerber Applesauce Stage 1 = 2.0

Attribute	Definition	References
		Musselman's Natural Applesauce = 14.0
Viscosity‡	The measure of flow as the product moves on the tongue when pressed between the tongue and the palate (2.46 mL).	Gerber Applesauce Stage 1 = 9.0** Musselman's Natural Applesauce = 11.0** Dillon's 1/2 and 1/2 = 2.0† Dillon's Whipping Cream = 4.0†
Mouthcoating‡	A sensation of having a slick coating on the tongue and other mouth surfaces (2.46 mL swallowed after 3 manipulations).	Dillon's Whipping Cream = 8.0
Density†	The degree of compactness of a sample when pressed between the tongue and palate.	Kraft Marshmallow Fluff = 5.0 Dillon's Sour Cream = 9.5
Meltdown†	The time required for the product to melt in the mouth when continuously pressed by the tongue against the palate. The number of seconds counted equals the numerical score (1/1,000 count). Sample size is 1.64 mL.	
Iciness†	The immediate perception of crystal-like particles within the sample. This measurement is taken immediately after sample has been placed in the mouth. The crystals often dissolve quickly at 1st manipulation. Sample size is 1.64 mL of icy portion.	Haagen Dazs Mango Sorbet that has been through a thaw-refreeze cycle = 7.5

*Only applies to fresh mango.
**Only applies to mango purée.
†Only applies to mango sorbet.
‡Only applies to mango purée and sorbet.

Test Design and Sample Evaluation

Panelists tested fresh sliced mango, mango purée, and mango sorbet made from each of the mango cultivars, evaluating 3 replications of each sample (3 types X 4 cultivars X 3 replications).

To prepare fresh sliced mangoes for serving, each mango was peeled, and the flesh was cut off of either side of the seed. Each half was cut into 4 pieces (2 middle and 2 edge pieces), and the flesh left on either edge of the seed was cut into 2 pieces. Panelists received 6 pieces for each evaluation. To provide panelists with samples representative of various portions of the mango, each serving included at least 1 middle piece, 1 edge piece, and 1 side piece randomly selected from different fruits. Pieces were selected from each fruit to minimize bias due to differences among individual mangoes. Flesh remaining after sample preparation was saved for TSS and pH measurements. Fresh mango samples were served directly after cutting in 226.8 mL Styrofoam bowls with lids (Dart Container Corp., Mason, Mich., U.S.A.).

Frozen mango purée samples were thawed in the refrigerator (3.5 °C) overnight and were served at room temperature (24 ± 1 °C). Panelists received 44.4 mL of each purée sample upon evaluation in covered 92.1 mL plastic cups (Sweetheart Cup Co. Inc., Owing Mills, Md., U.S.A.).

Sorbets were served at -10 °C (Marshall 2003) in 113.4 mL Styrofoam bowls (Dart Container Corp., Mason, Mich., U.S.A.). All samples were portioned out ahead of time in serving containers and were removed from the freezer on the day of testing. To maintain the correct sample temperature, panelists were served 2 sets of 40.0 g samples for each replication during testing. They evaluated the flavor of the 1st sample and the texture of the 2nd sample.

A randomized complete block design was used to determine the sample serving order. Samples were randomized within replications for each panelist and were served monadic sequentially. All serving containers were labeled with 3-digit random codes to avoid labeling bias. Testing was conducted over a period of 6 d, and the test design is listed in Appendix A. Panelists rated the intensities of each flavor and texture attribute established during orientation using a hybrid method adapted from the Flavor Profile Method (Keane 1992). They used a 15-point numerical scale with 0.5 increments. Scores on the scale correspond with the following intensities: 0.0 = none, 0.5 to 5.0 = slight, 5.5 to 10.0 = moderate, and 10.5 to 15.0 = high.

Panelists recorded their scores using Compusense® Commuter 2.0 (2005; Compusense Inc., Guelph, Ontario, Canada), and they also used paper ballots in case electronic scores were entered incorrectly or data was lost. Samples of the paper ballots are given in Appendix B. References were provided for each attribute to anchor values on the intensity scale, and samples of the definition and reference sheets given to the panelists during testing are provided in Appendix C. Unsalted crackers (Nabisco Premium Saltine Unsalted Top Crackers; Kraft Foods Inc., East Hanover, N.J., U.S.A.), mozzarella cheese (Low Moisture Part Skim Mozzarella; Kroger Co., Cincinnati, Ohio, U.S.A.), and reverse osmosis, deionized, carbon-filtered water were served as palate cleansers between samples. Expectoration during testing was permitted.

Data Analysis

One-way Analysis of Variance (ANOVA) was performed to compare intensities of flavor and texture properties across the various stages of processing (fresh, purée, and sorbet) for each cultivar. One-way ANOVA was conducted because there were significant interactions between processing stage and cultivar for several attributes. TSS and pH values were also compared across all samples, and these physico-chemical measurements were related with sensory data for sweetness and sourness. All ANOVAs conducted in this study used the MIXED procedure at the 95% confidence level, and means were separated by Fisher's Least Significant Difference (LSD). SAS® (version 9.2; SAS Institute Inc., Cary, N.C., U.S.A.) was used to perform ANOVA, and the SAS codes are provided in Appendix D. Principal component analysis (PCA) (Unscrambler, 2008, version 9.8; Camo A/S, Oslo, Norway) using the correlation matrix was performed to evaluate relationships among fresh mango, mango purée, and mango sorbet prepared from the 4 cultivars based on their flavor attributes.

Section 2 – Comparison of Sensory Attributes in Fresh Mangoes and Heat-treated Mango Purées Prepared from Thai Cultivars

Mango Samples

Six cultivars of Thai mangoes (Chok Anun, Kaew Leam Rung, Nam Dok Mai, Nung Klang Won, Ok Rong, and Thongdam) were purchased at Janted Farm in Prachuap Khiri Khan, Thailand. Chok Anun, Nam Dok Mai, Ok Rong, and Thongdam are common varieties in Thailand. Keaw Leam Rung is popular in southern Thailand, and Nung Klang Won is typically exported. All testing for the Thai cultivars was conducted in Thailand. The mangoes were ripened at room temperature (24 ± 1 °C), and they were used or processed within 4 d after ripening. Undamaged, ripe fruit were selected based on conventional ripeness indices (soft to touch and appropriately colored skin for a given cultivar). All mangoes were stored at room temperature until used (24 ± 1 °C).

Preparation of Purée

To evaluate the impact of processing on the sensory properties of mango cultivars, individual batches of heat-treated mango purée were prepared for 3 replications of each cultivar. Processing methods were consistent with methods used in a previous study by Ledeker and others (2011 *In Preparation*). For a single batch of purée, mangoes of a specific cultivar were manually peeled, and the flesh was cut from the seeds. The flesh (925.0 g) was puréed for 3 min with an immersion blender (Model HR1372/90; Philips U.S.A., Andover, Mass.), and the untreated purée was passed through a china cap with a 2.5 mm mesh size (Model CCCS-8C; Winco Industries Co., Lodi, N.J., U.S.A.) to remove large particles and create a homogenous purée. A sample of the purée at this stage was set aside for total soluble solids (TSS) and pH measurements. The remaining purée was heated with constant stirring in a saucepan (1.89 L; Magnalite, World Kitchen LLC, Greencastle, Pa., U.S.A.) on a gas stove (4 burner; Tecnogas, Singapore) until it remained at 85 °C for 15 s.

After heating, purées were cooled immediately to 35 °C using an ice bath, and they were placed in multipurpose plastic bags (3.79 L; Ziploc®, S. C. Johnson & Son, Inc., Racine, Wis., U.S.A.). Purées were used within 1 wk of preparation and were placed in a storage freezer (Rivacold, Montecchio, Italy) (-18 °C) until needed. Samples were placed in plastic bags rather

than being vacuum sealed as in the previous study by Ledeker and others (2011 *In Preparation*) because they were used soon after they were prepared.

Instrumental Measurements

TSS and pH measurements were taken to assess the acidity and approximate sugar content of all cultivars at the fresh stage and after processing into purée. TSS and pH were measured for all purée samples before heat-treatment on the day of preparation and after heat-treatment on the day of serving. In addition, measurements were taken on all fresh mango samples the day of serving. To prepare fresh mango samples for measurement, flesh remaining after serving was passed through a china cap with a 2.5 mm mesh size (Model CCCS-8C; Winco Industries Co., Lodi, N.J., U.S.A.).

For all samples, TSS was measured in °Brix using a digital refractometer (Model Palette PR101α; Atago U.S.A., Inc., Bellevue, Wash., U.S.A.), and pH was taken using a digital pH meter (Model CyberScan pH 510; Eutech Instruments Pte. Ltd., Singapore). Samples were evaluated at room temperature (24 ± 1 °C) for all TSS and pH measurements.

Sample Preparation and Serving

Panelists evaluated freshly sliced mangoes and mango purées prepared from each cultivar. Methods from the study by Ledeker and others (2011 *In Preparation*) were used in the current study for the preparation of all samples. To prepare fresh sliced samples for evaluation, mangoes from a single cultivar were peeled, and the flesh was cut off of either side of the seeds. Each mango half was cut into 4 pieces (2 middle and 2 edge pieces), and the flesh left on either edge of the seed was cut into 2 pieces. Panelists received 6 pieces for each evaluation. To provide panelists with samples representative of various portions of the mango, each serving included at least 1 middle piece, 1 edge piece, and 1 side piece randomly selected from different fruits. Pieces were selected from each fruit to minimize bias due to differences among individual mangoes. Flesh remaining after sample preparation was saved for TSS and pH measurements. Fresh mango samples were served in 100 mL plastic bowls with lids (Eastern Polypack Co., Ltd., Bangkok, Thailand) which were labeled with 3-digit random codes to avoid labeling bias.

Frozen mango purée samples were thawed in the refrigerator (3.5 °C) overnight and were served at room temperature (24 ± 1 °C). All cups were labeled with 3-digit random codes.

Panelists received 44.4 mL of each purée served in 85.0 mL plastic cups (Eastern Polypack Co., Ltd., Bangkok, Thailand) upon evaluation.

Orientation and Lexicon Development

Analysis was conducted by 7 highly-trained descriptive panelists at the Kasetsart University's Sensory and Consumer Research Center in Bangkok, Thailand. All panelists completed a 120-h training course and had more than 1,700 h of testing experience with a variety of food products.

Prior to testing, 3 d of orientation were held to familiarize the panelists with fresh sliced mango and mango purée samples prepared from each cultivar. Panelists were initially provided with lexicons on fresh mango and mango purée from a previous study by Ledeker and others (2011 *In Preparation*) to aid in terminology development. They 1st evaluated fresh sliced mango samples by independently tasting them and identifying all perceived flavor and texture attributes. Possible terms to add to the fresh mango lexicon were discussed, confusing terms were clarified, and attributes included in the lexicon that were not found in the samples were removed. Panelists compiled a final list of flavor and texture terms for testing. Attributes were organized by grouping similar ones and by placing predominant ones higher on the list. After developing a lexicon for fresh mango, panelists followed the same procedure to generate a lexicon for mango purée.

During orientation sessions panelists also developed definitions and selected references for each attribute included in the lexicons. As a starting point, they were provided with definitions and references established in the study by Ledeker and others (2011 *In Preparation*). Panelists were given several references brought from the U.S. that were used in the previous study (Ledeker and others, 2011 *In Preparation*); however, they selected references for new attributes and changed some existing references to more appropriate ones. For example, the aroma of chemical references brought from the U.S. for the terms fruity and floral/perfumy had faded during transportation, and therefore, panelists selected alternative references.

During orientation consistent evaluation procedures were discussed as well as appropriate serving sizes and serving procedures. Panelists selected references for each attribute and assigned intensities to each reference. They then practiced evaluating samples to ensure that everyone was scoring in the same way. If panelists were inconsistent with others in their scaling,

the panel discussed how to achieve consistency among everyone. By the end of orientation, all terms and definitions on the lexicons were clarified and all evaluation methods were established.

Many of the same terms were used to describe fresh and puréed samples, and with the exception of a few attributes, the lexicons used for testing in the current study were consistent with the study by Ledeker and others (2011 *In Preparation*). Panelists did not detect any animalic, black pepper, clove, cumin or woody flavors in the Thai cultivars, and these attributes were removed from the lexicons used in the previous study (2011 *In Preparation*). The terms guava and sulfur were added to the lexicon, whereas the texture term thickness was removed because the panelists found thickness to be too similar to viscosity. Panelists also added tongue burn and throat irritation to the fresh mango lexicon. The final lexicon used for testing fresh mangoes in the present study included 28 flavor attributes and 7 texture attributes, whereas the lexicon for mango purée included 28 flavor attributes and 8 texture attributes. Table 2.2 lists all attributes, definitions, and references used for testing.

Table 2.2 Terms, definitions, and references used in evaluating flavor and texture of freshly sliced mango and mango purée.

Attribute	Definition	References
Flavor		
Mango Identity มะม่วง	A sweet, fruity, green, somewhat woody and piney aromatic associated with mango that sometimes may include aromatics similar to other specific fruits, such as peach, orange, grapefruit, and/or pineapple. กลิ่นรสเฉพาะตัวของมะม่วง	Jumex Mango Nectar = 6.5 Reese Sliced Mango in Mango Juice = 7.5
Fruity ผลไม้	An aroma blend which is sweet and reminiscent of a variety of different fruits. When possible, specific fruits were described. กลิ่นรสที่ผสมผสานกันของความหอมหวาน ซึ่งทำให้ระลึกถึงผลไม้ต่างๆ ถ้าเป็นไปได้ให้ระบุชนิดของผลไม้ด้วย	Heinz Smooth Summer Fruit Gel = 6.0
Grapefruit เกรปฟรุต	A natural, sour, slightly sweet, fruity, somewhat musty, woody, pungent, citrus-like aromatic associated with grapefruit. กลิ่นรสเฉพาะตัวของเกรปฟรุต	Grapefruit Essential Oil (Aura Cacia) = 6.0
Guava** ฝรั่ง	A green, sweet aromatic associated with ripe guava. กลิ่นเขียว หวาน ซึ่งสัมพันธ์กับกลิ่นฝรั่งสุก	Guava Juice (Tipco) = 6.0
Orange ส้ม	A natural, sweet, fruity, floral, slightly sour and citrus-like aromatic associated with oranges. กลิ่นรสเฉพาะตัวของส้ม	Majestic Mountain Sage Orange Valencia Essential Oil = 6.5 Majestic Mountain Sage Orange 5-Fold Essential Oil = 8.5
Peach พีช	Aromatic associated with ripe peach which includes floral, perfumy, sweet, sometimes woody and green notes, and can have a hint of fermented note. กลิ่นรสเฉพาะตัวของพีชที่สุกแล้ว	Fresh Peach Pit = 8.0

Attribute	Definition	References
Pineapple สับปะรด	A sweet, woody, slightly sharp, floral aromatic associated with pineapple. กลิ่นรสเฉพาะตัวของสับปะรด	Diluted Dole Canned Pineapple Juice (1:1) = 6.0
Caramelized น้ำตาลเคี่ยว	A round, full bodied, medium brown aromatic. กลิ่นรสของน้ำตาลที่เคี่ยวด้วยความร้อนจนเปลี่ยนเป็นสีน้ำตาลทอง	C&H golden Brown Sugar = 9.0
Chemical เคมี	A general term associated with many different types of compounds generally known as chemicals. กลิ่นรสที่ให้ความรู้สึกเสมือนมีสารเคมี	Borneol (10,000 ppm) = 2.5
Cooked** สุกผ่านความร้อน	An aromatic impression associated with a cooked fruit rather than fresh, uncooked fruit. กลิ่นรสของผลไม้ที่ผ่านความร้อน	Jumex Mango Nectar = 6.0 Reese Sliced Mango in Mango Juice = 7.0
Green เขียว (ดิบ)	Slightly sour aromatic commonly associated with under-ripe fruit. กลิ่นรสเฉพาะของผลไม้ที่ยังไม่สุก ซึ่งมีกลิ่นเปรี้ยวเล็กน้อยและให้ความรู้สึกว่าฝาด	Green Granny Smith = 7.0
Green-viney เขียวสด	Green, fresh aromatic associated with newly cut vines and stems. It sometimes relates to cucumber. กลิ่นรสเขียวแบบสดชื่นของเถาวัลย์หรือกิ่งไม้ที่ตัดใหม่ๆ บางครั้งมีกลิ่นคล้ายกับกลิ่นของแตงกวา	2-Isobutylthiazole (Givaudan; 10,000 ppm) = 9.0
Fermented หมัก	A combination of aromatics that are sweet, slightly brown, overripe, and somewhat sour. กลิ่นรสที่ผสมผสานกันของกลิ่นรสหวาน สุกงอม	Blackberry WONF 3RA654 = 7.0

Attribute	Definition	References
	อาจเจือกลิ่นรสเปรี้ยว	
Floral/Perfumy ดอกไม้/น้ำหอม	A sweet, heavy aromatic blend of a combination of flowers which can be somewhat chemical and perfume-like. กลิ่นหอมรุนแรงของดอกไม้นานาพันธุ์ ซึ่งอาจคล้ายกลิ่นสารเคมีบางชนิดหรือกลิ่นน้ำหอม	Jasmine Flavor (Winner's) = 4.5
Musty อับชื้น	An aromatic that has a damp, earthy character similar to fresh mushrooms. กลิ่นอับชื้นหรือกลิ่นดินชื้นคล้ายกับกลิ่นของเห็ดสด	Sliced White Mushroom = 10.5 Geosmin (20 ppm) = 12.0
Peel-like เหมือนเปลือก	A slightly sharp aromatic that can be described as slightly sour and bitter. It is commonly associated with citrus peel. กลิ่นรสเปรี้ยวเล็กน้อยและขมของเปลือก โดยทั่วไปเป็นเปลือกของผลไม้สกุลส้ม	Lime peel = 13.0
Piney ยางสน	A slightly sharp resinous aromatic that may be medicinal or chemical in character. It is associated with green pine needles or pine pitch. กลิ่นรสของยางสนจากใบสนหรือลำต้นสน ซึ่งอาจมีกลิ่นคล้ายยาหรือสารเคมี	Isobornyl propionate (IFF; 10,000 ppm) = 6.5
Spicy เครื่องเทศ	A sweet brown, slightly musty aromatic reminiscent of cinnamon. กลิ่นรสหอมของเครื่องเทศอย่างอบเชย	McCormick Ground Allspice = 9.5
Starchy แป้ง	A bland, cooked vegetable-like aromatic associated with the meat of a baked sweet potato or squash. กลิ่นรสอ่อนๆ ของผักที่ทำให้สุกด้วยความร้อน อย่างกลิ่นของเนื้อมันฝรั่งอบหรือผักจำพวกแตงหรือน้ำเต้า	Baked Sweet potato = 8.0

Attribute	Definition	References
Sulfur ซัลเฟอร์	A slightly sweet acrid, pungent, harsh irritating aromatic reminiscent of matches, cap guns, gun powder, and Durian. กลิ่นฉุน แสบจมูก คล้ายกลิ่นที่เกิดขึ้นขณะจุดไม้ขีดไฟ และพบได้ในไข่ต้ม ทุเรียนสุกงอม	Durian Flavor (Winner's) in water = 6.5
Vegetable (yellow squash-like) ผัก (คล้ายสคอชสีเหลือง)	Sweet, musty, earthy aroma characteristic of yellow squash. กลิ่นเฉพาะของสคอชสีเหลืองซึ่งมีลักษณะหอมหวานและอับชื้น	Gerber Squash Baby Food = 7.5
Overall Sweet หวานโดยรวม	Aromatics and flavor notes associated with the impression of all sweet substances. กลิ่นรสที่ให้ความรู้สึกหวานหอม	Lorna Doone Cookie = 4.5 6% C&H Brown Sugar in water = 9.0
Overall Sour เปรี้ยวโดยรวม	Aromatics and flavor notes associated with the impression of all sour substances. กลิ่นรสที่ให้ความรู้สึกเปรี้ยว	Highland Sour Cream = 4.5 Heinz White Vinegar in water (1:8 dilution) = 8.0
Fundamental Tastes Sweet หวาน	The fundamental taste sensation of which sucrose is typical. การรับรู้รสพื้นฐานของลิ้นเมื่อถูกกระตุ้นด้วยน้ำตาลซูโครส	2% Sucrose Solution = 2.0 4% Sucrose Solution = 4.0 6% Sucrose Solution = 6.0
Bitter ขม	The fundamental taste sensation of which caffeine or quinine are typical. การรับรู้รสพื้นฐานของลิ้นเมื่อถูกกระตุ้นด้วยคาเฟอีน	0.02% Caffeine Solution = 3.5

Attribute	Definition	References
Sour เปรี้ยว	The fundamental taste sensation of which citric acid is typical. การรับรู้รสพื้นฐานของลิ้นเมื่อถูกกระตุ้นด้วยกรดซิตริก	0.015% Citric Acid Solution = 1.5 0.050% Citric Acid Solution = 3.5
Metallic โลหะ	The chemical feeling factor on the tongue described as flat, associated with iron, copper, and silver spoons. ความรู้สึกทางเคมีบนลิ้น ซึ่งเกิดจากกลิ่นรสที่รับรู้ได้หลังจากที่ดึงช้อนที่ทำจากของโลหะพวกเหล็ก ทองแดง หรือเงินออกจากปาก	0.10% Potassium Chloride Solution = 1.5
Astringent ฝาด	The complex of drying, puckering, shrinking sensations in the oral cavity. ความรู้สึกแห้ง ฝืด ขึ้น ปร่าหรือเฝื่อน ในช่องปาก	0.05% Alum Solution = 2.5 0.1% Alum Solution = 5.0
Throat Irritation* ระคายคอ	An irritating feeling in the throat that causes one to feel like coughing. This may result from the taste or texture of the sample after swallowing. Two pieces are evaluated at a time. ความรู้สึกคัน ระคายเคือง แสบคอ ซึ่งอาจเกิดจากรสชาติหรือเนื้อสัมผัสของตัวอย่างหลังกลืน	Tong Garden Salted Peanuts = 5.0
Tongue Burn* แสบลิ้น	A burning feeling, prickling, and/or numbness of the tongue. However, it does not cover heat burn. ความรู้สึกทิมแทง แสบ ชา บริเวณลิ้น ทั้งนี้ไม่รวมความรู้สึกเผ็ดร้อน	Heinz White Vinegar in water (1:8) = 8.0
Texture		
Chalky Mouthfeel เหมือนผงชอล์ก	A dry, powdery sensation in the mouth. ความรู้สึกแห้ง เป็นผงละเอียดภายในปาก	10 g Argo cornstarch in 1,000 mL water = 3.0 Highland Sour Cream = 10.0

Attribute	Definition	References
Slimy เป็นเมือก	Degree to which a thick, mucous-like substance is perceived in the mouth during mastication. ระดับความเป็นเมือกของตัวอย่างที่รู้สึกได้ขณะเคี้ยว	Trappey's Cut Okra (canned) = 7.5 Fresh Okra = 11.0
Slickness ความลื่น	Ease with which a product slides around in the mouth during mastication (2.46 mL of product). ความสามารถในการลื่นไหลของตัวอย่างภายในปากซึ่งรู้สึกได้ขณะเคี้ยว (2.46 มล.)	Kraft Miracle Whip Light = 7.5
Fiber Awareness เส้นใย	The degree to which fiber are present. Evaluated during mastication after 5 to 8 chews (excluding skin). ปริมาณเส้นใยของตัวอย่างที่รู้สึกได้หลังจากเคี้ยวตัวอย่าง 5-8 ครั้ง ทั้งนี้ไม่รวมเปลือกหรือผิวนอกของตัวอย่าง)	Creative Gourmet Frozen Whole Strawberries = 2.0 Dole Canned Pineapple Rings = 10.0
Pulpy Residue กาก	A soft moist residue. กากเนื้อในที่นุ่มและชุ่มน้ำของตัวอย่างที่เหลืออยู่หลังเคี้ยว	Del Monte Lite Peaches = 2.0
Cohesiveness of Mass* การเกาะตัวของมวล	Degree to which the mass holds together after 7 chews. ระดับการเกาะรวมตัวกันของมวลตัวอย่าง หลังจากเคี้ยว 7 ครั้ง	Oscar Mayer Wieners = 6.5 Sweet potato = 9.0
Firmness* ความแข็ง	The force required to compress the sample between the tongue and palate. แรงที่ใช้กดตัวอย่างโดยใช้ ลิ้นและเพดานปาก จนตัวอย่างเสียรูปร่าง	Highland Sour Cream = 5.5 Philadelphia Light Cream Cheese (tub) =7.0 Philadelphia Cream Cheese (tub) = 10.0 Philadelphia Cream Cheese (block) = 14.0
Viscosity** ความหนืด	The measure of flow as the product moves on the tongue when pressed between the tongue and the palate (2.46 mL of product).	Gerber Applesauce Stage 1 = 9.0 Musselman's Natural Applesauce = 11.0

Attribute	Definition	References
	ความสามารถในการไหลของตัวอย่างบนลิ้น เมื่อกดตัวอย่างระหว่างลิ้นกับเพดานปาก (ใช้ตัวอย่าง 2.46 มล.)	
Mealy** ร่วน / ซุย	The perception of fine, soft particles distributed within the product. ความรู้สึกว่ามีชิ้นตัวอย่างขนาดเล็กและอ่อนนุ่มกระจายอยู่ในมวลตัวอย่าง	Gerber Applesauce Stage 1 = 2.0 Musselman's Natural Applesauce = 14.0
Mouthcoating** เคลือบปาก	Sensation of having a slick coating on the tongue and other mouth surfaces (2.46 mL swallowed after 3 manipulations). ความรู้สึกถึงตัวอย่างที่เคลือบภายในปากหลังกลืน ประเมินโดยใช้ตัวอย่าง 2.46 มล. เคี้ยว 3 ครั้ง แล้วกลืน	Dillon's Whipping Cream = 8.0 Karo Light Syrup = 10.0

*Only applies to fresh mango.
**Only applies to mango purée.

Test Design and Sample Evaluation

Panelists tested fresh sliced mango and mango purée samples prepared from each cultivar, evaluating 3 replicates for each sample (2 types X 6 cultivars X 3 replications). All panelists tested the same sample at the same time because of constraints of long evaluation times. With extended evaluation times, fresh mango samples were prepared immediately before evaluation, and each sample was served to the panelists at the same time to allow for randomization of mango pieces among panelists. A randomized complete block design was used to determine the serving order by randomizing samples within each replication. Samples were served monadic sequentially, and testing was conducted over 6 d. The test design is listed in Appendix A.

Panelists rated the intensities of flavor and texture attributes on a 15-point numerical scale with 0.5 increments using a hybrid method adapted from the Flavor Profile Method (Keane 1992). Scores on the scale correspond with the following intensities: 0.0 = none, 0.5 to 5.0 = slight, 5.5 to 10.0 = moderate, and 10.5 to 15.0 = high. All panelists performed evaluations independently. References were provided during evaluations to anchor values on the intensity scale (Lawless and Heymann 1999), and samples of the definition and reference sheets given to the panelists during testing are provided in Appendix C. Panelists used paper ballots to record their scores, and samples of these ballots are provided in Appendix B. During evaluations unsalted crackers (Jacob's Cream Crackers; Kraft Foods Malaysia, Petaling Jaya) and reverse osmosis, carbon-filtered water were served as palate cleansers between samples. Expectoration of samples was permitted.

Data Analysis

Analysis of Variance (ANOVA) was performed to compare physico-chemical properties and flavor and texture attributes among cultivars in the fresh and puréed form. Differences in TSS and pH measurements among samples were evaluated using one-way ANOVA, and the results were compared to sensory data for sweetness and sourness intensities. Because there was twice as much physico-chemical data on fresh samples compared to purées, the data on fresh samples was collapsed by averaging values across each replicate for fresh samples and untreated purées. Using one-way ANOVA, all flavor and texture attribute intensities were compared across cultivars at each processing stage to evaluate the effect of thermal processing on the descriptive

properties of each cultivar. One-way ANOVA was conducted because there were significant interactions between processing stage and cultivar for several attributes. The MIXED procedure was used to conduct ANOVA, and the means of each attribute showing significant differences were separated using Fisher's Least Significant Difference (LSD) at the 95% confidence level (SAS® version 9.2; SAS Institute Inc., Cary, N.C., U.S.A.). Codes used for ANOVA are listed in Appendix D. To further evaluate the effect of heat processing on the flavor attributes of each cultivar, principal component analysis (PCA) (Unscrambler, 2008, version 9.8; Camo A/S, Oslo, Norway) using the correlation matrix was performed, summarizing the relationship among samples and their attribute intensities.

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CHAPTER 3 - Changes in the Sensory Characteristics of Mango Cultivars during the Production of Mango Purée and Sorbet

Abstract

The effects of processing on the flavor and texture properties of 4 mango cultivars available in the U.S. were studied. Descriptive panelists evaluated fresh mango, mango purée, and mango sorbet prepared from each cultivar. Purées were made by pulverizing mango flesh, passing it through a china cap, and heating it to 85 °C for 15 s. To prepare the sorbets, purées were diluted with water (1:1), sucrose was added to increase the total soluble solids (TSS) to 32 ± 2 °Brix, and the sweetened bases were frozen in a batch-type ice cream freezer. Many of the flavor distinctions among cultivars carried over from fresh to purée samples, but much of the texture variation was lost. Thermal processing had unique effects on the flavor of the cultivars, especially Haden and Kent. Results suggest that mango cultivars for purées should be selected based on properties after thermal treatment. Processing purées into sorbets minimized flavor variation among cultivars, and results show that Tommy Atkins was the only cultivar to have flavor differences from the others when it was in sorbet. Based on the current study only very distinct flavor properties of mango cultivars may carry over to sorbets.

Practical Application: Findings from the present study can help mango purée and sorbet manufacturers select appropriate cultivars for their products by understanding the transformation that mango undergoes as it is processed into mango purée and subsequently mango sorbet.

Introduction

Mangoes have a short shelf-life (Mohammed and Brecht 2002; Nair and Singh 2009) and are often processed to facilitate exportation and to preserve the fruit past its season; however, little research has been conducted on the effects of processing on mango flavor. One study compared the descriptive properties of fresh mango purée to mango purée processed at 40 °C and showed that the intensities of sweet, peachy, sweet potato, and banana attributes were lower after thermal treatment, whereas the intensities of sour, bitter, and orange peel attributes increased (Malundo and others 1996). Some of those changes in flavor may be attributed to the reduction

or interaction of volatile compounds during heat processing (Malundo and others 1996; Yen and Lin 1999).

One application for mango purée is the production of sorbet. Sorbet is a frozen dessert containing a mixture of fruit purée, sugar, and water that is frozen churned to incorporate air (Migoya 2008). It is dairy-free and typically fat-free, making it a healthier alternative to ice cream (Stogo 1998). Sorbet does not yet have a standard of identity, and minimal research has been conducted on mango sorbet. Results from one study suggest that mango provides sorbet with an impression of fat feel and mouthcoating even in the absence of dairy (Thompson and others 2009).

Over 1,000 varieties of mangoes are available worldwide (Mukherjee 1953), and a number of these can be used in mango purée and sorbet. Mango cultivars vary greatly in terms aroma, flavor, and texture (Araiza and others 2005; Quijano and others 2007; Jha and others 2010), and some studies have used descriptive analysis to show perceptible differences in fresh mango flavor and texture among cultivars. Malundo and others (2001) indicated that the flavor attributes sweet, biting, sour, and peachy varied greatly between Tommy Atkins and Van Dyke cultivars. Vásquez-Caicedo and others (2002) evaluated 9 Thai cultivars, showing that Okrong Kiew was highest in sour taste and lowest in sweet taste, whereas Chok Anun was highest in firmness and chewiness. Characteristics of cultivars used in fruit sorbets have been found to affect the quality of the final product. A study on selecting suitable strawberry varieties for sorbet showed that hedonic scores for flavor, appearance, and acceptability differed based on cultivar (Avitable-Leva and others 2006). To our knowledge the effects of cultivar variation on the descriptive sensory properties of mango purée and sorbet have not been studied.

Studying the transformation that mango cultivars undergo throughout purée and sorbet production could help manufacturers select appropriate mango varieties for their products. If cultivar characteristics carry over to purées and sorbets, manufacturers can select varieties based on the properties of fresh mango. Thus, the objectives of the present study were to 1) evaluate changes in flavor and texture properties of cultivars as they are processed from fresh mango to mango purée to mango sorbet and 2) compare the flavor and texture among cultivars in the fresh, purée, and sorbet forms.

Materials and Methods

Samples

Four cultivars of mangoes imported from Mexico into the United States (U.S.) (Haden, Kent, Manila, and Tommy Atkins) were supplied by Splendid Products, Burlingame, CA. Undamaged, ripe fruit were selected using conventional ripeness indices (soft to touch and yellowish green or yellowish red skin). Mangoes were stored at room temperature (24 ± 1 °C) and were used or processed within 7 d of purchase at the ripe stage.

Sample preparation

Individual batches of purées were made for 3 replications of each cultivar. For each batch, 4 to 6 mangoes of a single cultivar were manually peeled, the flesh was cut from the seeds, and the flesh (925 g) was combined and puréed for 3 min using an immersion blender (Model WSB33; Waring Products, Torrington, Conn., U.S.A.). The purée was then passed through a china cap with a 2.5 mm mesh size (Model CCCS-8C; Winco Industries Co., Lodi, N.J., U.S.A.) and was heated rapidly in a saucepan (1.89 L; Magnalite, World Kitchen LLC, Greencastle, Pa., U.S.A.) on an electric stove with constant stirring until it remained at 85 °C for 15 s (Isaacs 1991). After heating, each batch was cooled immediately to 35 °C using an ice bath, and purées were packaged with a vacuum sealer (Model VS107; Seal-a-Meal®, Jarden Corp., Rye, N.Y., U.S.A.). They were kept frozen at -17 °C and were tested within 2 wk of preparation. According to MacLeod and Snyder (1988), freezing of mangoes has little effect on volatile composition.

Sorbets were prepared using each mango cultivar, and individual batches were made for 3 replications of each sample (4 cultivars X 3 replications). Separate batches of heat-treated purée were prepared for each sorbet batch, and the purées were refrigerated (3.5 °C) and used within 5 d of preparation. To prepare each batch of sorbet, 350 mL of heat-treated purée was combined with 350 mL of distilled water (Migoya 2008). A refractometer (Model Palette PR101α; Atago U.S.A., Inc., Bellevue, Wash., U.S.A.) was used to measure total soluble solids (TSS), and sucrose was added to increase TSS to 32 ± 2 °Brix (Migoya 2008). The sweetened purées were vacuum sealed and refrigerated (3.5 °C) overnight. They were frozen in a batch ice cream freezer

(Model Lello Pola 5030; Lello, Musso, Italy) and placed in a storage freezer (-17 °C). Sorbets were evaluated within 10 d of preparation.

Instrumental measurements

To compare the acidity and approximate sugar content of cultivars at each processing stage, TSS and pH measurements were taken. TSS and pH were measured for fresh samples, heat-treated purées, and sorbet bases using a digital refractometer (Model Palette PR101α; Atago U.S.A., Inc., Bellevue, Wash., U.S.A.) and a digital pH meter (Model CyberScan pH 510; Eutech Instruments Pte. Ltd., Singapore), respectively. All measurements were taken at room temperature (24 ± 1 °C).

Orientation and lexicon development

Six highly-trained panelists from the Sensory Analysis Center at Kansas State Univ. (Manhattan, KS, U.S.) performed evaluations on all samples. Each panelist completed a 120-h training in descriptive sensory testing and had about 2,000 h of testing experience with a variety of food products. Facilities for sensory testing had controlled temperature, lighting, and humidity. Prior to testing, 3 orientation sessions of 1.5 h were held during which panelists developed lexicons describing the flavor and texture of fresh mango, mango purée, and mango sorbet. They used language from a previous study on mangoes (Suwonsichon and others, *Personal Communication*) and a previous study on gelato (Thompson and others 2009) to assist in identifying attributes. Panelists tasted all samples and discussed possible terms, compiling a final list of attributes, definitions, and references for testing (Table 3.1).

Table 3.1 Terms, definitions, and references used in evaluating fresh mango, mango purée, and mango sorbet.

Attribute	Definition	References
Flavor		
Mango Identity	A sweet, fruity, green, somewhat woody and piney aromatic associated with mango that sometimes may include aromatics similar to other specific fruits, such as peach, orange, grapefruit, and/or pineapple.	Jumex Mango Nectar = 6.5 Reese Sliced Mango in Mango Juice = 7.5
Fruity	An aroma blend which is sweet and reminiscent of a variety of different fruits. When possible, specific fruits were described.	Trans-2-Hexenal (10,000 ppm) = 5.0
Grapefruit	A natural, sour, slightly sweet, fruity, somewhat musty, woody, pungent, citrus-like aromatic associated with grapefruit.	Grapefruit Essential Oil (Aura Cacia) = 6.0
Orange	A natural, sweet, fruity, floral, slightly sour and citrus-like aromatic associated with oranges.	Majestic Mountain Sage Orange Valencia Essential Oil = 6.5 Majestic Mountain Sage Orange 5-Fold Essential Oil = 8.5
Peach	Aromatic associated with ripe peach which includes floral, perfumy, sweet, sometimes woody and green notes, and can have a hint of fermented note.	Fresh Peach Pit = 8.0
Pineapple	A sweet, woody, slightly sharp, floral aromatic associated with pineapple.	Diluted Dole Canned Pineapple Juice (1:1) = 6.0
Cooked‡	An aromatic impression associated with a cooked fruit rather than fresh, uncooked fruit.	Jumex Mango Nectar = 6.0 Reese Sliced Mango in Mango Juice = 7.0
Animalic	Aromatic associated with sulfur compounds which exhibit skunk-like characteristic commonly associated with decaying animals.	Tincture of Civet = 6.0
Black Pepper	Spicy, pungent, musty, and woody aromatics characteristic of ground black pepper.	McCormick Ground Black Pepper = 13.0

Attribute	Definition	References
Caramelized	A round, full bodied, medium brown aromatic.	C&H golden Brown Sugar = 9.0
Clove	A pungent, brown spicy aromatic.	LorAnne Gourmet Clove Leaf Oil = 12.0
Chemical	A general term associated with many different types of compounds generally known as chemicals.	Borneol (10,000 ppm) = 2.5
Cumin	A musty, brown, sweet, slightly pungent aromatic.	McCormick Ground Cumin = 13.0
Green	Slightly sour aromatic commonly associated with under-ripe fruit.	Green Granny Smith = 7.0
Green-viney	Green, fresh aromatic associated with newly cut vines and stems. It sometimes relates to cucumber.	2-Isobutylthiazole (Givaudan; 10,000 ppm) = 9.0
Fermented	A combination of aromatics that are sweet, slightly brown, overripe, and somewhat sour.	Blackberry WONF 3RA654 = 7.0
Floral/Perfumy	A sweet, heavy aromatic blend of a combination of flowers which can be somewhat chemical and perfume-like.	Geraniol (IFF; 10,000 ppm) = 7.5
Musty	An aromatic that has a damp, earthy character similar to fresh mushrooms.	Sliced White Mushroom = 10.5
Peel-like	A slightly sharp aromatic that can be described as slightly sour and bitter. It is commonly associated with citrus peel.	Lime peel = 13.0
Piney	A slightly sharp resinous aromatic that may be medicinal or chemical in character. It is associated with green pine needles or pine pitch.	Isobornyl propionate (IFF; 10,000 ppm) = 6.5
Spicy	A sweet brown, slightly musty aromatic reminiscent of cinnamon.	McCormick Ground Allspice = 9.5

Attribute	Definition	References
Starchy	A bland, cooked vegetable-like aromatic associated with the meat of a baked sweet potato or squash.	Baked Sweet potato = 8.0
Vegetable (yellow squash-like)	Sweet, musty, earthy aroma characteristic of yellow squash.	Gerber Squash Baby Food = 7.5
Woody	Flat, dark, dry, musty aromatics associated with the bark of a tree.	Oil of Cedar Wood (Aldrich; 10,000 ppm) = 6.0
Overall Sweet	Aromatics and flavor notes associated with the impression of all sweet substances.	Lorna Doone Cookie = 4.5 6% C&H Brown Sugar in water = 9.0
Overall Sour	Aromatics and flavor notes associated with the impression of all sour substances.	Highland Sour Cream = 4.5
Sweet	The fundamental taste sensation of which sucrose is typical.	2% Sucrose Solution = 2.0 4% Sucrose Solution = 4.0 6% Sucrose Solution = 6.0
Bitter	The fundamental taste sensation of which caffeine or quinine are typical.	0.02% Caffeine Solution = 3.5
Sour	The fundamental taste sensation of which citric acid is typical.	0.015% Citric Acid Solution = 1.5 0.050% Citric Acid Solution = 3.5
Metallic	The chemical feeling factor on the tongue described as flat, associated with iron, copper, and silver spoons rated after spoon has been removed.	0.10% Potassium Chloride Solution = 1.5
Astringent	The complex of drying, puckering, shrinking sensations in the oral cavity.	0.05% Alum Solution = 2.5 0.1% Alum Solution = 5.0
Texture		

Attribute	Definition	References
Chalky Mouthfeel	A dry, powdery sensation in the mouth.	10 g Argo cornstarch in 1000 mL water = 3.0 Highland Sour Cream = 10.0
Slimy	Degree to which a thick, mucous-like substance is perceived in the mouth during mastication.	Kroger Frozen Cut Okra = 13.0
Slickness	Ease with which a product slides around in the mouth during mastication (2.46 mL of product).	Kraft Miracle Whip Light = 7.5
Fiber Awareness	The degree to which fibers are present. Evaluated during mastication after 5 to 8 chews (excluding skin).	Private Selection Frozen Whole Strawberries = 2.0
Pulpy Residue	A soft moist residue.	Del Monte Lite Peaches = 2.0
Cohesiveness of Mass*	Degree to which the mass holds together after 7 chews.	Oscar Mayer Wieners = 6.5 Sweet potato = 9.0
Particles*	The amount of small pieces of sample remaining in mouth just after swallowing. This does not incorporate toothpacking and refers only to particulate matter on mouth surface other than in and between the molar teeth. Evaluate 3 pieces at a time.	Cheerios = 3.0
Firmness*	The force required to compress the sample between the tongue and palate.	Highland Sour Cream = 5.5 Philadelphia Light Cream Cheese (tub) =7.0 Philadelphia Cream Cheese (tub) = 10.0 Philadelphia Cream Cheese (block) = 14.0
Thickness**	A measure of the consistency of a product when manipulating a sample on the roof of the mouth with the tongue.	Diluted Contadina Tomato Paste (1:1) = 7.5† Contadina Tomato Paste = 14.0†
Mealy**	The perception of fine, soft particles distributed within the product.	Gerber Applesauce Stage 1 = 2.0 Musselman's Natural Applesauce = 14.0

Attribute	Definition	References
Viscosity‡	The measure of flow as the product moves on the tongue when pressed between the tongue and the palate (2.46 mL of product).	Gerber Applesauce Stage 1 = 9.0** Musselman's Natural Applesauce = 11.0** Dillon's 1/2 and 1/2 = 2.0† Dillon's Whipping Cream = 4.0†
Mouthcoating‡	Sensation of having a slick coating on the tongue and other mouth surfaces (2.46 mL swallowed after 3 manipulations).	Dillon's Whipping Cream = 8.0
Density†	The degree of compactness of a sample when pressed between the tongue and palate.	Kraft Marshmallow Fluff = 5.0 Dillon's Sour Cream = 9.5
Meltdown†	The time required for the product to melt in the mouth when continuously pressed by the tongue against the palate. The number of seconds counted equals the numerical score (1/1,000 count). Sample size is 1.64 mL.	
Iciness†	The immediate perception of crystal-like particles within the sample. This measurement is taken immediately after sample has been placed in the mouth. The crystals often dissolve quickly at first manipulation. Sample size is 1.64 mL of icy portion.	Haagen Dazs Mango Sorbet that has been through a thaw-refreeze cycle = 7.5

*Only applies to fresh mango.
**Only applies to mango purée.
†Only applies to mango sorbet.
‡Only applies to mango purée and sorbet.

Test design and sample evaluation

Panelists tested fresh, purée, and sorbet samples made from each of the 4 mango cultivars, evaluating 3 replications of each sample. A completely randomized design was used to determine the sample serving order for each panelist, and samples were randomized within replications. To prepare fresh sliced mangoes for serving, each mango was peeled, and the flesh was cut off of either side of the seed. Each half was cut into 4 pieces (2 middle and 2 edge pieces), and the flesh left on either edge of the seed was cut into 2 pieces. Panelists received 6 pieces for every evaluation with at least 1 middle piece, 1 edge piece, and 1 side piece randomly selected from different fruits. Samples were served directly after cutting in 226.8 mL Styrofoam bowls with lids (Dart Container Corp., Mason, Mich., U.S.A.). Frozen mango purées were thawed in the refrigerator (3.5 °C) overnight and were served at room temperature in 92.1 mL plastic cups with lids (Sweetheart Cup Co. Inc., Owing Mills, Md., U.S.A.). Every panelist received 44.4 mL of each purée for evaluation. Sorbets were served at -10 °C (Marshall 2003) in 118 mL Styrofoam bowls (Dart Container Corp., Mason, Mich., U.S.A.), and panelists were served two sets of 40.0 g sorbet samples for each replication during testing to provide temperature control. They evaluated the flavor of the first sample and the texture of the 2nd sample. All fresh, purée, and sorbet samples were labeled with 3-digit random codes.

Panelists rated the intensities of each flavor and texture attribute using a hybrid method adapted from the Flavor Profile Method (Keane 1992). They used a numerical scale from 0 (none) to 15 (extremely high) with 0.5 increments to rate attribute intensities. References were provided for each attribute to anchor values on the intensity scale. Data were collected using Compusense Commuter data collection software (version 4.6.702; Compusense Inc., Guelph, Ontario, Canada). Unsalted crackers (Nabisco Premium Saltine Unsalted Top Crackers; Kraft Foods, Inc., East Hanover, N.J., U.S.A.) and reverse osmosis, deionized, carbon-filtered water were served as palate cleansers between samples.

Data Analysis

One-way Analysis of Variance (ANOVA) was performed to compare TSS content, pH, and flavor and texture attributes across the various stages of processing (fresh, purée, and sorbet) for each cultivar. All ANOVAs conducted in this study used the MIXED procedure in SAS® (version 9.2, 2002-2008; SAS Institute Inc., Cary, N.C., U.S.A.) at the 95% confidence level, and

means were separated by Fisher's Least Significant Difference (LSD). Principal component analysis (PCA) (Unscrambler®, 2008, version 9.8; Camo A/S, Oslo, Norway) was used to evaluate relationships among fresh mango, mango purée, and mango sorbet prepared from the 4 cultivars based on their flavor attributes.

Results and Discussion

Physicochemical analyses

Out of the fresh and purée samples Manila had the highest ($P < 0.05$) TSS content and Tommy Atkins had the lowest ($P < 0.05$) TSS content (Table 3.2). TSS content was not significantly different ($P > 0.05$) between Haden and Kent for both fresh and puréed samples. Sorbet samples did not vary ($P > 0.05$) in TSS based on cultivar because sugar was added during preparation of sorbets to achieve constant sugar composition. TSS did not differ ($P > 0.05$) between fresh and purée samples for any of the cultivars; however, TSS of sorbets was significantly higher ($P < 0.05$) for all cultivars compared to their fresh and puréed forms because of the addition of sucrose. Compared to the other cultivars Tommy Atkins had the lowest ($P < 0.05$) pH for fresh, purée, and sorbet samples, whereas Haden had the highest pH ($P < 0.05$) (Table 3.2). Kent had a slightly higher pH than Manila, although significant differences ($P < 0.05$) in pH between these cultivars were only noted for their fresh and sorbet forms. Processing fresh samples into purées and sorbets did not significantly affect ($P > 0.05$) the pH for any of the cultivars. Data for pH and TSS are consistent with previous studies on fruit and vegetable juices, which indicate that thermal pasteurization at temperatures lower than 100 °C has little effect on pH and TSS (Zhou and others 2009; Zhang and others 2010).

Table 3.2 Mean scores and separation of TSS and pH measurements for 4 cultivars in the form of fresh mango, mango purée, and mango sorbet.

		TSS	pH
Fresh	Haden	17.4^{c}	5.08^{a}
	Kent	16.6^{c}	4.80^{cd}
	Manila	21.2^{b}	4.56^{e}
	Tommy	12.0^{d}	4.13^{f}
Purée	Haden	17.4^{c}	5.04^{ab}
	Kent	17.0^{c}	4.74^{cde}
	Manila	22.3^{b}	4.54^{e}
	Tommy	12.4^{d}	4.14^{f}
Sorbet	Haden	32.5^{a}	5.14^{a}
	Kent	32.5^{a}	4.83^{bc}
	Manila	32.5^{a}	4.59^{de}
	Tommy	32.5^{a}	4.20^{f}

Means with different superscripts within a column are significantly different ($P < 0.05$).

Flavor

Overall processing effect

Panelists used the same terminology to describe the flavor of fresh, purée, and sorbet samples with the exception of an additional cooked flavor detected in purées and sorbets. Some of the changes in flavor throughout processing were common to all or most cultivars. Fruity character was lower ($P < 0.05$) in purées and sorbets than in fresh samples for almost all cultivars (Table 3.3). This attribute may be associated with aromatic compounds in mango (Boonbumrung and others 2001), and the reduced intensity of fruity flavor in purées and sorbets may result from degradation or loss of aromatic compounds during thermal processing (Yen and Lin 1999) and the reduced volatility of aromatic compounds due to chilling (for sorbets) (Covarrubias-Cervantes and others 2004). The intensity of metallic character was higher ($P < 0.05$) in sorbet samples than in fresh samples for all cultivars. This attribute may have increased throughout processing as a result of contact with metal equipment during purée and sorbet production

(Hunziker and others 1929); however, further studies should be conducted on the effects processing on metallic flavor in mango. For all cultivars astringent character decreased ($P < 0.05$) when purées were processed into sorbets, and fresh samples had higher ($P < 0.05$) intensities of overall sour and sour attributes than sorbets for most cultivars. The suppression of perceived astringency by the addition of sucrose may have led to the reduced intensity of astringent character in sorbets (Courregelongue and others 1999). Results suggest that sorbets have reduced intensities of astringent, sour, and overall sour notes, which may be perceived as undesirable. However, processing decreased fruity flavor and increased metallic character relative to intensities of these attributes in fresh mango.

Table 3.3 Mean scores and separation of flavor and texture attributes for 4 cultivars in the form of fresh mango, mango purée, and mango sorbet.

	Fresh				Purée				Sorbet			
Attribute	**Haden**	**Kent**	**Manila**	**Tommy**	**Haden**	**Kent**	**Manila**	**Tommy**	**Haden**	**Kent**	**Manila**	**Tommy**
Mango ID	7.0	7.9	8.2	6.6	7.1	6.5	7.3	6.0	6.8	6.6	6.9	6.1
Fruity	5.2^{ab}	5.4^{a}	5.6^{a}	4.9^{abc}	4.3^{cd}	4.0^{cd}	4.4^{bcd}	3.8^{d}	4.4^{bcd}	4.3^{cd}	4.0^{d}	4.1^{cd}
Peach	2.3	3.3	2.8	2.3	2.8	2.7	3.1	2.2	2.6	2.3	2.5	2.1
Orange	1.1	1.0	1.4	0.9	1.3	0.8	0.9	0.8	1.2	1.4	1.1	0.8
Grapefruit	1.1	0.4	0.9	1.0	0.8	0.7	0.8	1.1	0.8	0.5	0.6	1.1
Pineapple	0.6	0.4	0.7	0.7	0.6	0.5	0.4	0.9	0.9	0.6	0.6	0.8
Cooked	-	-	-	-	4.3^{ab}	4.6^{a}	4.3^{ab}	3.3^{ab}	3.0^{b}	3.0^{b}	3.3^{ab}	3.0^{b}
Animalic	0.9^{a}	0.2^{bc}	0.2^{bc}	0.6^{ab}	0.5^{ab}	0.1^{bc}	0.2^{bc}	0.4^{abc}	0.1^{bc}	0.1^{bc}	0.2^{bc}	0.0^{c}
Black Pepper	0.3	0.2	0.3	0.3	0.3	0.1	0.2	0.2	0.1	0.1	0.3	0.3
Caramelized	2.5^{cde}	3.2^{abcd}	3.7^{ab}	1.5^{e}	3.5^{abc}	3.3^{abc}	3.7^{ab}	2.1^{de}	4.0^{a}	3.5^{abc}	3.9^{a}	2.6^{bcde}
Clove	0.1	0.3	0.4	0.2	0.2	0.2	0.2	0.0	0.2	0.2	0.3	0.3
Chemical	1.4^{a}	0.5^{c}	0.6^{bc}	1.2^{a}	0.2^{c}	0.1^{c}	0.1^{c}	1.1^{ab}	0.1^{c}	0.1^{c}	0.0^{c}	0.3^{c}
Cumin	0.2	0.3	0.5	0.1	0.4	0.2	0.2	0.1	0.2	0.1	0.3	0.1
Green	1.1^{bc}	0.9^{c}	0.9^{c}	2.3^{a}	0.6^{c}	0.8^{c}	0.5^{c}	1.8^{a}	0.9^{c}	0.6^{c}	0.5^{c}	1.7^{ab}
Green-viney	1.6^{abc}	1.6^{abc}	1.9^{ab}	2.0^{a}	1.2^{c}	1.3^{bc}	1.2^{c}	1.9^{ab}	1.3^{abc}	1.1^{c}	1.0^{c}	1.9^{ab}
Fermented	1.6^{a}	0.9^{abcd}	1.0^{abc}	0.9^{abcd}	1.2^{ab}	0.7^{bcd}	1.0^{abcd}	0.7^{bcd}	0.4^{cd}	0.4^{cd}	0.6^{bcd}	0.3^{d}
Floral/Perfumy	2.9	2.8	3.2	2.3	2.4	2.0	2.2	2.0	2.1	2.1	2.1	2.2
Musty	2.4^{a}	1.7^{ab}	1.6^{ab}	2.4^{a}	1.6^{ab}	1.1^{b}	1.1^{b}	1.9^{ab}	0.9^{b}	1.1^{b}	0.9^{b}	0.9^{b}
Peel-like	0.6	0.3	0.4	0.8	0.3	0.4	0.4	0.9	0.2	0.3	0.2	0.6
Piney	2.4	1.7	2.6	1.9	2.3	1.9	1.9	2.2	2.3	2.5	2.3	2.6
Spicy	1.0^{ab}	1.1^{ab}	1.4^{a}	0.5^{b}	1.4^{a}	1.1^{ab}	1.1^{ab}	0.5^{b}	0.9^{ab}	0.9^{ab}	0.9^{ab}	0.5^{b}
Starchy	2.6^{bcd}	2.7^{bcd}	2.4^{cd}	1.8^{d}	4.1^{a}	3.6^{ab}	3.6^{ab}	3.0^{bc}	3.2^{abc}	3.2^{abc}	3.3^{abc}	3.0^{bc}

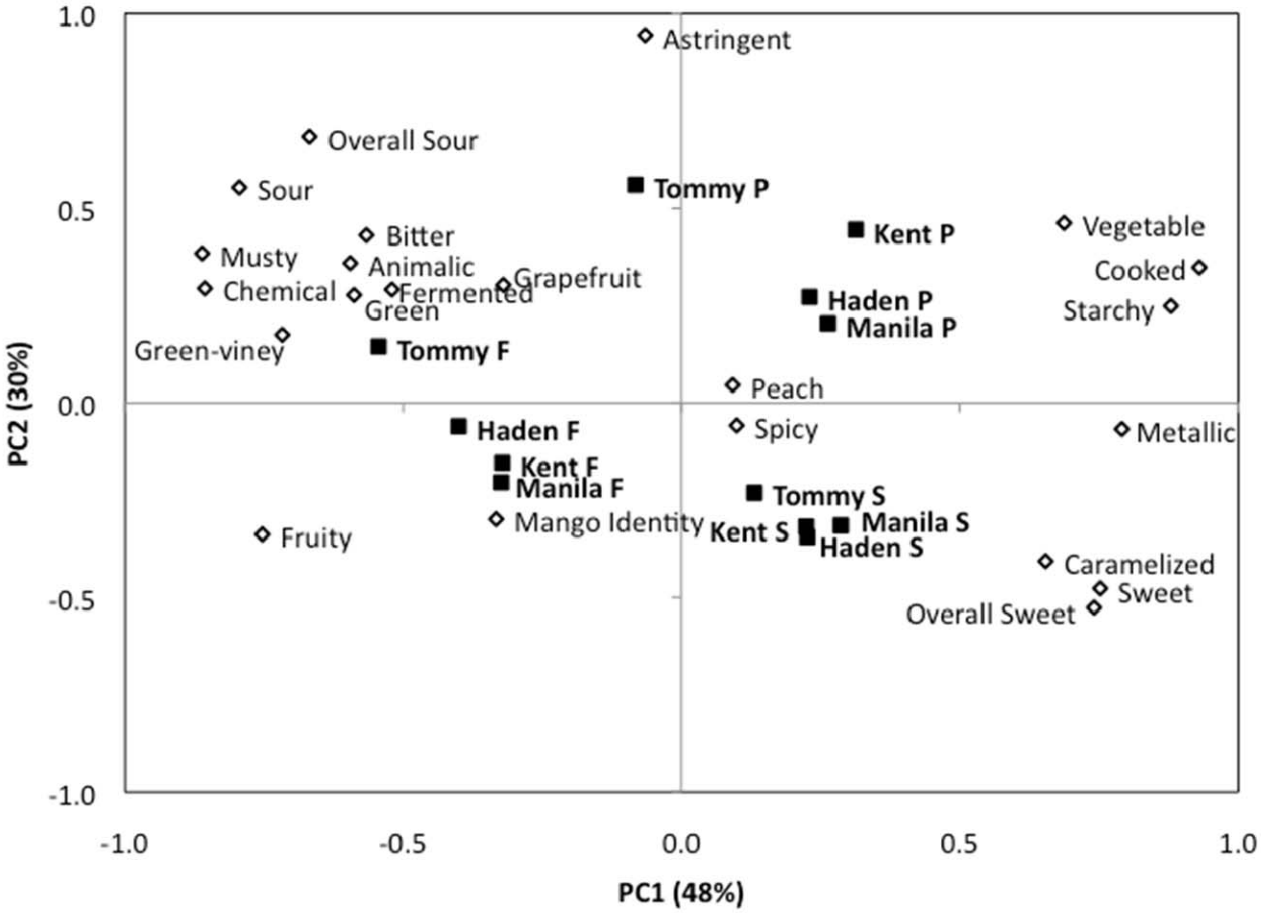
	Fresh				Purée				Sorbet			
Attribute	**Haden**	**Kent**	**Manila**	**Tommy**	**Haden**	**Kent**	**Manila**	**Tommy**	**Haden**	**Kent**	**Manila**	**Tommy**
Vegetable	1.0^{c}	0.9^{c}	1.2^{c}	1.3^{bc}	1.8^{abc}	2.2^{a}	1.6^{abc}	2.3^{a}	1.5^{abc}	1.7^{abc}	2.1^{ab}	1.5^{abc}
Woody	1.8	1.8	2.1	1.6	2.2	2.0	2.3	1.9	2.0	1.9	2.0	2.2
Overall Sweet	6.9^{b}	7.0^{ab}	7.3^{ab}	5.0^{c}	7.5^{ab}	7.7^{ab}	7.8^{ab}	5.5^{c}	8.1^{ab}	8.1^{ab}	8.2^{a}	7.8^{ab}
Overall Sour	2.6^{ab}	2.2^{abc}	2.6^{ab}	2.6^{abc}	2.1^{bcd}	2.4^{abc}	2.0^{bcd}	2.9^{a}	1.4^{d}	1.4^{d}	1.4^{d}	1.8^{cd}
Sweet	5.0^{ab}	4.9^{abc}	5.1^{ab}	4.2^{bc}	5.4^{a}	5.8^{a}	5.6^{a}	3.9^{c}	5.9^{a}	5.8^{a}	5.7^{a}	5.6^{a}
Bitter	2.8	2.3	2.4	2.9	2.6	2.3	2.5	2.8	2.3	2.3	2.4	2.5
Sour	1.9^{abc}	1.8^{abc}	2.0^{ab}	2.3^{a}	1.6^{bcde}	1.5^{cde}	1.7^{bcd}	2.3^{a}	1.2^{e}	1.2^{de}	1.2^{e}	1.5^{cde}
Astringent	2.4^{bcd}	2.4^{cd}	2.3^{cd}	2.7^{bc}	3.9^{abc}	5.1^{a}	3.7^{abc}	4.5^{ab}	0.6^{d}	0.6^{d}	0.6^{d}	0.6^{d}
Metallic	0.6^{c}	0.6^{c}	0.6^{c}	0.8^{bc}	1.3^{abc}	1.8^{abc}	1.3^{abc}	1.9^{ab}	2.0^{a}	2.1^{a}	2.1^{a}	2.1^{a}
Chalky Mouthfeel	2.9^{ab}	3.3^{a}	3.2^{a}	3.5^{a}	2.3^{abcd}	1.1^{d}	1.7^{bcd}	1.4^{cd}	2.9^{ab}	2.6^{abc}	2.6^{abc}	2.4^{abcd}
Slimy	8.9^{ab}	10.3^{a}	9.2^{ab}	9.4^{ab}	6.8^{bc}	4.5^{c}	6.2^{bc}	4.8^{c}	6.4^{bc}	6.4^{bc}	6.5^{bc}	6.5^{bc}
Slickness	6.7	7.3	6.7	6.2	6.4	6.7	6.2	6.8	6.6	7.0	6.7	7.1
Fiber Awareness	5.4^{a}	3.1^{b}	2.9^{b}	5.7^{a}	1.0^{c}	0.2^{c}	0.4^{c}	0.3^{c}	0.1^{c}	0.1^{c}	0.3^{c}	0.4^{c}
Pulpy Residue	2.5^{a}	2.4^{ab}	2.5^{a}	2.3^{abc}	1.9^{abc}	1.3^{bcd}	1.3^{cd}	1.6^{abcd}	0.6^{d}	0.7^{d}	0.9^{d}	0.7^{d}
Cohesiveness of Mass	5.0	4.8	4.9	5.4	-	-	-	-	-	-	-	-
Particles	1.1	0.6	0.8	1.4	-	-	-	-	-	-	-	-
Firmness	10.5	10.6	11.2	12.1	-	-	-	-	8.3	8.3	8.3	8.8
Thickness	-	-	-	-	6.0	2.8	4.9	3.1	-	-	-	-
Mealy	-	-	-	-	4.7	6.1	3.6	5.8	-	-	-	-
Viscosity	-	-	-	-	8.6	6.9	7.4	7.1	4.5	4.7	4.6	4.3
Mouthcoating	-	-	-	-	5.3	4.8	5.1	4.8	6.1	5.7	6.2	5.6
Density	-	-	-	-	-	-	-	-	7.7	7.2	7.8	7.4
Meltdown	-	-	-	-	-	-	-	-	6.4	6.0	6.4	6.1

	Fresh				Purée				Sorbet			
Attribute	**Haden**	**Kent**	**Manila**	**Tommy**	**Haden**	**Kent**	**Manila**	**Tommy**	**Haden**	**Kent**	**Manila**	**Tommy**
Iciness	-	-	-	-	-	-	-	-	2.6	1.6	2.0	1.9

Means with different superscripts within a row are significantly different ($P < 0.05$). Attributes found in sample types (fresh, purée, and sorbet) were evaluated across all samples. Attributes found in 1 or 2 sample types were evaluated across cultivars within sample type. Dashes indicate that attributes were not evaluated.

PCA was used to evaluate relationships among the various processing stages for the 4 cultivars based on flavor attributes. Fig 3.1 shows a plot of the first 2 principal components (PCs) of PCA, which explain 48% and 30% of the variance, respectively. PC 1 distinguishes between fresh and processed samples, whereas PC 2 explains cultivar variation and differences among fresh, purée, and sorbet samples. Most of the sorbet and purée samples are located on the right side of the PCA biplot, indicating that they were higher in cooked, vegetable, starchy, and metallic attributes than fresh samples. Fresh samples are located on the left side of the plot, showing that they were higher in chemical, fruity, green-viney, musty, sour, and overall sour attributes. The PCA biplot distinguishes purées as high in astringent, overall sour, and sour characteristics. Heating of fruit juices has been found to increase the perceived intensity of astringency (Watson 1973), which may be caused by increases in free phenolic compounds during heat processing (Xu and others 2007). Sorbet samples are located in the lower right quadrant of the PCA biplot, indicating that they were higher in caramelized, sweet, and overall sweet attributes. This is not surprising because sugar was added to the sorbet samples. A previous study on ice cream suggests that there might be a relationship between perceived sweetness and caramel flavor; the study showed that as sugar content and sweetness increased, caramel notes also increased (Stampanoni Koeferli and others 1996).

Figure 3.1 Score plot of PC1 and PC2 comparing fresh mango, mango purée, and mango sorbet for 4 cultivars based on descriptive flavor attributes.



F = fresh; P = purée. Attributes with $P > 0.1$ based on ANOVA are not shown.

Cultivar variation

Fresh and puréed samples had more flavor attributes with significantly different intensities among cultivars than sorbets (Table 3.3). These results suggest that much of the perceptible flavor variation among cultivars was lost once purées were processed into sorbets. The PCA biplot (Fig 3.1) supports these findings, showing cultivars to be grouped closer together for sorbets than for fresh samples and purées. Although freezing has been found to have little effect on aromatic composition of mangoes (MacLeod and Snyder 1988), research shows that temperatures below freezing reduce the volatility of aromatic compounds (Covarrubias-

Cervantes and others 2004). This may reduce perceived intensities of flavor attributes in mango sorbet, making it difficult to distinguish among cultivars.

Fresh Kent and Manila were similar to each other in flavor. Fresh Tommy Atkins had the most distinct flavor properties from the other cultivars; it had a higher ($P < 0.05$) intensity of green flavor and a lower ($P < 0.05$) intensity of overall sweet flavor compared to all other cultivars. It was also relatively low in caramelized flavor compared to the other cultivars. As in its fresh form, Tommy Atkins purée had higher ($P < 0.05$) intensities of green and sour flavors and lower ($P < 0.05$) intensities of overall sweet and sweet flavors than all other cultivars. It was also higher in chemical, green-viney, and overall sour flavors and lower in caramelized flavor than most other cultivars. Tommy Atkins sorbet was the only sorbet with distinct flavor characteristics. It had a lower intensity ($P < 0.05$) of caramelized flavor compared to Haden and Manila samples, and it had a higher intensity ($P < 0.05$) of green-viney flavor than Kent and Manila samples. Tommy Atkins sorbet was higher ($P < 0.05$) in green character than all other sorbets. Results suggest that Tommy Atkins had the most distinct flavor of all the cultivars at each processing stage. This cultivar has been found to have a lower total volatiles content than Haden and Manila (Quijano and others 2007), which may contribute to its lower intensities of spicy and peach flavors. In the PCA biplot (Fig 3.1) Tommy Atkins was located above and to the left of the other cultivars at each processing stage because of its high intensities of green, green-viney, chemical, sour, overall sour, and bitter attributes and its low intensities of caramelized, peach, and spicy flavors. The PCA biplot also shows that fresh Kent and Manila were similar in flavor, whereas Haden and Manila purées were similar in flavor. However, the variation in flavor attributes among Haden, Kent, and Manila cultivars detectable in fresh and purée samples were not perceived in the sorbet samples, which were grouped closely together on the PCA biplot.

Haden and Tommy Atkins had more attributes that distinguished among processing steps than Kent and Manila, indicating that Haden and Tommy Atkins underwent greater transformations in flavor throughout processing (Table 3.3). Fresh Manila had a lower intensity ($P < 0.05$) of vegetable flavor than Manila sorbet, whereas it had a higher intensity ($P < 0.05$) of green-viney flavor than Manila sorbet and purée. Fresh Kent was lower ($P < 0.05$) in vegetable flavor than Kent purée. Haden sorbet had a higher intensity ($P < 0.05$) of caramelized flavor and lower intensities ($P < 0.05$) of animalic, fermented, and musty attributes compared to its fresh form. Haden sorbet and purée were lower ($P < 0.05$) in chemical flavor than fresh Haden.

Similar to Haden, Tommy Atkins sorbet was lower ($P < 0.05$) in animalic, chemical, and musty flavors compared to fresh Tommy Atkins. Results suggest that processing fresh Haden and Tommy Atkins into sorbet reduces intensities of unpleasant or off-flavors. Although Haden and Tommy Atkins purées were higher ($P < 0.05$) in starchy flavor than fresh samples, intensities of starchy flavor in sorbets prepared from these cultivars were indistinguishable ($P > 0.05$) from fresh or puréed forms. Tommy Atkins was the only cultivar with a significant decrease ($P < 0.05$) in astringency and significant increases ($P < 0.05$) in sweet and overall sweet flavors from fresh to sorbet forms, which suggests that processing Tommy Atkins into sorbet may increase its palatability more so than for other cultivars.

On the PCA biplot fresh Haden is positioned higher than fresh Kent and Manila, whereas Haden purée is located between Kent and Manila purées (Fig 3.1). Haden's downward shift on the plot relative to the other cultivars may be caused by heat processing decreasing chemical flavor in Haden. Mango identity decreased slightly after processing for all cultivars except Haden, and results suggest that heat processing may maintain the characteristic mango flavor of fresh Haden while reducing undesirable chemical flavors. Compared to Kent in its fresh form Kent purée was shifted upwards and to the left relative to the other cultivars because of significant increases in vegetable, astringent, and metallic notes during thermal processing. This suggests that processing fresh Kent into purée intensifies some potentially undesirable flavors in this cultivar.

Texture

The texture attributes chalky mouthfeel, slimy, slickness, fiber awareness, and pulpy residue were used to evaluate all product types (fresh mango, mango purée, and mango sorbet). The remaining texture attributes used in this study were specific to product types. The only texture attribute that varied in intensity among cultivars within a product type was fiber awareness (Table 3.3); fresh Haden and Tommy Atkins had higher intensities ($P < 0.05$) of fiber awareness than fresh Kent and Manila. None of the attributes for purée samples varied in intensity, suggesting that some of the texture variation among mango cultivars was lost when fresh mango was processed into purées and sorbets.

For the texture attributes common to fresh, purée, and sorbet samples, processing significantly influenced intensities of chalky mouthfeel, slimy, slickness, fiber awareness, and

pulpy residue (Table 3.3). Pulpy residue for Kent and Manila purées was lower ($P < 0.05$) than for fresh Kent and Manila, and all sorbets were significantly lower ($P < 0.05$) in pulpy residue than fresh samples. Fresh samples were higher ($P < 0.05$) in fiber awareness than purées and sorbets, which resulted from removing fibers before thermally processing purées. Kent was the only cultivar that was significantly lower ($P < 0.05$) in slimy texture in its sorbet form than in fresh form. Intensities of chalky mouthfeel for Kent, Manila, and Tommy Atkins decreased ($P < 0.05$) after fresh samples were made into purées; however, chalky mouthfeel intensities did not differ ($P > 0.05$) between any of the fresh and sorbet samples. These results suggest that although chalky mouthfeel generally decreased when fresh mango was thermally processed, this attribute became more noticeable when purées were transformed into sorbets. The terms chalkiness or chalky are prominent characteristics of fruit-based frozen desserts, and they have been used in previous studies to describe the texture of these products (McPherson and others 1978; Thompson and others 2009).

Comparison of sensory and physicochemical data

Panelists detected relatively low sweetness intensities for Tommy Atkins in the fresh and purée forms compared to the other cultivars (Table 3.3), which was consistent with TSS measurements. However, they did not distinguish fresh Manila and Manila purée as being sweeter than Haden and Kent in these forms. Although TSS content of sorbets was significantly higher ($P < 0.05$) than that of fresh and purée samples (Table 3.2), sensory scores for sweetness did not vary ($P > 0.05$) among fresh, purée, and sorbet samples, with the exception of Tommy Atkins (Table 3.3). Results suggest that sweetness levels of mango sorbet are not perceived to be higher than fresh mango and mango purée. Studies have found colder products to be lower in perceived sweetness (Calviño 1986; Green and Frankmann 1988), and this temperature effect may prevent sweetness intensity from rising once fresh mango and mango purée are transformed into sorbet. Tommy Atkins, the cultivar with the lowest TSS content in fresh and puréed form, was the only variety with a significant increase ($P < 0.05$) in perceived sweetness after processing into sorbet.

Although pH measurements indicate varying levels of acidity among cultivars for each of the processing stages (Table 3.2), panelists only distinguished Tommy Atkins purée as being higher in sourness than the other purées (Table 3.3). The pH did not change for any of the

cultivars at the various processing stages; however, sorbets were perceived as less sour than fresh and purée samples. All pH measurements were taken at room temperature, but studies show that pH increases at temperatures below freezing (Williams-Smith and others 1977) and this change in hydrogen ion concentration may reduce the perceived sourness intensity in mango sorbet. Also, previous research reports that sucrose suppresses the perceived intensity of citric acid (McBride and Johnson 1987), which may also lead to lower intensities of sourness in sorbet samples.

Conclusions

Many of the flavor distinctions among mango cultivars carried over from fresh mangoes to mango purées. Thermal processing had unique effects on the flavor of some cultivars; it maintained the mango flavor of fresh Haden while reducing the intensity of this attribute in other cultivars, and it significantly increased vegetable, astringent, and metallic notes in fresh Kent. Much of the texture variation among cultivars was lost after fresh samples were transformed into purées. Mango purée manufacturers should therefore select cultivars based on their properties after thermal treatment. Processing purées into sorbets minimized flavor variations among cultivars, and results show that Tommy Atkins was the only cultivar with a distinct flavor from the others in sorbet. Sorbets had reduced intensities of astringent, sour, and overall sour notes compared to purées, which is likely due to increased sugar content and reduced temperature. Based on results from the present study, sorbet manufacturers should keep in mind that 1) some of the flavor properties of mango are masked in mango sorbet and 2) only very distinct flavor properties of mango cultivars carry over to sorbets.

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CHAPTER 4 - Comparison of Sensory Attributes in Fresh Mangoes and Heat-treated Mango Purées Prepared from Thai Cultivars

Abstract

Evaluating the effects of heat processing on the sensory properties of mango cultivars can assist in determining possible applications and markets for mango purées, and it can also aid in selecting varieties that will satisfy consumer demand. Six mango cultivars grown in Thailand were investigated in this study. Highly trained descriptive panelists evaluated the flavor and texture of fresh samples and heat-treated purées prepared from each cultivar. Purées were made by pulverizing mango flesh, passing it through a china cap (2.5 mm mesh size), and heating it to 85 °C for 15 s. In general thermal processing increased caramelized, cooked, and vegetable flavors and eliminated throat irritation and tongue burn. It had unique effects on the flavor of each cultivar, especially Nam Dok Mai and Chok Anun; mango identity and peach flavor notes decreased significantly in Nam Dok Mai, whereas Chok Anun showed significant increases in mango identity, pineapple, and sweet flavor notes. Although a slight amount of flavor variation among cultivars was lost because of thermal processing, most of the variation in texture was eliminated. Because of significant changes in flavor and texture after heat treatment of mango cultivars, manufacturers should select cultivars for mango purées based on their properties after thermal processing.

Introduction

Often called "The King of Fruits," mango (*Mangifera indica* L.) is one of the most popular tropical fruits worldwide. Statistics from 2008 indicate that mangoes comprised 31.5 out of 82.7 million metric tons of global tropical fruit production (FAO 2009). A major limitation on the exportation of fresh mango is its short shelf-life; mangoes are subject to chilling injury during storage, but increasing storage temperatures leads to rapid decay in fruit quality (Mohammed and Brecht 2002; Nair and Singh 2009). Therefore, fresh mango is often processed to extend its shelf-life and facilitate exportation. Thailand is one of the leading mango producers (USDA 2010) and exporters of mango purée (FAOSTAT 2008).

To maintain the quality of mango purée, heat is applied to reduce microbial count and the activities of enzymes that contribute to browning (Vásquez-Caicedo and others 2004). Heat

treatment leads to carotenoid degradation and therefore color loss (Vásquez-Caicedo and others 2007), and it has been found to decrease concentrations of volatile compounds (Kimura and others 1994; Yen and Lin 1999). Thermal processing typically has little effect on more stable compounds such as sugars and acids (Garde-Cerdán and others 2007; Zhou and others 2009; Zhang and others 2010); however, high processing temperatures (> 160 °C) may degrade citric acid (Thankitunthorn and others 2009).

Over a thousand varieties of mangoes are available worldwide (Mukherjee 1953), and mango purée can be prepared with any of these varieties. Mango cultivars vary greatly in aroma, flavor, and texture. Total soluble solids (TSS) content, an indication of sweetness, ranges from 12.0 to 23.0 °Brix among cultivars for ripe mangoes, whereas acidity ranges from 0.12 to 0.38% (Jha and others 2010a). More than 285 volatile compounds were identified in various cultivars (Singh and others 2004) with hydrocarbon monoterpenes and sesquiterpenes being the dominant volatiles in most varieties (Ollé and others 1998; Quijano and others 2007; Pandit and others 2009). Mango cultivars have been found to vary in volatile composition (Tamura and others 2000; Pino and others 2005; Quijano and others 2007; Pandit and others 2009), flesh firmness (Chaikiattiyos and others 2000; Araiza and others 2005), and dietary fiber composition (Zaied and others 2007).

Although instrumental measurements on mango cultivars are well documented, only a few studies have used descriptive analysis to determine the effects of cultivar variation on the sensory qualities of mango. Malundo and others (1996) developed a lexicon to describe flavor characteristics of fresh mango, and using this terminology, a later study showed that the attributes sweet, biting, sour, and peachy varied greatly between Tommy Atkins and Van Dyke cultivars (Malundo and others 2001). In a study by Vásquez-Caicedo and others (2002), 9 Thai cultivars were evaluated using terms to describe basic tastes, aroma, feeling factors, aftertaste, and texture. The study showed that Okrong Kiew was highest in sour taste and lowest in sweet taste, whereas Chok Anun was highest in firmness and chewiness. Suwonsichon and others (*Personal Communication*) expanded the fresh mango lexicon and evaluated 9 cultivars grown in Thailand, showing that Nam Dok Mai ranked highest for mango identity, fruity, and sweet attributes, whereas Ok Rong had distinct chemical, peel-like, sour, and bitter flavors.

Very limited research has been conducted to evaluate the effect of processing on the sensory properties of mango. One study evaluated the effect of concentrating volatile compounds

through evaporation at mild temperatures (40 ºC), showing that processing lowered the intensities of sweet, peachy, sweet potato, and banana attributes, whereas it increased the intensities of sour, bitter, and orange peel attributes (Malundo and others 1996). A study on U.S. cultivars indicated that mango purées were generally lower in fruity flavor and higher in metallic, vegetable, and starchy flavors compared to fresh mango (Ledeker and others 2011 *In Preparation*). This study also showed that thermal processing affected the flavor properties of cultivars in different ways, such as reducing chemical flavor in Haden and increasing astringency in Kent (2011 *In Preparation*). Further research on how the perceived flavor and texture of mango cultivars change as they are processed into purée could assist exporters in selecting varieties that will be successful in their target markets.

The present study evaluates the effects of processing on the sensory qualities of mango cultivars commonly grown in Thailand. The objectives of this study were to 1) compare the flavor and texture properties of various mango cultivars in fresh and puréed forms and 2) evaluate the effect of heat processing on the flavor and texture of these cultivars.

Materials and Methods

Mango samples

Six Thai cultivars (Chok Anun, Kaew Leam Rung, Nam Dok Mai, Nung Klang Won, Ok Rong, and Thongdam) were obtained from Janted Farm in Prachuap Khiri Khan Province, Thailand. The mangoes were harvested at the mature-green stage, ripened at room temperature (24 ± 1 °C), and used or processed within 4 d after ripening. For all samples, undamaged, ripe fruit were selected based on conventional ripeness indices (soft to touch and appropriately colored skin for a given cultivar).

Preparation of purée

Mango purées were made from each cultivar and were prepared in separate batches for each replication based on methods adapted from a previous study (Ledeker and others 2011 *In Preparation*). For each batch, mangoes of a single cultivar were manually peeled, and the flesh was cut from the seeds. The flesh (925.0 g) was combined and puréed for 3 min using an immersion blender (Model HR1372/90; Philips U.S.A., Andover, Mass.), which was then passed through a china cap with a 2.5 mm mesh size (Model CCCS-8C; Winco Industries Co., Lodi,

N.J., U.S.A.). The purée was heated rapidly in a saucepan (1.89 L; Magnalite, World Kitchen LLC, Greencastle, Pa., U.S.A.) on a gas stove with constant stirring until it remained at 85 °C for 15 s (Isaacs 1991). After heating, each batch was cooled immediately to 35 °C using an ice bath, and purées were placed in multipurpose bags (3.79 L; Ziploc®, S. C. Johnson & Son, Inc., Racine, Wis., U.S.A.), frozen at -18 °C, and tested within 1 wk of preparation. According to MacLeod and Snyder (1988), freezing of mangoes has little effect on their volatile composition.

Instrumental measurements

TSS and pH of fresh and purée samples were measured using a digital refractometer (Model Palette PR101α; Atago U.S.A., Inc., Bellevue, Wash., U.S.A.) and a digital pH meter (Model CyberScan pH 510; Eutech Instruments Pte. Ltd., Singapore), respectively. All measurements were taken at room temperature (24 ± 1 °C).

Orientation and lexicon development

Seven highly-trained panelists from Kasetsart University's Sensory and Consumer Research Center (Bangkok, Thailand) evaluated the fresh and purée samples prepared from each of the 6 cultivars. Panelists completed a 120-h descriptive training course and had more than 1,700 h of testing experience with a variety of food products. Prior to testing, 3 d of orientation were held during which panelists developed lexicons describing the flavor and texture of fresh mango and mango purée. To assist in identifying attributes they were provided with terminology used in a previous study by Ledeker and others (2011 *In Preparation*). Panelists tasted all samples, discussed possible terms, and compiled a final list of attributes for testing. During orientation, panelists also discussed attribute definitions, attribute references, and evaluation procedures. Most attributes, definitions, and references were consistent with the lexicons for fresh mango and mango purée used by Ledeker and others (2011 *In Preparation*); however, the terms guava, sulfur, throat irritation, and tongue burn were added to the lexicons. All attributes and definitions used for testing in the current study are listed in Table 4.1.

Table 4.1 Terms and definitions used in evaluating fresh mango and mango puree.

Attribute	Definition
Flavor	
Mango Identity	A sweet, fruity, green, somewhat woody and piney aromatic associated with mango that sometimes may include aromatics similar to other specific fruits, such as peach, orange, grapefruit, and/or pineapple.
Fruity	An aroma blend which is sweet and reminiscent of a variety of different fruits. When possible, specific fruits were described.
Grapefruit	A natural, sour, slightly sweet, fruity, somewhat musty, woody, pungent, citrus-like aromatic associated with grapefruit.
Guava**	A green, sweet aromatic associated with ripe guava.
Orange	A natural, sweet, fruity, floral, slightly sour and citrus-like aromatic associated with oranges.
Peach	Aromatic associated with ripe peach which includes floral, perfumy, sweet, sometimes woody and green notes, and can have a hint of fermented note.
Pineapple	A sweet, woody, slightly sharp, floral aromatic associated with pineapple.
Caramelized	A round, full bodied, medium brown aromatic.
Cooked**	An aromatic impression associated with a cooked fruit rather than fresh, uncooked fruit.
Chemical	A general term associated with many different types of compounds generally known as chemicals.
Green	Slightly sour aromatic, commonly associated with under-ripe fruit.
Green-viney	Green, fresh aromatic associated with newly cut vines and stems. It sometimes relates to cucumber.
Fermented	A combination of aromatics that are sweet, slightly brown, overripe, and somewhat sour.
Floral/Perfumy	A sweet, heavy aromatic blend of a combination of flowers which can be somewhat chemical and perfume-like.

Attribute	Definition
Musty	An aromatic that has a damp, earthy character similar to fresh mushrooms.
Peel-like	A slightly sharp aromatic that can be described as slightly sour and bitter. It is commonly associated with citrus peel.
Piney	A slightly sharp resinous aromatic that may be medicinal or chemical in character. It is associated with green pine needles or pine pitch.
Spicy	A sweet brown, slightly musty aromatic reminiscent of cinnamon.
Starchy	A bland, cooked vegetable-like aromatic associated with the meat of a baked sweet potato or squash.
Sulfur	A slightly sweet acrid, pungent, harsh irritating aromatic reminiscent of matches, cap guns, gun powder, and Durian.
Vegetable (yellow squash-like)	Sweet, musty, earthy aroma characteristic of yellow squash.
Overall Sweet	Aromatics and flavor notes associated with the impression of all sweet substances.
Overall Sour	Aromatics and flavor notes associated with the impression of all sour substances.
Sweet	The fundamental taste sensation of which sucrose is typical.
Bitter	The fundamental taste sensation of which caffeine or quinine are typical.
Sour	The fundamental taste sensation of which citric acid is typical.
Astringent	The complex of drying, puckering, shrinking sensations in the oral cavity.
Metallic	The chemical feeling factor on the tongue described as flat, associated with iron, copper, and silver spoons.
Throat Irritation*	An irritating feeling in the throat that causes one to feel like coughing. This may result from the taste or texture of the

Attribute	Definition
	sample after swallowing. Two pieces are evaluated at a time.
Tongue Burn*	A burning feeling, prickling, and/or numbness of the tongue. However, it does not cover heat burn.
Texture	
Chalky Mouthfeel	A dry, powdery sensation in the mouth.
Slimy	Degree to which a thick, mucous-like substance is perceived in the mouth during mastication.
Slickness	Ease with which a product slides around in the mouth during mastication (2.46 mL of product).
Fiber Awareness	The degree to which fibers are present. Evaluated during mastication after 5 to 8 chews (excluding skin).
Pulpy Residue	A soft moist residue.
Cohesiveness of Mass*	Degree to which the mass holds together after 7 chews.
Firmness*	The force required to compress the sample between the tongue and palate.
Viscosity**	The measure of flow as the product moves on the tongue when pressed between the tongue and the palate (2.46 mL of product).
Mealy**	The perception of fine, soft particles distributed within the product.
Mouthcoating**	Sensation of having a slick coating on the tongue and other mouth surfaces (2.46 mL swallowed after 3 manipulations).

*Only applies to fresh mango.
**Only applies to mango purée.

Sample preparation and serving

Fresh sliced samples were prepared as described in a study by Ledeker and others (2011 *In Preparation*). For each evaluation, panelists received 6 pieces randomly selected from fruits of a single cultivar, and samples were served directly after cutting in 100 mL plastic bowls with lids (Eastern Polypack Co., Ltd., Bangkok, Thailand). Frozen mango purée samples were thawed in the refrigerator (3.5 °C) overnight and served at room temperature (24 ± 1 °C). Panelists received 44.4 mL of each purée sample in 85.0 mL plastic cups (Eastern Polypack Co., Ltd., Bangkok, Thailand) upon evaluation. All samples were labeled with 3-digit random codes.

Test design and sample evaluation

Three replicates were evaluated for each sample, and a completely randomized design was used to determine the serving order within each replication. Panelists rated the intensities of each attribute on a scale from 0 (none) to 15 (extremely high) with 0.5 increments using a hybrid method adapted from the Flavor Profile Method (Keane 1992). References were provided during evaluations to anchor values on the scale. Reverse osmosis purified water and unsalted crackers (Jacob's Cream Crackers; Kraft Foods Malaysia, Petaling Jaya) were used to cleanse the palate between samples.

Data analysis

One-way Analysis of Variance (ANOVA) was performed to compare physico-chemical properties across all samples and to compare flavor and texture attributes among cultivars in the fresh and purée forms. The MIXED procedure in SAS® (version 9.2; SAS Institute Inc., Cary, N.C., U.S.A.) was used to conduct ANOVA, and the means of each attribute showing significant differences were separated using Fisher's Least Significant Difference (LSD) at 5% level of significance. To evaluate the effect of heat processing on the flavor of each cultivar, principal component analysis (PCA) was carried out (Unscrambler, 2008, version 9.8; Camo A/S, Oslo, Norway).

Results and Discussion

Physicochemical analyses

Kaew Leam Rung had the highest ($P < 0.05$) TSS values for both fresh and purée samples (Table 4.2), whereas all other cultivars had similar ($P < 0.05$) TSS content. Fresh Nam Dok Mai had a higher ($P < 0.05$) pH than fresh Chok Anun, Nung Klang Won, and Thongdam. Purées varied less in pH among cultivars than fresh samples. The only significant difference in pH for purées was that the Nung Klang Won sample had a lower pH than the Kaew Leam Rung and Nam Dok Mai samples. Heat processing did not significantly ($P < 0.05$) affect TSS or pH for any of the cultivars. These results are consistent with previous studies on fruit and vegetable juices supporting that thermal pasteurization at temperatures lower than 100 °C has little effect on pH and TSS (Garde-Cerdán and others 2007; Zhang and others 2010; Zhou and others 2009).

Table 4.2 TSS content and pH values of fresh mango and mango purée prepared from Thai cultivars.

	Cultivar	TSS (°Brix)	pH
Fresh	Chok Anun	16.5^{b}	4.61^{c}
	Kaew Leam Rung	21.1^{a}	4.88^{ab}
	Nam Dok Mai	17.6^{b}	5.02^{a}
	Nung Klang Won	15.9^{b}	4.54^{c}
	Ok Rong	18.4^{b}	4.70^{abc}
	Thongdam	16.3^{b}	4.70^{bc}
Purée	Chok Anun	17.5^{b}	4.62^{abc}
	Kaew Leam Rung	21.6^{a}	4.91^{a}
	Nam Dok Mai	17.3^{b}	4.87^{ab}
	Nung Klang Won	17.0^{b}	4.42^{c}
	Ok Rong	17.7^{b}	4.68^{abc}
	Thongdam	15.7^{b}	4.71^{abc}

Means with different superscripts within a column are significantly different ($P < 0.05$).

Flavor evaluation

ANOVA results show that 20 out of 30 flavor attributes significantly differed among the samples tested. Table 4.3 shows mean scores of attributes for all samples. Nam Dok Mai and Ok Rong had the most distinct flavor profiles compared to the other cultivars. Fresh and processed Nam Dok Mai were higher ($P < 0.05$) in caramelized and overall sweet flavors and lower in grapefruit, green, and green-viney flavors than most other cultivars. Fresh Nam Dok Mai also had the highest intensities ($P < 0.05$) of floral/perfumy and sweet flavors and the lowest intensity ($P < 0.05$) of piney flavor. With the exception of Ok Rong, fresh Nam Dok Mai was higher ($P < 0.05$) in mango identity than the other cultivars. For Ok Rong, both fresh and processed samples had higher intensities ($P < 0.05$) of mango identity, fruity, floral/perfumy, and sweet attributes than most other cultivars, and they had lower intensities ($P < 0.05$) of vegetable flavor. The dominant aromatic compound in Nam Dok Mai and Ok Rong is terpinolene, which has a floral, fragrant scent and may contribute to the floral/perfumy flavor of these cultivars (MacLeod and Snyder 1985; Tamura and others 2000). Fresh Ok Rong was also relatively high in caramelized flavor and low in chemical flavor, while Ok Rong purée was relatively high in pineapple flavor.

Table 4.3 Mean scores of flavor and texture attributes for fresh mango and mango purée prepared from Thai cultivars.

	Fresh						Purée					
Attribute	**CA**	**KR**	**NM**	**NW**	**OR**	**TH**	**CA**	**KR**	**NM**	**NW**	**OR**	**TH**
Flavor												
Mango Identity	4.1^{f}	4.5^{ef}	7.6^{ab}	4.5^{def}	7.7^{a}	5.0^{def}	7.8^{a}	5.2^{de}	5.4^{de}	5.6^{cd}	8.1^{a}	6.6^{bc}
Fruity	2.9^{abcd}	2.3^{def}	2.6^{bcde}	2.5^{cdef}	3.3^{a}	2.5^{cdef}	3.1^{ab}	2.1^{ef}	2.0^{f}	2.4^{cdef}	2.9^{abc}	2.8^{abcd}
Peach	2.3^{a}	0.7^{gh}	2.2^{ab}	0.7^{h}	1.8^{bcd}	2.0^{abc}	1.7^{cde}	1.1^{f}	1.5^{def}	1.1^{fg}	1.3^{ef}	1.7^{cde}
Orange	1.5^{bcd}	1.2^{d}	1.6^{abc}	1.2^{d}	1.6^{abc}	1.9^{a}	1.7^{ab}	1.3^{cd}	1.5^{bcd}	1.5^{bcd}	1.8^{ab}	1.8^{ab}
Grapefruit	0.6^{cdef}	1.2^{a}	0.3^{ef}	1.0^{ab}	0.7^{bcd}	0.3^{def}	0.6^{bcde}	0.7^{bc}	0.2^{f}	0.8^{abc}	0.7^{bc}	0.6^{cdef}
Guava	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.5^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.1^{b}	0.4^{a}
Pineapple	1.5^{bcde}	1.6^{abcde}	1.5^{cde}	1.8^{abcd}	1.9^{abc}	1.4^{de}	2.0^{a}	1.4^{e}	1.4^{e}	1.8^{abcde}	2.0^{ab}	1.5^{bcde}
Caramelized	1.4^{d}	1.6^{d}	2.5^{abc}	1.3^{d}	2.2^{c}	1.6^{d}	2.4^{bc}	3.1^{a}	2.9^{ab}	2.6^{abc}	2.5^{bc}	2.3^{c}
Cooked	-	-	-	-	-	-	7.3^{c}	7.8^{a}	7.8^{ab}	7.5^{c}	7.5^{bc}	7.4^{c}
Chemical	1.2^{abc}	1.4^{a}	0.7^{e}	1.1^{abc}	0.8^{de}	1.0^{bcd}	1.0^{cde}	1.2^{ab}	0.9^{cde}	1.1^{bcd}	1.1^{abc}	1.2^{abc}
Green	2.2^{ab}	2.4^{a}	1.4^{ef}	2.2^{ab}	1.8^{cd}	1.6^{cde}	1.7^{cde}	1.8^{cd}	1.0^{f}	1.8^{cd}	1.9^{bc}	1.5^{de}
Green-viney	2.0^{bc}	2.5^{a}	1.4^{d}	2.0^{bc}	1.7^{cd}	1.6^{cd}	1.8^{cd}	2.6^{a}	1.5^{d}	2.4^{ab}	2.6^{a}	1.7^{cd}
Fermented	1.0^{cd}	1.2^{bcd}	1.7^{a}	1.0^{d}	1.5^{ab}	1.6^{ab}	1.4^{abc}	1.5^{ab}	1.6^{ab}	1.2^{bcd}	1.3^{bcd}	1.5^{ab}
Floral/Perfumy	2.1^{def}	1.9^{f}	3.4^{a}	1.9^{ef}	2.9^{b}	2.1^{def}	2.6^{bcd}	2.2^{cdef}	2.3^{cdef}	2.4^{bcde}	2.7^{bc}	2.2^{cdef}
Musty	0.1	0.2	0.2	0.1	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Peel-like	2.3^{ab}	2.5^{a}	1.6^{c}	2.5^{a}	2.0^{bc}	1.8^{c}	1.7^{c}	1.7^{c}	1.1^{d}	2.0^{bc}	2.0^{bc}	1.6^{c}
Piney	2.0^{ab}	2.2^{a}	1.4^{d}	2.0^{ab}	1.9^{abc}	1.9^{abc}	1.5^{cd}	1.9^{abc}	1.4^{d}	1.8^{bcd}	1.9^{abc}	1.6^{bcd}
Spicy	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Starchy	1.4	1.5	1.2	1.5	1.4	1.5	1.7	1.8	1.5	1.5	1.6	1.7
Sulfur	1.0	1.6	1.5	1.1	1.2	1.0	1.2	1.8	1.1	1.2	1.4	1.3

Vegetable	2.3^{bcde}	2.1^{de}	2.0^{ef}	2.0^{e}	1.6^{f}	2.5^{abc}	2.5^{abc}	2.7^{a}	2.7^{a}	2.5^{abcd}	2.2^{cde}	2.6^{ab}
Overall Sweet	3.2^{c}	3.5^{bc}	5.2^{a}	3.1^{c}	4.7^{ab}	3.5^{bc}	4.4^{abc}	4.7^{ab}	4.2^{abc}	3.9^{abc}	4.8^{ab}	3.8^{bc}
Overall Sour	1.7	1.5	1.4	2.0	2.0	1.6	2.0	1.5	1.2	1.7	1.9	1.7
Sweet	5.6^{g}	6.6^{def}	8.1^{a}	5.7^{fg}	7.1^{bcde}	6.3^{efg}	6.9^{cde}	8.0^{ab}	7.7^{abc}	7.0^{cde}	7.5^{abcd}	6.8^{cde}
Bitter	1.3	1.1	0.6	1.0	0.8	0.9	0.8	0.8	0.8	0.8	0.8	1.2
Sour	1.5	1.5	1.1	1.7	1.7	1.5	2.0	1.3	1.0	1.6	2.0	1.7
Astringent	1.3	1.3	1.0	1.3	1.1	1.1	1.2	1.1	1.1	1.3	1.2	1.2
Metallic	0.9	1.0	0.9	1.0	0.9	0.9	0.9	1.0	0.8	0.9	1.0	1.0
Throat Irritation	1.2^{b}	1.8^{a}	1.2^{b}	1.8^{a}	1.7^{a}	1.2^{b}	-	-	-	-	-	-
Tongue Burn	1.3	1.5	1.4	1.7	1.7	1.3	-	-	-	-	-	-
Texture												
Chalky Mouthfeel	0.7^{cd}	0.8^{bcd}	0.5^{d}	0.8^{bcd}	0.9^{abc}	0.5^{d}	1.1^{a}	1.1^{ab}	0.8^{abcd}	1.0^{ab}	0.9^{abc}	0.9^{abc}
Slimy	8.3^{cd}	8.7^{ab}	8.8^{a}	8.7^{ab}	8.5^{abcd}	8.6^{abc}	8.3^{d}	8.4^{bcd}	8.2^{d}	8.5^{abcd}	8.3^{cd}	8.4^{bcd}
Slickness	8.0^{bc}	8.5^{a}	8.8^{a}	8.4^{ab}	8.5^{a}	8.4^{ab}	7.6^{c}	7.7^{c}	7.8^{c}	7.8^{c}	7.8^{c}	8.0^{bc}
Fiber Awareness	3.3^{b}	3.1^{bc}	2.9^{bc}	3.1^{bc}	4.3^{a}	2.9^{c}	1.6^{d}	1.1^{ef}	0.8^{f}	1.3^{de}	1.2^{ef}	1.1^{ef}
Pulpy Residue	2.7^{b}	2.7^{b}	2.7^{b}	2.8^{b}	3.3^{a}	2.7^{b}	1.4^{c}	1.0^{d}	0.8^{d}	1.2^{cd}	1.0^{d}	0.8^{d}
Cohesiveness of Mass	7.4	7.2	7.0	7.1	7.1	7.2	-	-	-	-	-	-
Firmness	10.7^{a}	9.0^{cd}	8.1^{de}	10.2^{ab}	7.7^{e}	9.3^{bc}	-	-	-	-	-	-
Viscosity	-	-	-	-	-	-	9.8^{a}	9.8^{a}	6.7^{c}	9.2^{a}	7.5^{bc}	8.7^{ab}
Mealy	-	-	-	-	-	-	1.2^{a}	1.1^{ab}	0.8^{c}	1.2^{a}	1.0^{bc}	1.0^{abc}
Mouthcoating	-	-	-	-	-	-	8.7	8.6	8.4	8.5	8.6	8.6

Means with different superscripts within a row are significantly different (LSD, $P < 0.05$).
Attributes found in both fresh and purée samples were evaluated across all samples. Dashes indicate that attributes were not evaluated.
CA = Chok Anun; KR = Kaew Leam Rung; NM = Nam Dok Mai; NW = Nung Klang Won; OR = Ok Rong; TH = Thongdam.

Fresh Nung Klang Won had lower intensities of peach, orange, and fermented notes than most other cultivars, whereas Nung Klang Won purée was higher in pineapple and green-viney flavors than most other cultivars (Table 4.3). Fresh and processed Thongdam were relatively low in green-viney flavor, and fresh Thongdam was also relatively low in grapefruit, green, and peel-like flavors. Compared to the other cultivars Thongdam and Chok Anun purées were higher ($P < 0.05$) in guava flavor, and Chok Anun purée was also higher in mango identity, fruity, and pineapple flavors. Kaew Leam Rung purée had the highest ($P < 0.05$) intensity of green-viney flavor, and it was also high in caramelized, cooked, and sweet flavors. Fresh Kaew Leam Rung had a lower intensity ($P < 0.05$) of peach flavor than the other cultivars with the exception of Nung Klang Won. Fresh Kaew Leam Rung, Nung Klang Won, and Ok Rong were higher ($P < 0.05$) in throat irritation than Chok Anun, Nam Dok Mai, and Thongdam. Throat irritation may result from a combination of factors such as acidity, astringency, and fibrous texture (Lee and Lawless 1991; Gilmore and Green 1993; Dessirier and others 2000), although the relationship between throat irritation and these properties is not clear.

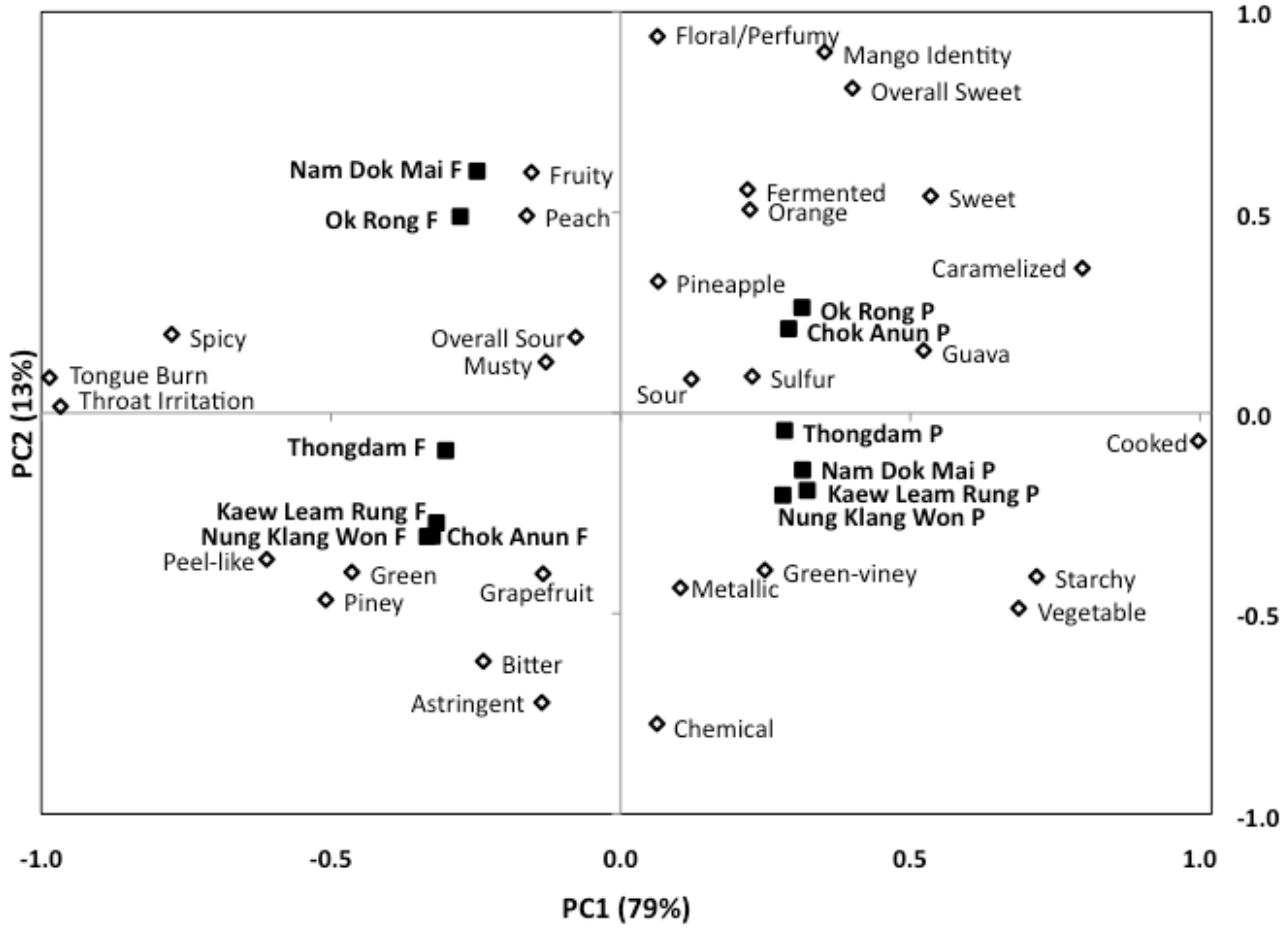
All purée samples had a cooked flavor that was not detected in fresh samples, whereas the attributes throat irritation and tongue burn were eliminated when fresh samples were processed into purées. Vegetable flavor increased ($P < 0.05$) in Kaew Leam Rung, Nam Dok Mai, Nung Klang Won, and Ok Rong as a result of processing, and it only slightly increased in Chok Anun and Thongdam (Table 4.3). The interaction of volatile compounds during heat processing may have changed the perceived flavor of the samples (Malundo and others 1996), and this may have led to an increase in vegetable flavor. Further studies should be conducted to evaluate the effect of heating on vegetable flavor in mango. Processing increased ($P < 0.05$) caramelized flavor in most of the cultivars with the exception of Nam Dok Mai and Ok Rong, which only had slight increases in caramelized flavor. The intensity of this attribute may have increased because of the development of aromatic compounds during browning reactions when purées were heated (Hodge and others 1972). Although a previous study on U.S. mango cultivars showed that fruity character decreased when fresh mango was processed into purée (Ledeker and others 2011 *In Preparation*), the present study on Thai cultivars does not show the same effect.

Processing had unique effects on individual cultivars. It increased ($P < 0.05$) the sweet taste of Chok Anun, Kaew Leam Rung, and Nung Klang Won. Processing also increased ($P < 0.05$) the intensity of mango identity for Chok Anun and Thongdam, whereas it decreased ($P <$

0.05) the intensities of mango identity, fruity, and peach attributes for Nam Dok Mai. Although processing lowered ($P < 0.05$) the intensity of peach flavor for Ok Rong, it increased ($P < 0.05$) the intensity of this attribute for Kaew Leam Rung and Nung Klang Won. Pineapple flavor was more noticeable ($P < 0.05$) in Chok Anun purée than in fresh Chok Anun, and the intensity of peel-like flavor decreased ($P < 0.05$) in Chok Anun, Kaew Leam Rung, and Nung Klang Won after processing. Ok Rong was the only cultivar with a significant ($P < 0.05$) increase in green-viney flavor due to processing, and although guava flavor was not detectable in any of the fresh samples, it was detected in slight amounts for Chok Anun and Thongdam purées.

PCA was used in addition to ANOVA to determine the effect of processing on the 6 Thai cultivars. The first 2 PCs explain 79% and 13% of the variance, respectively. PC 1 shows the effects of thermal processing, whereas PC 2 distinguishes among cultivars (Fig 4.1). PC 1 indicates that purées were generally higher in caramelized, cooked, starchy, and vegetable notes, which is relatively consistent with ANOVA results. Although starchy flavor has been found to be negatively correlated with heat processing of soymilk (N'Kouka and others 2004), this attribute in mango may be affected by heat in a different way. PC1 also indicates that fresh samples were generally higher in green, peel-like, piney, throat irritation, and tongue burn characteristics. These attributes may be associated with aromatic compounds (MacLeod and Snyder 1985; Boonbumrung and others 2001), and their intensities may be decreased by heat treatment due to the degradation of aromatic compounds (Kimura and others 1994; Yen and Lin 1999). Although a study by Varming and others (2004) on black currant juice suggests that perceptible changes in flavor due to heat degradation of volatiles only occur at high temperatures (> 90 °C), the current study shows that certain flavor characteristics decrease even with milder processing methods.

Figure 4.1 Sensory map of the first 2 principal components for comparing flavor attributes of fresh mango and mango purée.



F = fresh; P = purée.

On the PCA plot fresh samples have a larger spread than purées, indicating that some of the flavor variation among cultivars was lost because of thermal processing (Fig 4.1). Fresh and puréed Kaew Leam Rung, Nung Klang Won, and Thongdam samples were plotted on the lower half of the graph. Kaew Leam Rung and Nung Klang Won were similar to each other in flavor for each sample type, whereas Thongdam was positioned higher on the plot than these cultivars because of its higher peach intensity and its slightly lower intensities of green, green-viney, and peel-like flavors. Ok Rong was positioned on the upper half of the PCA plot because of its low

intensity of vegetable flavor and its high intensities of mango identity, floral/perfumy, fruity, and sweet flavors; however, Ok Rong purée was lower on the plot than fresh Ok Rong because processing increased green-viney flavor and decreased peach flavor. Nam Dok Mai and Chok Anun had the most dramatic shifts on the plot after processing. Although Nam Dok Mai was high in caramelized and sweet flavors and low in grapefruit, green, green-viney, peel-like, and piney flavors, processing significantly decreased the intensities of mango identity and peach, shifting Nam Dok Mai downward on the plot. These results suggest that heat treatment significantly reduces fruit-related characteristics in Nam Dok Mai. Chok Anun, on the other hand, moved upward on the PCA plot after processing because of significant increases in mango identity, pineapple, and sweet flavors, indicating that heat treatment heightened fruit-related characteristics in Chok Anun.

Texture evaluation

Panelists used chalky mouthfeel, slimy, slickness, fiber awareness, and pulpy residue to describe both fresh and purée samples. They used cohesiveness of mass and firmness to describe only fresh samples, whereas they used viscosity, mealy and mouthcoating to describe only purée samples. Based on ANOVA results, 8 out of 10 texture attributes showed significant differences ($P < 0.05$) among samples (Table 4.3). Cultivars generally increased in chalky mouthfeel after processing, which is inconsistent with a previous study on U.S. cultivars (Ledeker and others 2011 *In Preparation*). Processing may have a different effect on the Thai cultivars than on the U.S. cultivars. Compared to fresh samples, purées were generally lower in slimy texture and slickness, and they were significantly lower ($P < 0.05$) in fiber awareness for all cultivars. Slimy texture has been studied in more mucilaginous products like okra, and studies suggest that polysaccharide content contributes to slimy texture (Woolfe and others 1977; Sengkhamparn and others 2010). Homogenization of mango during the production of purée may reduce the perceived sliminess of these compounds; however, more studies need to be conducted to on this topic.

Fresh samples had more texture variation among cultivars than purées. Fresh Ok Rong was higher ($P < 0.05$) in fiber awareness and pulpy residue than all other cultivars. Fresh Chok Anun was lower ($P < 0.05$) in slickness than Kaew Leam Rung, Nam Dok Mai, and Ok Rong, and it was also lower ($P < 0.05$) in slimy texture than Kaew Leam Rung, Nam Dok Mai, and

Nung Klang Won. Slickness and slimy texture may be related since slimy texture may contribute to the ease with which samples slide around in the mouth. Firmness varied greatly among fresh samples. Cultivars were ordered in the following way from least to most firm: Chok Anun, Nung Klang Won, Thongdam, Kaew Leam Rung, Nam Dok Mai, and Ok Rong. Results are consistent with a previous study in which fresh Chok Anun rated highest in perceived firmness out 9 Thai mango cultivars (Vásquez-Caicedo and others 2002). Although one study suggests that mango cultivar firmness is related to TSS (Jha and others 2010b), results from the current study do not support this finding.

The texture of purées varied only slightly among cultivars. Chok Anun purée was higher ($P < 0.05$) in pulpy residue and fiber awareness than all cultivars except Nung Klang Won. Nam Dok Mai purée was lower ($P < 0.05$) in viscosity than purées prepared from the other cultivars. Previous studies have shown that mango purées prepared from various cultivars differ in instrumentally measured viscosity (Kansci and others 2003; Gowda and Huddar 2004), and the current study indicates that they also vary in perceived viscosity. Despite some texture variation among purée samples, results suggest that much of the texture variation among cultivars was lost during processing. None of the texture properties for mango purées contributed to texture variation as greatly as firmness did for fresh samples. Also, variation in slimy texture and slickness was reduced during processing, which may have resulted from the homogenization step of processing.

Comparison of physicochemical and sensory data

Sensory scores for sweet taste did not reflect trends in TSS. Although processing had no significant effect ($P < 0.05$) on TSS for any of the cultivars (Table 4.2), panelists detected higher levels ($P < 0.05$) of sweetness in purées compared to fresh samples for Chok Anun, Kaew Leam Rung, and Nung Klang Won (Table 4.3). The perceived sweetness may have been heightened by the increase in caramelized flavor during processing (Stampanoni Koeferli and others 1996). Panelists perceived Kaew Leam Rung purée to be high in sweetness, which was consistent with TSS measurements; however, they found fresh Nam Dok Mai to be sweeter ($P < 0.05$) than fresh Kaew Leam Rung, which was not consistent with TSS data. The high intensity of mango identity in fresh Nam Dok Mai may have increased perceived sweetness because of the association of fruity flavors with sweetness (Bonnans and Noble 1993). Heat processing did not significantly

affect perceived sourness intensity of the cultivars, which was consistent with pH measurements. Although pH measurements suggest variability in acidity among cultivars, perceived sourness did not vary significantly ($P < 0.05$) among cultivars.

Conclusions

In general thermal processing increased caramelized, cooked, and vegetable flavors and eliminated throat irritation and tongue burn in the Thai mango cultivars. It had unique effects on the flavor of each cultivar evaluated in this study, especially Nam Dok Mai and Chok Anun. The intensities of mango identity and peach significantly decreased in Nam Dok Mai after processing, whereas processing significantly increased mango identity, pineapple, and sweet flavors in Chok Anun. Therefore, manufacturers should select mango cultivars for purées based on their flavor properties after heat treatment. Further studies should be conducted to determine how these flavor properties affect consumer preference for mango purées. Although a slight amount of flavor variation among cultivars was lost due to thermal processing, most of the texture variation was eliminated, and therefore, it is likely that texture will have a negligible impact on the selection of mango varieties in the production of purées.

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Appendix A - Test design

Table A.1 Experimental design used in U.S. for fresh sliced mango, mango purée, and mango sorbet.

Date	Panelist	Sample	Code	Replication
6/10/2010	45	Kent Fresh	890	1
6/10/2010	45	Manila Fresh	973	1
6/10/2010	45	Haden Fresh	681	1
6/10/2010	45	Kent Fresh	386	2
6/10/2010	45	Tommy Fresh	610	1
6/10/2010	45	Tommy Fresh	123	2
6/10/2010	60	Tommy Fresh	123	1
6/10/2010	60	Tommy Fresh	610	2
6/10/2010	60	Kent Fresh	386	1
6/10/2010	60	Manila Fresh	973	1
6/10/2010	60	Haden Fresh	681	1
6/10/2010	60	Kent Fresh	890	2
6/10/2010	61	Tommy Fresh	123	1
6/10/2010	61	Tommy Fresh	610	2
6/10/2010	61	Manila Fresh	973	1
6/10/2010	61	Haden Fresh	681	1
6/10/2010	61	Kent Fresh	890	1
6/10/2010	61	Kent Fresh	386	2
6/10/2010	64	Kent Fresh	386	1
6/10/2010	64	Haden Fresh	681	1
6/10/2010	64	Manila Fresh	973	1
6/10/2010	64	Tommy Fresh	123	1
6/10/2010	64	Kent Fresh	890	2
6/10/2010	64	Tommy Fresh	610	2
6/10/2010	65	Tommy Fresh	123	1
6/10/2010	65	Haden Fresh	681	1
6/10/2010	65	Tommy Fresh	610	2
6/10/2010	65	Kent Fresh	386	1
6/10/2010	65	Kent Fresh	890	2
6/10/2010	65	Manila Fresh	973	1
6/10/2010	67	Manila Fresh	973	1
6/10/2010	67	Haden Fresh	681	1
6/10/2010	67	Kent Fresh	890	1

6/10/2010	67	Kent Fresh	386	2
6/10/2010	67	Tommy Fresh	123	1
6/10/2010	67	Tommy Fresh	610	2
6/11/2010	45	Haden Fresh	544	2
6/11/2010	45	Tommy Fresh	761	3
6/11/2010	45	Manila Fresh	330	2
6/11/2010	45	Haden Fresh	908	3
6/11/2010	45	Manila Fresh	747	3
6/11/2010	45	Kent Fresh	755	3
6/11/2010	60	Haden Fresh	908	2
6/11/2010	60	Kent Fresh	755	3
6/11/2010	60	Manila Fresh	747	2
6/11/2010	60	Haden Fresh	544	3
6/11/2010	60	Tommy Fresh	761	3
6/11/2010	60	Manila Fresh	330	3
6/11/2010	61	Kent Fresh	755	3
6/11/2010	61	Haden Fresh	544	2
6/11/2010	61	Manila Fresh	330	2
6/11/2010	61	Tommy Fresh	761	3
6/11/2010	61	Manila Fresh	747	3
6/11/2010	61	Haden Fresh	908	3
6/11/2010	64	Kent Fresh	755	3
6/11/2010	64	Haden Fresh	544	2
6/11/2010	64	Haden Fresh	908	3
6/11/2010	64	Tommy Fresh	761	3
6/11/2010	64	Manila Fresh	747	2
6/11/2010	64	Manila Fresh	330	3
6/11/2010	65	Haden Fresh	908	2
6/11/2010	65	Kent Fresh	755	3
6/11/2010	65	Haden Fresh	544	3
6/11/2010	65	Tommy Fresh	761	3
6/11/2010	65	Manila Fresh	747	2
6/11/2010	65	Manila Fresh	330	3
6/11/2010	67	Haden Fresh	908	2
6/11/2010	67	Tommy Fresh	761	3
6/11/2010	67	Manila Fresh	747	2
6/11/2010	67	Kent Fresh	755	3
6/11/2010	67	Manila Fresh	330	3
6/11/2010	67	Haden Fresh	544	3

6/15/2010	45	Kent Purée	422	1
6/15/2010	45	Haden Purée	647	1
6/15/2010	45	Manila Purée	807	1
6/15/2010	45	Haden Purée	752	2
6/15/2010	45	Tommy Purée	336	1
6/15/2010	45	Manila Purée	685	2
6/15/2010	60	Tommy Purée	336	1
6/15/2010	60	Kent Purée	422	1
6/15/2010	60	Haden Purée	752	1
6/15/2010	60	Manila Purée	807	1
6/15/2010	60	Manila Purée	685	2
6/15/2010	60	Haden Purée	647	2
6/15/2010	61	Manila Purée	807	1
6/15/2010	61	Kent Purée	422	1
6/15/2010	61	Manila Purée	685	2
6/15/2010	61	Tommy Purée	336	1
6/15/2010	61	Haden Purée	752	1
6/15/2010	61	Haden Purée	647	2
6/15/2010	64	Kent Purée	422	1
6/15/2010	64	Manila Purée	685	1
6/15/2010	64	Haden Purée	752	1
6/15/2010	64	Haden Purée	647	2
6/15/2010	64	Manila Purée	807	2
6/15/2010	64	Tommy Purée	336	1
6/15/2010	65	Tommy Purée	336	1
6/15/2010	65	Haden Purée	647	1
6/15/2010	65	Haden Purée	752	2
6/15/2010	65	Manila Purée	685	1
6/15/2010	65	Manila Purée	807	2
6/15/2010	65	Kent Purée	422	1
6/15/2010	67	Haden Purée	647	1
6/15/2010	67	Manila Purée	685	1
6/15/2010	67	Kent Purée	422	1
6/15/2010	67	Haden Purée	752	2
6/15/2010	67	Tommy Purée	336	1
6/15/2010	67	Manila Purée	807	2
6/16/2010	45	Manila Purée	552	3
6/16/2010	45	Tommy Purée	539	2
6/16/2010	45	Kent Purée	198	2

6/16/2010	45	Tommy Purée	891	3
6/16/2010	45	Haden Purée	671	3
6/16/2010	45	Kent Purée	271	3
6/16/2010	60	Kent Purée	271	2
6/16/2010	60	Tommy Purée	891	2
6/16/2010	60	Manila Purée	552	3
6/16/2010	60	Haden Purée	671	3
6/16/2010	60	Tommy Purée	539	3
6/16/2010	60	Kent Purée	198	3
6/16/2010	61	Kent Purée	198	2
6/16/2010	61	Tommy Purée	891	2
6/16/2010	61	Tommy Purée	539	3
6/16/2010	61	Kent Purée	271	3
6/16/2010	61	Manila Purée	552	3
6/16/2010	61	Haden Purée	671	3
6/16/2010	64	Manila Purée	552	3
6/16/2010	64	Tommy Purée	891	2
6/16/2010	64	Tommy Purée	539	3
6/16/2010	64	Kent Purée	271	2
6/16/2010	64	Haden Purée	671	3
6/16/2010	64	Kent Purée	198	3
6/16/2010	65	Tommy Purée	891	2
6/16/2010	65	Haden Purée	671	3
6/16/2010	65	Kent Purée	271	2
6/16/2010	65	Manila Purée	552	3
6/16/2010	65	Tommy Purée	539	3
6/16/2010	65	Kent Purée	198	3
6/16/2010	67	Manila Purée	552	3
6/16/2010	67	Haden Purée	671	3
6/16/2010	67	Tommy Purée	891	2
6/16/2010	67	Kent Purée	198	2
6/16/2010	67	Kent Purée	271	3
6/16/2010	67	Tommy Purée	539	3
6/21/2010	45	Haden Sorbet	604	1
6/21/2010	45	Tommy Sorbet	948	1
6/21/2010	45	Kent Sorbet	944	1
6/21/2010	45	Manila Sorbet	784	1
6/21/2010	45	Tommy Sorbet	812	2
6/21/2010	45	Kent Sorbet	871	2

6/21/2010	60	Tommy Sorbet	812	1
6/21/2010	60	Manila Sorbet	784	1
6/21/2010	60	Kent Sorbet	871	1
6/21/2010	60	Tommy Sorbet	948	2
6/21/2010	60	Kent Sorbet	944	2
6/21/2010	60	Haden Sorbet	604	1
6/21/2010	61	Manila Sorbet	784	1
6/21/2010	61	Haden Sorbet	604	1
6/21/2010	61	Tommy Sorbet	948	1
6/21/2010	61	Kent Sorbet	944	1
6/21/2010	61	Tommy Sorbet	812	2
6/21/2010	61	Kent Sorbet	871	2
6/21/2010	64	Tommy Sorbet	812	1
6/21/2010	64	Tommy Sorbet	948	2
6/21/2010	64	Kent Sorbet	944	1
6/21/2010	64	Haden Sorbet	604	1
6/21/2010	64	Manila Sorbet	784	1
6/21/2010	64	Kent Sorbet	871	2
6/21/2010	65	Haden Sorbet	604	1
6/21/2010	65	Tommy Sorbet	812	1
6/21/2010	65	Kent Sorbet	944	1
6/21/2010	65	Tommy Sorbet	948	2
6/21/2010	65	Manila Sorbet	784	1
6/21/2010	65	Kent Sorbet	871	2
6/21/2010	67	Tommy Sorbet	812	1
6/21/2010	67	Haden Sorbet	604	1
6/21/2010	67	Kent Sorbet	944	1
6/21/2010	67	Tommy Sorbet	948	2
6/21/2010	67	Kent Sorbet	871	2
6/21/2010	67	Manila Sorbet	784	1
6/22/2010	45	Kent Sorbet	774	3
6/22/2010	45	Manila Sorbet	988	2
6/22/2010	45	Haden Sorbet	619	2
6/22/2010	45	Haden Sorbet	817	3
6/22/2010	45	Manila Sorbet	542	3
6/22/2010	45	Tommy Sorbet	629	3
6/22/2010	60	Manila Sorbet	542	2
6/22/2010	60	Tommy Sorbet	629	3
6/22/2010	60	Manila Sorbet	988	3

6/22/2010	60	Kent Sorbet	774	3
6/22/2010	60	Haden Sorbet	817	2
6/22/2010	60	Haden Sorbet	619	3
6/22/2010	61	Haden Sorbet	817	2
6/22/2010	61	Tommy Sorbet	629	3
6/22/2010	61	Haden Sorbet	619	3
6/22/2010	61	Manila Sorbet	542	2
6/22/2010	61	Kent Sorbet	774	3
6/22/2010	61	Manila Sorbet	988	3
6/22/2010	64	Manila Sorbet	988	2
6/22/2010	64	Haden Sorbet	619	2
6/22/2010	64	Tommy Sorbet	629	3
6/22/2010	64	Kent Sorbet	774	3
6/22/2010	64	Manila Sorbet	542	3
6/22/2010	64	Haden Sorbet	817	3
6/22/2010	65	Manila Sorbet	988	2
6/22/2010	65	Haden Sorbet	817	2
6/22/2010	65	Tommy Sorbet	629	3
6/22/2010	65	Manila Sorbet	542	3
6/22/2010	65	Haden Sorbet	619	3
6/22/2010	65	Kent Sorbet	774	3
6/22/2010	67	Haden Sorbet	817	2
6/22/2010	67	Tommy Sorbet	629	3
6/22/2010	67	Manila Sorbet	988	2
6/22/2010	67	Haden Sorbet	619	3
6/22/2010	67	Kent Sorbet	774	3
6/22/2010	67	Manila Sorbet	542	3

Table A.2 Experimental design used in Thailand for fresh sliced mango and mango purée.

Date	Sample	Code	Replication
4/27/2011	Nung Klang Won Fresh	962	1
4/27/2011	Nam Dok Mai Fresh	821	1
4/27/2011	Kaew Leam Rung Fresh	385	1
4/28/2011	Ok Rong Fresh	494	1
4/28/2011	Chok Anun Fresh	609	1
4/28/2011	Thongdam Fresh	512	1
4/28/2011	Ok Rong Fresh	836	2
4/28/2011	Kaew Leam Rung Fresh	294	2
4/28/2011	Nung Klang Won Fresh	116	2
4/28/2011	Chok Anun Fresh	532	2
4/29/2011	Thongdam Fresh	945	2
4/29/2011	Nam Dok Mai Fresh	454	2
4/29/2011	Kaew Leam Rung Fresh	363	3
4/29/2011	Chok Anun Fresh	472	3
4/29/2011	Nam Dok Mai Fresh	765	3
4/29/2011	Ok Rong Fresh	660	3
4/29/2011	Thongdam Fresh	968	3
4/29/2011	Nung Klang Won Fresh	126	3
5/2/2011	Nam Dok Mai Purée	162	1
5/2/2011	Ok Rong Purée	896	1
5/2/2011	Nung Klang Won Purée	763	1
5/3/2011	Chok Anun Purée	354	1
5/3/2011	Kaew Leam Rung Purée	923	1
5/3/2011	Thongdam Purée	498	1
5/3/2011	Chok Anun Purée	937	2
5/3/2011	Nung Klang Won Purée	408	2
5/3/2011	Ok Rong Purée	163	2
5/3/2011	Thongdam Purée	370	2
5/4/2011	Nam Dok Mai Purée	595	2
5/4/2011	Kaew Leam Rung Purée	774	2
5/4/2011	Nung Klang Won Purée	241	3
5/4/2011	Thongdam Purée	332	3
5/4/2011	Nam Dok Mai Purée	500	3
5/4/2011	Ok Rong Purée	795	3
5/4/2011	Kaew Leam Rung Purée	674	3
5/4/2011	Chok Anun Purée	137	3

Appendix B - Ballots for descriptive testing

Ballot used in the U.S. for fresh sliced mango

Panelist:_____ Date:_____

	Flavor	*Sample:*	*Sample:*	*Sample:*	*Sample:*	*Sample:*	*Sample:*
1	Mango Identity						
2	Fruity						
3	Peach						
4	Orange						
5	Grapefruit						
6	Pineapple						
7	Animalic						
8	Black Pepper						
9	Caramelized						
10	Clove						
11	Chemical						
12	Cumin						
13	Green						
14	Green-viney						
15	Fermented						
16	Floral/Perfumy						
17	Musty						
18	Peel-like						
19	Piney						
20	Spicy						
21	Starchy						
22	Vegetable						
23	Woody						
24	Overall Sweet						
25	Overall Sour						
	Fundamental Taste						
26	Sweet						
27	Bitter						
28	Sour						
	Texture						
29	Firmness						
30	Cohesiveness of Mass						
31	Chalky Mouthfeel						
32	Particles						

33	Slimy						
34	Slickness						
35	Astringent						
36	Metallic						
37	Fiber Awareness						
38	Pulpy Residue						

Ballot used in the U.S. for mango purée

Panelist:_____ Date:_____

	Flavor	*Sample:*	*Sample:*	*Sample:*	*Sample:*	*Sample:*	*Sample:*
1	Mango Identity						
2	Fruity						
3	Peach						
4	Orange						
5	Grapefruit						
6	Pineapple						
7	Cooked						
8	Animalic						
9	Black Pepper						
10	Caramelized						
11	Clove						
12	Chemical						
13	Cumin						
14	Green						
15	Green-viney						
16	Fermented						
17	Floral/Perfumy						
18	Musty						
19	Peel-like						
20	Piney						
21	Spicy						
22	Starchy						
23	Vegetable						
24	Woody						
25	Overall Sweet						
26	Overall Sour						
	Fundamental Taste						
27	Sweet						
28	Bitter						
29	Sour						
	Texture						
30	Thickness						
31	Viscosity						
32	Mealy						
33	Chalky Mouthfeel						
34	Slimy						

35	Slickness						
36	Mouthcoating						
37	Astringent						
38	Metallic						
39	Fiber Awareness						
40	Pulpy Residue						

Ballot used in the U.S. for mango sorbet

Panelist:_____ Date:_____

	Flavor	*Sample:*	*Sample:*	*Sample:*	*Sample:*	*Sample:*	*Sample:*
1	Mango Identity						
2	Fruity						
3	Peach						
4	Orange						
5	Grapefruit						
6	Pineapple						
7	Cooked						
8	Animalic						
9	Black Pepper						
10	Caramelized						
11	Clove						
12	Chemical						
13	Cumin						
14	Green						
15	Green-viney						
16	Fermented						
17	Floral/Perfumy						
18	Musty						
19	Peel-like						
20	Piney						
21	Spicy						
22	Starchy						
23	Vegetable						
24	Woody						
25	Overall Sweet						
26	Overall Sour						
	Fundamental Taste						
27	Sweet						
28	Bitter						
29	Sour						
	Texture						
30	Metallic						
31	Astringent						
32	Firmness						
33	Density						
34	Meltdown						
35	Viscosity						

36	Iciness						
37	Mouthcoating						
38	Slimy						
39	Slickness						
40	Fiber Awareness						
41	Pulpy Residue						
42	Chalky Mouthfeel						

Ballot used in Thailand for fresh sliced mango

Panelist: _____ **Sample Code: _____** **Date _____**

FLAVOR

Mango Identity	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	**6.5**	7	**7.5**	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Fruity	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	**6**	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Peach	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	**8**	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Orange	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	**6.5**	7	7.5	8	**8.5**	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Grapefruit	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	**6**	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Pineapple	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	**6**	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Caramelized	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	**9**	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Chemical	0	0.5	1	1.5	2	**2.5**	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Green	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	**7**	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Green-viney	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	**9**	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Fermented	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	**7**	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Floral/Perfumy	0	0.5	1	1.5	2	2.5	3	3.5	4	**4.5**	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Musty	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	**10.5**	11	11.5	12	12.5	13	13.5	14	14.5	15
Peel-like	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	**13**	13.5	14	14.5	15
Piney	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	**6.5**	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Spicy	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	**9.5**	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Starchy	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	**8**	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Sulfur	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	**6.5**	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15

Vegetable	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	**7.5**	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Overall Sweet	0	0.5	1	1.5	2	2.5	3	3.5	4	**4.5**	5	5.5	6	6.5	7	7.5	8	8.5	**9**	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Overall Sour	0	0.5	1	1.5	2	2.5	3	3.5	4	**4.5**	5	5.5	6	6.5	7	7.5	**8**	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Sweet	0	0.5	1	1.5	**2**	2.5	3	3.5	**4**	4.5	5	5.5	**6**	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Sour	0	0.5	1	**1.5**	2	2.5	3	**3.5**	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Bitter	0	0.5	1	1.5	2	2.5	3	**3.5**	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
TEXTURE																															
Firmness	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	**5.5**	6	6.5	**7**	7.5	8	8.5	9	9.5	**10**	10.5	11	11.5	12	12.5	13	13.5	**14**	14.5	15
Cohesiveness of Mass	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	**6.5**	7	7.5	8	8.5	**9**	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Chalky Mouthfeel	0	0.5	1	1.5	2	2.5	**3**	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	**10**	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Slimy	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	**7.5**	8	8.5	9	9.5	10	10.5	**11**	11.5	12	12.5	13	13.5	14	14.5	15
Slickness	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	**7.5**	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Fiber Awareness	0	0.5	1	1.5	**2**	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	**10**	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Pulpy Residue	0	0.5	1	1.5	**2**	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Throat Irritation	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	**5**	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Tongue Burn	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	**8**	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Astringent	0	0.5	1	1.5	2	**2.5**	3	3.5	4	4.5	**5**	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Metallic	0	0.5	1	**1.5**	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15

Ballot used in Thailand for mango purée

Panelist: _____ **Sample Code: _____** **Date _____**

FLAVOR

Mango Identity	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	**6.5**	7	**7.5**	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Fruity	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	**6**	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Peach	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	**8**	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Orange	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	**6.5**	7	7.5	8	**8.5**	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Grapefruit	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	**6**	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Pineapple	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	**6**	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Guava	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	**6**	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Cooked	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	**6**	6.5	**7**	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Caramelized	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	**9**	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Chemical	0	0.5	1	1.5	2	**2.5**	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Green	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	**7**	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Green-viney	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	**9**	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Fermented	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	**7**	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Floral/Perfumy	0	0.5	1	1.5	2	2.5	3	3.5	4	**4.5**	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Musty	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	**10.5**	11	11.5	12	12.5	13	13.5	14	14.5	15
Peel-like	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	**13**	13.5	14	14.5	15
Piney	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	**6.5**	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Spicy	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	**9.5**	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15

Starchy	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	**8**	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Sulfur	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	**6.5**	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Vegetable	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	**7.5**	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Overall Sweet	0	0.5	1	1.5	2	2.5	3	3.5	4	**4.5**	5	5.5	6	6.5	7	7.5	8	8.5	**9**	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Overall Sour	0	0.5	1	1.5	2	2.5	3	3.5	4	**4.5**	5	5.5	6	6.5	7	7.5	**8**	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Sweet	0	0.5	1	1.5	**2**	2.5	3	3.5	**4**	4.5	5	5.5	**6**	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Sour	0	0.5	1	**1.5**	2	2.5	3	**3.5**	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Bitter	0	0.5	1	1.5	2	2.5	3	**3.5**	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
TEXTURE																															
Viscosity	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	**9**	9.5	10	10.5	**11**	11.5	12	12.5	13	13.5	14	14.5	15
Mealy	0	0.5	1	1.5	**2**	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	**14**	14.5	15
Chalky Mouthfeel	0	0.5	1	1.5	2	2.5	**3**	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	**10**	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Slimy	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	**7.5**	8	8.5	9	9.5	10	10.5	**11**	11.5	12	12.5	13	13.5	14	14.5	15
Slickness	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	**7.5**	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Mouthcoating	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	**8**	8.5	9	9.5	**10**	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Fiber Awareness	0	0.5	1	1.5	**2**	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Pulpy Residue	0	0.5	1	1.5	**2**	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Astringent	0	0.5	1	1.5	2	**2.5**	3	3.5	4	4.5	**5**	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15
Metallic	0	0.5	1	**1.5**	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15

Appendix C - Attributes, definitions, and references used in descriptive analysis

Definitions and references used in the U.S. to evaluate fresh mango

Mango Identity: A sweet, fruity, green, somewhat woody, and piney aromatic associated with mango that sometimes may include aromatics similar to other specific fruits, such as peach, orange, grapefruit, and/or pineapple.
Reference: Jumex Mango Nectar = 6.5
Reese Sliced Mango in Mango Juice = 7.5
Preparation: Cut Sliced Mango into 2.54 cm chunks and serve without juice in 92.1 g cups.

Fruity: An aroma blend, which is sweet and reminiscent of a variety of different fruits. When possible, specific fruits were described.
Reference: Trans-2-Hexenal (10,000 ppm) = 5.0
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Peach: Aromatic associated with ripe peach which includes floral, perfumy, sweet, sometimes woody, and green notes, and can have a hint of fermented note.
Reference: Fresh Peach Pit = 8.0
Preparation: Remove flesh from pit and place pit in medium snifter, covered.

Orange: A natural, sweet, fruity, floral, slightly sour, and citrus-like aromatic associated with oranges.
Reference: Majestic Mountain Sage Orange Valencia Essential Oil = 6.5
Majestic Mountain Sage Orange 5-Fold Essential Oil = 8.5
Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Grapefruit: A natural, sour, slightly sweet, fruity, somewhat musty, woody, pungent, citrus-like aromatic associated with grapefruit.
Reference: Grapefruit Essential Oil (Aura Cacia) = 6.0
Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Pineapple: A sweet, woody, slightly sharp, floral aromatic associated with pineapple.
Reference: Dole Canned Pineapple Juice and water (1:1 dilution) = 6.0

Animalic: Aromatic associated with sulfur compounds which exhibit skunk-like characteristic commonly associated with decaying animals.
Reference: Tincture of Civet = 6.0
Preparation: Place 1 drop on a cotton ball in a medium snifter, cover.

Black Pepper: Spicy, pungent, musty, and woody aromatics characteristic of ground black pepper.
Reference: McCormick Ground Black Pepper = 13.0
Preparation: Place 1.27 cm of pepper in medium snifter, cover.

Caramelized: A round, full bodied, medium brown aromatic.
Reference: C&H golden Brown Sugar = 9.0

Clove: A pungent, brown spicy aromatic.
Reference: LorAnne Gourmet Clove Leaf Oil = 12.0
Preparation: Place 1 drop of oil on cotton ball in covered snifter.

Chemical: A general term associated with many different types of compounds generally known as chemicals.
Reference: Borneol (10,000 ppm) = 2.5
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Cumin: A musty, brown, sweet, slightly pungent aromatic.
Reference: McCormick Ground Cumin=13.0
Preparation: 0.62 mL ground cumin in covered snifter.

Green: Slightly sour aromatic commonly associated with under-ripe fruit.
Reference: Green Granny Smith = 7.0
Preparation: Remove peel. Core and slice 1 apple into 10 slices using apple cutter. Cut each slice into 3 pieces. Serve in 92.1 g cups.

Green-viney: Green, fresh aromatic associated with newly cut vines and stems. It sometimes relates to cucumber.
Reference: 2-Isobutylthiazole (Givaudan; 10,000 ppm) = 9.0
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Fermented: A combination of aromatics that are sweet, slightly brown, overripe, and somewhat sour.
Reference: Blackberry WONF 3RA654 (Full Strength) = 7.0
Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Floral/ Perfumy: A sweet, heavy aromatics blend of a combination of flowers which can be somewhat chemical and perfume-like.
Reference: Geraniol (IFF; 10,000 ppm) = 7.5
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Musty: An aromatic that has a damp, earthy character similar to fresh mushrooms.
Reference: Sliced White Mushroom = 10.5
Preparation: Place sliced mushrooms in 92.1 g cup with lid.

Peel-like: A slightly sharp aromatic that can be described as slightly sour and bitter. It is commonly associated with citrus peel.
Preparation: Lime peel = 13.0
Preparation: In medium covered snifter. Measure out 3.2 g.

Piney: A slightly sharp resinous aromatic that may be medicinal or chemical in character. It is associated with green pine needles or pine pitch.
Reference: Isobornyl propionate (IFF) = 6.5
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Spicy: A sweet brown, slightly musty aromatics reminiscent of cinnamon.
Reference: McCormick Ground Allspice = 9.5
Preparation: A 2.46 mL in a medium snifter, covered.

Starchy: A bland, cooked vegetable-like aromatics associated with the meat of a baked sweet potato or squash.
Reference: Baked Sweet potato = 8.0
Preparation: Microwave a scrubbed baking potato on high for 8 min on high. Only meat portion is cut into 1.27 cm cubes.

Vegetable (yellow squash-like): Sweet, musty, earthy aroma characteristic of yellow squash.
Reference: Gerber squash baby food = 7.5

Woody: Flat, dark, dry, musty aromatics associated with the bark of a tree.
Reference: Oil of Cedar Wood (Aldrich; 10,000 ppm) = 6.0
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Overall Sweet: Aromatics and flavor notes associated with the impression of all sweet substances.
Reference: Lorna Doone Cookie = 4.5
6% C&H Brown Sugar in water = 9.0

Overall Sour: Aromatics and flavor notes associated with the impression of all sour substances.
Reference: Highland Sour Cream = 4.5

Fundamental Tastes:

Sweet: The fundamental taste sensation of which sucrose is typical.
Reference: 2% Sucrose Solution = 2.0
4% Sucrose Solution = 4.0
6% Sucrose Solution = 6.0

Bitter: The fundamental taste sensation of which caffeine or quinine are typical.

Reference: 0.02% Caffeine Solution = 3.5

Sour: The fundamental taste sensation of which citric acid is typical
Reference: 0.015% Citric Acid Solution = 1.5
0.050% Citric Acid Solution = 3.5

Metallic: The chemical feeling factor on the tongue described as flat, associated with iron, copper, and silver spoons.
Reference: 0.10% Potassium Chloride Solution = 1.5

Astringent: The complex of drying, puckering, shrinking sensations in the oral cavity.
Reference: 0.05% Alum Solution = 2.5
0.1% Alum Solution = 5.0

Texture:

Firmness: The force required to compress the sample between the tongue and palate.
Reference: Highland Sour Cream = 5.5
Philadelphia Light Cream Cheese (tub) = 7.0
Philadelphia Cream Cheese (tub) = 10.0
Philadelphia Cream Cheese = 14.0

Cohesiveness of Mass: Degree to which the mass holds together after 7 chews.
Reference: Oscar Mayer Wieners = 6.5
Sweet potato = 9.0
Preparation: Cut wieners into 1.27 cm cross-sections.
Microwave a scrubbed sweet potato on high for 8 min. Only meat portion is cut into 1.27 cm cubes.

Chalky Mouthfeel: A dry, powdery sensation in the mouth.
Reference: Highland Sour Cream = 10.0

Particles: The amount of small pieces of sample remaining in mouth just after swallowing. This does not incorporate toothpacking and refers only to particulate matter on mouth surface other than in and between the molar teeth.
Reference: Cheerios = 3.0

Slimy: Degree to which a thick, mucous-like substance is perceived in the mouth during mastication.
Reference: Kroger Frozen Cut Okra = 13.0
Preparation: Microwave 236.6 mL 3 min on high, covered with saran wrap.

Slickness: Ease with which a product slides around in the mouth during mastication.
Reference: Kraft Miracle Whip Light = 7.5

Fiber The degree to which fiber are present. Evaluated during mastication after

Awareness: 5 to 8 chews (excluding skin).
Reference: Private Selection Frozen Whole Strawberries = 2.0
Dole Canned Chunks Pineapple = 10.0 (evaluated using 1 piece)
Preparation: Weigh 230 g of strawberries then cook in microwave 2.50 min

Pulpy Residue: A soft moist residue.
Reference: Del Monte Lite Peaches = 2.0
Preparation: Cut into 2.54 cm chunks.

Definitions and references used in the U.S. to evaluate mango purée

Mango Identity: A sweet, fruity, green, somewhat woody, and piney aromatic associated with mango that sometimes may include aromatics similar to other specific fruits, such as peach, orange, grapefruit, and/or pineapple.
- Reference: Jumex Mango Nectar = 6.5
  Reese Sliced Mango in Mango Juice = 7.5
- Preparation: Cut Sliced Mango into 2.54 cm chunks and serve without juice in 92.1 g cups.

Fruity: An aroma blend which is sweet and reminiscent of a variety of different fruits. When possible, specific fruits were described.
- Reference: Trans-2-Hexenal (10,000 ppm) = 5.0
- Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Peach: Aromatic associated with ripe peach which includes floral, perfumy, sweet, sometimes woody, and green notes, and can have a hint of fermented note.
- Reference: Fresh Peach Pit = 8.0
- Preparation: Remove flesh from pit and place pit in medium snifter, covered.

Orange: A natural, sweet, fruity, floral, slightly sour, and citrus-like aromatic associated with oranges.
- Reference: Majestic Mountain Sage Orange Valencia Essential Oil = 6.5
  Majestic Mountain Sage Orange 5-Fold Essential Oil = 8.5
- Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Grapefruit: A natural, sour, slightly sweet, fruity, somewhat musty, woody, pungent, citrus-like aromatic associated with grapefruit.
- Reference: Grapefruit Essential Oil (Aura Cacia) = 6.0
- Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Pineapple: A sweet, woody, slightly sharp, floral aromatic associated with pineapple.
- Reference: Dole Canned Pineapple Juice and water (1:1 dilution) = 6.0

Cooked: An aromatic impression associated with a cooked fruit rather than fresh, uncooked fruit.
- Reference: Jumex Mango Nectar = 6.0
  Reese Sliced Mango in Mango Juice = 7.0
- Preparation: Cut Sliced Mango into 2.54 cm chunks and serve without juice in 92.1 g cups.

Animalic: Aromatic associated with sulfur compounds which exhibit skunk-like characteristic commonly associated with decaying animals.
- Reference: Tincture of Civet = 6.0

Preparation: Place 1 drop on a cotton ball in a medium snifter, cover.

Black Pepper: Spicy, pungent, musty, and woody aromatics characteristic of ground black pepper.
Reference: McCormick Ground Black Pepper = 13.0
Preparation: Place 1.27 cm of pepper in medium snifter, cover.

Caramelized: A round, full bodied, medium brown aromatic.
Reference: C&H golden Brown Sugar = 9.0

Clove: A pungent, brown spicy aromatic.
Reference: LorAnne Gourmet Clove Leaf Oil = 12.0
Preparation: Place 1 drop of oil on cotton ball in covered snifter.

Chemical: A general term associated with many different types of compounds generally known as chemicals.
Reference: Borneol (10,000 ppm) = 2.5
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Cumin: A musty, brown, sweet, slightly pungent aromatic.
Reference: McCormick Ground Cumin=13.0
Preparation: 0.62 mL ground cumin in covered snifter.

Green: Slightly sour aromatic commonly associated with under-ripe fruit.
Reference: Green Granny Smith = 7.0
Preparation: Remove peel. Core and slice 1 apple into 10 slices using apple cutter. Cut each slice into 3 pieces. Serve in 92.1 g cups.

Green-viney: Green, fresh aromatic associated with newly cut vines and stems. It sometimes relates to cucumber.
Reference: 2-Isobutylthiazole (Givaudan; 10,000 ppm) = 9.0
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Fermented: A combination of aromatics that are sweet, slightly brown, overripe, and somewhat sour.
Reference: Blackberry WONF 3RA654 (Full Strength) = 7.0
Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Floral/ Perfumy: A sweet, heavy aromatics blend of a combination of flowers which can be somewhat chemical and perfume-like.
Reference: Geraniol (IFF; 10,000 ppm) = 7.5
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Musty: An aromatic that has a damp, earthy character similar to fresh mushrooms.
Reference: Sliced White Mushroom = 10.5
Preparation: Place sliced mushrooms in 92.1 g cup with lid.

Peel-like: Slightly sharp aromatic that can be described as slightly sour and bitter. It is commonly associated with citrus peel.
Preparation: Lime peel = 13.0
Preparation: In medium covered snifter. Measure out 3.2 g.

Piney: A slightly sharp resinous aromatic that may be medicinal or chemical in character. It is associated with green pine needles or pine pitch.
Reference: Isobornyl propionate (IFF) = 6.5
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Spicy: A sweet brown, slightly musty aromatics reminiscent of cinnamon.
Reference: McCormick Ground Allspice = 9.5
Preparation: A 1.27 cm in a medium snifter, covered.

Starchy: A bland, cooked vegetable-like aromatics associated with the meat of a baked sweet potato or squash.
Reference: Baked Sweet potato = 8.0
Preparation: Microwave a scrubbed baking potato on high for 8 min on high. Only meat portion is cut into 1.27 cm cubes.

Vegetable (yellow squash-like): Sweet, musty, earthy aroma characteristic of yellow squash.
Reference: Gerber squash baby food = 7.5

Woody: Flat, dark, dry, musty aromatics associated with the bark of a tree.
Reference: Oil of Cedar Wood (Aldrich; 10,000 ppm) = 6.0
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Overall Sweet: Aromatics and flavor notes associated with the impression of all sweet substances.
Reference: Lorna Doone Cookie = 4.5
6% C&H Brown Sugar in water = 9.0

Overall Sour: Aromatics and flavor notes associated with the impression of all sour substances.
Reference: Highland Sour Cream = 4.5

Fundamental Tastes:

Sweet: The fundamental taste sensation of which sucrose is typical.
Reference: 2% Sucrose Solution = 2.0
4% Sucrose Solution = 4.0

6% Sucrose Solution = 6.0

Bitter: The fundamental taste sensation of which caffeine or quinine are typical.
Reference: 0.02% Caffeine Solution = 3.5

Sour: The fundamental taste sensation of which citric acid is typical
Reference: 0.015% Citric Acid Solution = 1.5
0.050% Citric Acid Solution = 3.5

Metallic The chemical feeling factor on the tongue described as flat, associated with iron, copper, and silver spoons.
Reference: 0.10% Potassium Chloride Solution = 1.5

Astringent: The complex of drying, puckering, shrinking sensations in the oral cavity.
Reference: 0.05% Alum Solution = 2.5
0.1% Alum Solution = 5.0

Texture:

Thickness: A measure of the consistency of a product when manipulating a sample on the roof of the mouth with the tongue.
Reference: Diluted Contadina tomato paste (1:1) = 7.5
Contadina tomato paste = 14.0

Viscosity: The measure of flow as a product moves on the tongue when pressed between the tongue and the palate (2.46 mL of product).
Reference: Gerber Applesauce Stage 1 = 9.0
Musselman's Natural Applesauce = 11.0

Mealy: The perception of fine, soft particles distributed within the product.
Reference: Gerber Applesauce Stage 1 = 2.0
Musselman's Natural Applesauce = 14.0

Chalky Mouthfeel: A dry, powdery sensation in the mouth.
Reference: 10 g Argo cornstarch in 1,000 mL water = 3.0

Slimy: Degree to which a thick, mucous-like substance is perceived in the mouth during mastication.
Reference: Kroger Frozen Cut Okra = 13.0
Preparation: Microwave 236.6 mL 3 min on high, covered with saran wrap.

Slickness: Ease with which a product slides around in the mouth during mastication (2.46 mL of product).
Reference: Kraft Miracle Whip Light = 7.5

Mouthcoating: Sensation of having a slick coating on the tongue and other mouth surfaces (2.46 mL swallowed after 3 manipulations).

Reference: Dillon's Whipping Cream = 8.0

Fiber Awareness: The degree to which fiber are present. Evaluated during mastication after 5 to 8 chews (excluding skin).
Reference: Private Selection Frozen Whole Strawberries = 2.0
Preparation: Weigh 230 g of strawberries then cook in microwave 2.50 min.

Pulpy Residue: A soft moist residue.
Reference: Del Monte Lite Peaches = 2.0
Preparation: Cut into 2.54 cm chunks.

Definitions and references used in the U.S. to evaluate mango sorbet

Mango Identity: A sweet, fruity, green, somewhat woody, and piney aromatic associated with mango that sometimes may include aromatics similar to other specific fruits, such as peach, orange, grapefruit, and/or pineapple.
Reference: Jumex Mango Nectar = 6.5
Reese Sliced Mango in Mango Juice = 7.5
Preparation: Cut Sliced Mango into 2.54 cm chunks and serve without juice in 92.1 g cups.

Fruity: An aroma blend which is sweet and reminiscent of a variety of different fruits. When possible, specific fruits were described.
Reference: Trans-2-Hexenal (10,000 ppm) = 5.0
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Peach: Aromatic associated with ripe peach which includes floral, perfumy, sweet, sometimes woody, and green notes, and can have a hint of fermented note.
Reference: Fresh Peach Pit = 8.0
Preparation: Remove flesh from pit and place pit in medium snifter, covered.

Orange: A natural, sweet, fruity, floral, slightly sour and citrus-like aromatic associated with oranges.
Reference: Majestic Mountain Sage Orange Valencia Essential Oil = 6.5
Majestic Mountain Sage Orange 5-Fold Essential Oil = 8.5
Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Grapefruit: A natural, sour, slightly sweet, fruity, somewhat musty, woody, pungent, citrus-like aromatic associated with grapefruit.
Reference: Grapefruit Essential Oil (Aura Cacia) = 6.0
Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Pineapple: A sweet, woody, slightly sharp, floral aromatic associated with pineapple.
Reference: Dole Canned Pineapple Juice and water (1:1 dilution) = 6.0

Cooked: An aromatic impression associated with a cooked fruit rather than fresh, uncooked fruit.
Reference: Jumex Mango Nectar = 6.0
Reese Sliced Mango in Mango Juice = 7.0
Preparation: Cut Sliced Mango into 2.54 cm chunks and serve without juice in 92.1 g cups.

Animalic: Aromatic associated with sulfur compounds which exhibit skunk-like characteristic commonly associated with decaying animals.
Reference: Tincture of Civet = 6.0

Preparation: Place 1 drop on a cotton ball in a medium snifter, cover.

Black Pepper: Spicy, pungent, musty, and woody aromatics characteristic of ground black pepper.
Reference: McCormick Ground Black Pepper = 13.0
Preparation: Place 2.46 mL of pepper in medium snifter, cover.

Caramelized: A round, full bodied, medium brown aromatic.
Reference: C&H golden Brown Sugar = 9.0

Clove: A pungent, brown spicy aromatic.
Reference: LorAnne Gourmet Clove Leaf Oil= 12.0
Preparation: Place 1 drop of oil on cotton ball in covered snifter.

Chemical: A general term associated with many different types of compounds generally known as chemicals.
Reference: Borneol (10,000 ppm) = 2.5
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Cumin: A musty, brown, sweet, slightly pungent aromatic.
Reference: McCormick Ground Cumin = 13.0
Preparation: 0.62 mL ground cumin in covered snifter.

Green: Slightly sour aromatic commonly associated with under-ripe fruit.
Reference: Green Granny Smith = 7.0
Preparation: Remove peel. Core and slice 1 apple into 10 slices using apple cutter. Cut each slice into 3 pieces. Serve in 92.1 g cups.

Green-viney: Green, fresh aromatic associated with newly cut vines and stems. It sometimes relates to cucumber.
Reference: 2-Isobutylthiazole (Givaudan; 10,000 ppm) = 9.0
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Fermented: A combination of aromatics that are sweet, slightly brown, overripe, and somewhat sour.
Reference: Blackberry WONF 3RA654 (Full Strength) = 7.0
Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Floral/ Perfumy: A sweet, heavy aromatics blend of a combination of flowers which can be somewhat chemical and perfume-like.
Reference: Geraniol (IFF; 10,000 ppm) = 7.5
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Musty: An aromatic that has a damp, earthy character similar to fresh mushrooms.
Reference: Sliced White Mushroom = 10.5
Preparation: Place sliced mushrooms in 92.1 g cup with lid.

Peel-like: A slightly sharp aromatic that can be described as slightly sour and bitter. It is commonly associated with citrus peel.
Preparation: Lime peel = 13.0
Preparation: In medium covered snifter. Measure out 3.2 g.

Piney: A slightly sharp resinous aromatics that may be medicinal or chemical in character. It is associated with green pine needles or pine pitch.
Reference: Isobornyl propionate (IFF) = 6.5
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Spicy: A sweet brown, slightly musty aromatics reminiscent of cinnamon.
Reference: McCormick Ground Allspice = 9.5
Preparation: A 2.46 mL in a medium snifter, covered.

Starchy: A bland, cooked vegetable-like aromatics associated with the meat of a baked sweet potato or squash.
Reference: Baked Sweet potato = 8.0
Preparation: Microwave a scrubbed baking potato on high for 8 min on high. Only meat portion is cut into 1.27 cm cubes.

Vegetable (yellow squash-like): Sweet, musty, earthy aroma characteristic of yellow squash.
Reference: Gerber squash baby food = 7.5

Woody: Flat, dark, dry, musty aromatics associated with the bark of a tree.
Reference: Oil of Cedar Wood (Aldrich; 10,000 ppm) = 6.0
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Overall Sweet: Aromatics and flavor notes associated with the impression of all sweet substances.
Reference: Lorna Doone Cookie = 4.5
6% C&H Brown Sugar in water = 9.0

Overall Sour: Aromatics and flavor notes associated with the impression of all sour substances.
Reference: Highland Sour Cream = 4.5

Fundamental Tastes:

Sweet: The fundamental taste sensation of which sucrose is typical.
Reference: 2% Sucrose Solution = 2.0
4% Sucrose Solution = 4.0

6% Sucrose Solution = 6.0

Bitter: The fundamental taste sensation of which caffeine or quinine are typical.
Reference: 0.02% Caffeine Solution = 3.5

Sour: The fundamental taste sensation of which citric acid is typical
Reference: 0.015% Citric Acid Solution = 1.5
0.050% Citric Acid Solution = 3.5

Metallic The chemical feeling factor on the tongue described as flat, associated with iron, copper, and silver spoons.
Reference: 0.10% Potassium Chloride Solution = 1.5

Astringent: The complex of drying, puckering, shrinking sensations in the oral cavity.
Reference: 0.05% Alum Solution = 2.5
0.1% Alum Solution = 5.0

Texture:

Firmness: The force required to compress the sample between the tongue and palate after 1 s in the mouth.
Reference: Dillon's Sour Cream = 5.5
Philadelphia Light Cream Cheese (tub) =7.0
Philadelphia Cream Cheese (tub) = 10.0
Philadelphia Cream Cheese = 14.0

Density: The degree of compactness of a sample when pressed between the tongue and palate.
Reference: Kraft Marshmallow Fluff = 5.0
Dillon's Sour Cream = 9.5

Meltdown: The time required for the product to melt in the mouth when continuously pressed by the tongue against the palate. The number of seconds counted equals the numerical score (1/1,000 count). Sample size is 1.64 mL.

Viscosity: The measure of flow as the product moves on the tongue when pressed between the tongue and the palate (2.46 mL of product).
Reference: Dillon's 1/2 and 1/2 = 2.0
Dillon's Whipping Cream = 4.0

Iciness: The immediate perception of crystal-like particles within the sample. This measurement is taken immediately after sample has been placed in the mouth. The crystals often dissolve quickly at 1st manipulation. Sample size is 1.64 mL of icy portion.
Reference: Haagen Dazs Mango Sorbet that has been through a thaw-refreeze cycle = 7.5

Preparation: Leave 1 pint container of Haagen Dazs Mango Sorbet out at room temperature for 2 h and place back in the freezer. Freeze overnight, and serve in 113.4 g Styrofoam cups at -10 °C.

Mouthcoating: Sensation of having a slick coating on the tongue and other mouth surfaces (2.46 mL swallowed after 3 manipulations).
Reference: Dillon's Whipping Cream = 8.0

Slimy: Degree to which a thick, mucous-like substance is perceived in the mouth during mastication.
Reference: Kroger Frozen Cut Okra = 13.0
Preparation: Microwave 236.6 mL 3 min on high.

Slickness: Ease with which a product slides around in the mouth during mastication.
Reference: Kraft Miracle Whip Light = 7.5

Fiber Awareness: The degree to which fiber are present. Evaluated during mastication after 5 to 8 chews (excluding skin).
Reference: Private Selection Frozen Whole Strawberries = 2.0
Preparation: Weigh 230 g of strawberries then cook in microwave 2.50 min.

Pulpy Residue: A soft moist residue.
Reference: Del Monte Lite Peaches = 2.0
Preparation: Cut into 2.54 cm chunks.

Chalky Mouthfeel: A dry, powdery sensation in the mouth.
Reference: 10 g Argo cornstarch in 1,000 mL water = 3.0

Definitions and references used in Thailand to evaluate fresh mango

Mango Identity: A sweet, fruity, green, somewhat woody, and piney aromatic associated with mango that sometimes may include aromatics similar to other specific fruits, such as peach, orange, grapefruit, and/or pineapple.

มะม่วง กลิ่นรสเฉพาะตัวของมะม่วง

Reference: Jumex Mango Nectar = 6.5
Reese Sliced Mango in Mango Juice = 7.5
Preparation: Cut Sliced Mango into 2.54 cm chunks and serve without juice in 92.1 g cups.

Fruity: An aroma blend which is sweet and reminiscent of a variety of different fruits. When possible, specific fruits were described.

ผลไม้ กลิ่นรสที่ผสมผสานกันของความหอมหวาน ซึ่งทำให้ระลึกถึงผลไม้ต่างๆ ถ้าเป็นไปได้ให้ระบุชนิดของผลไม้ด้วย

Reference: Heinz Smooth Summer Fruit Gel = 6.0

Peach: Aromatic associated with ripe peach which includes floral, perfumy, sweet, sometimes woody, and green notes, and can have a hint of fermented note.

พีช กลิ่นรสเฉพาะตัวของพีชที่สุกแล้ว

Reference: Fresh Peach Pit = 8.0
Preparation: Remove flesh from pit and place pit in medium snifter, covered.

Orange: A natural, sweet, fruity, floral, slightly sour and citrus-like aromatic associated with oranges.

ส้ม กลิ่นรสเฉพาะตัวของส้ม

Reference: Majestic Mountain Sage Orange Valencia Essential Oil = 6.5
Majestic Mountain Sage Orange 5-Fold Essential Oil = 8.5
Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Grapefruit: A natural, sour, slightly sweet, fruity, somewhat musty, woody, pungent, citrus-like aromatic associated with grapefruit.

เกรปฟรุต กลิ่นรสเฉพาะตัวของเกรปฟรุต

Reference: Grapefruit Essential Oil (Aura Cacia) = 6.0
Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Pineapple: A sweet, woody, slightly sharp, floral aromatic associated with pineapple.

สับปะรด กลิ่นรสเฉพาะตัวของสับปะรด

Reference: Dole Canned Pineapple Juice and water (1:1 dilution) = 6.0

Caramelized: A round, full bodied, medium brown aromatic.

น้ำตาลเคี่ยว

กลิ่นรสของน้ำตาลที่เคี่ยวด้วยความร้อนจนเปลี่ยนเป็นสีน้ำตาลทอง

Reference: C&H golden Brown Sugar = 9.0

Chemical: A general term associated with many different types of compounds generally known as chemicals.

เคมี กลิ่นรสที่ให้ความรู้สึกเสมือนมีสารเคมี

Reference: Borneol (10,000 ppm) = 2.5
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Green: Slightly sour aromatic commonly associated with under-ripe fruit.

เขียว (ดิบ) กลิ่นรสเฉพาะของผลไม้ที่ยังไม่สุก ซึ่งมีกลิ่นเปรี้ยวเล็กน้อย และให้ความรู้สึกว่าฝาด

Reference: Green Granny Smith = 7.0
Preparation: Remove peel. Core and slice 1 apple into 10 slices using apple cutter. Cut each slice into 3 pieces. Serve in 92.1 g cups.

Green-viney: Green, fresh aromatic associated with newly cut vines and stems. It sometimes relates to cucumber.

เขียวสด กลิ่นรสเขียวแบบสดของเถาวัลย์หรือกิ่งไม้ที่ตัดใหม่ๆ บางครั้งมีกลิ่นคล้ายกับกลิ่นของแตงกวา

Reference: 2-Isobutylthiazole (Givaudan; 10,000 ppm) = 9.0
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Fermented: A combination of aromatics that are sweet, slightly brown, overripe, and somewhat sour.

หมัก กลิ่นรสที่ผสมผสานกันของกลิ่นรสหวาน สุกงอม อาจเจือกลิ่นรสเปรี้ยว

Reference: Blackberry WONF 3RA654 (Full Strength) = 7.0
Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Floral/ Perfumy: A sweet, heavy aromatics blend of a combination of flowers which can be somewhat chemical and perfume-like.

ดอกไม้/น้ำหอม กลิ่นหอมรุนแรงของดอกไม้นานาพันธุ์ ซึ่งอาจคล้ายกลิ่นสารเคมีบางชนิดหรือกลิ่นน้ำหอม

Reference: Jasmine Flavor (Winner's) = 4.5
Preparation: Place 1 drop in 200 mL water.

Musty: An aromatic that has a damp, earthy character similar to fresh mushrooms.

อับชื้น กลิ่นอับชื้นหรือกลิ่นดินชื้นคล้ายกับกลิ่นของเห็ดสด

Reference: Fresh Button Mushroom = 10.5
Geosmin (20 ppm) = 12.0

Preparation: Cut mushroom into thin slices (about 0.64 cm).
Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Peel-like: Slightly sharp aromatic that can be described as slightly sour and bitter. It is commonly associated with citrus peel.

เหมือนเปลือก กลิ่นรสเปรี้ยวเล็กน้อยและขมของเปลือก
โดยทั่วไปเป็นเปลือกของผลไม้สกุลส้ม

Preparation: Lime peel = 13.0
Preparation: In medium covered snifter. Measure out 3.2 g.

Piney: A slightly sharp resinous aromatic that may be medicinal or chemical in character. It is associated with green pine needles or pine pitch.

ยางสน กลิ่นรสของยางสนจากใบสนหรือลำต้นสน
ซึ่งอาจมีกลิ่นคล้ายยาหรือสารเคมี

Reference: Isobornyl propionate (IFF) (10,000 ppm) = 6.5
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Spicy: A sweet brown, slightly musty aromatics reminiscent of cinnamon.

เครื่องเทศ กลิ่นรสหอมของเครื่องเทศอย่างอบเชย

Reference: McCormick Ground Allspice = 9.5
Preparation: A 2.46 mL in a medium snifter, covered.

Starchy: A bland, cooked vegetable-like aromatics associated with the meat of a baked sweet potato or squash.

แป้ง กลิ่นรสอ่อนๆ ของผักที่ทำให้สุกด้วยความร้อน
อย่างกลิ่นของเนื้อมันฝรั่งอบหรือผักจำพวกแตงหรือน้ำเต้า

Reference: Baked Sweet potato = 8.0
Preparation: Microwave a scrubbed baking potato on high for 8 min on high. Only meat portion (no skin) is cut into 1.27 cm cubes.

Sulfur: Reference: Durian Flavor (Winner's) in water = 6.5
Preparation: Add 1 drop of durian flavor to 100 mL water.

Vegetable (yellow squash-like): Sweet, musty, earthy aroma characteristic of yellow squash.

ผัก กลิ่นเฉพาะของสคอชสีเหลืองซึ่งมีลักษณะหอมหวานและอับชื้น
(คล้ายสคอชสีเหลือง)

Reference: Gerber squash baby food = 7.5

Overall Sweet: Aromatics and flavor notes associated with the impression of all sweet substances.

หวานโดยรวม กลิ่นรสที่ให้ความรู้สึกหวานหอม

Reference: Lorna Doone Cookie = 4.5
6% C&H Brown Sugar in water = 9.0

Overall Sour: Aromatics and flavor notes associated with the impression of all sour substances.
เปรี้ยวโดยรวม กลิ่นรสที่ให้ความรู้สึกเปรี้ยว

Reference: Highland Sour Cream = 4.5
Heinz White Vinegar in water (1:8 dilution) = 8.0

Fundamental Tastes:

Sweet: The fundamental taste sensation of which sucrose is typical.
หวาน การรับรู้รสพื้นฐานของลิ้นเมื่อถูกกระตุ้นด้วยน้ำตาลซูโครส

Reference: 2% Sucrose Solution = 2.0
4% Sucrose Solution = 4.0
6% Sucrose Solution = 6.0

Bitter: The fundamental taste sensation of which caffeine or quinine are typical.
ขม การรับรู้รสพื้นฐานของลิ้นเมื่อถูกกระตุ้นด้วยคาเฟอีน

Reference: 0.02% Caffeine Solution = 3.5

Sour: The fundamental taste sensation of which citric acid is typical.
เปรี้ยว การรับรู้รสพื้นฐานของลิ้นเมื่อถูกกระตุ้นด้วยกรดซิตริก

Reference: 0.015% Citric Acid Solution = 1.5
0.050% Citric Acid Solution = 3.5

Metallic The chemical feeling factor on the tongue described as flat, associated with iron, copper, and silver spoons.
โลหะ ความรู้สึกทางเคมีบนลิ้น ซึ่งเกิดจากกลิ่นรสที่รับรู้ได้หลังจากที่ดึงช้อนที่ทำจากของโลหะพวกเหล็ก ทองแดง หรือเงินออกจากปาก

Reference: 0.10% Potassium Chloride Solution = 1.5

Astringent: The complex of drying, puckering, shrinking sensations in the oral cavity.
ฝาด ความรู้สึกแห้ง ฝืด ขึ้น ปร่าหรือเฝื่อน ในช่องปาก

Reference: 0.05% Alum Solution = 2.5
0.1% Alum Solution = 5.0

Texture:

Firmness: The force required to compress the sample between the tongue and palate.
ความแข็ง แรงที่ใช้กดตัวอย่างโดยใช้ ลิ้นและเพดานปาก จนตัวอย่างเสียรูปร่าง

Reference: Highland Sour Cream = 5.5
Philadelphia Light Cream Cheese (tub) = 7.0

Philadelphia Cream Cheese (tub) = 10.0
Philadelphia Cream Cheese (block) = 14.0

Preparation: Cut block cream cheese into 1.27 cm cubes.

Cohesiveness of Mass: Degree to which the mass holds together after 7 chews.

การเกาะตัวของมวล ระดับการเกาะรวมตัวกันของมวลตัวอย่าง หลังจากเคี้ยว 7 ครั้ง

Reference: Oscar Mayer Wieners = 6.5
Sweet potato = 9.0

Preparation: Cut off ends of wieners, and cut remaining portion into 1.27 cm cross-sections.
Microwave a scrubbed sweet potato on high for 8 min. Only meat portion is cut into 1.27 cm cubes.

Chalky Mouthfeel: A dry, powdery sensation in the mouth.

เหมือนผงชอล์ก ความรู้สึกแห้ง เป็นผงละเอียดภายในปาก

Reference: 10 g Argo cornstarch in 1,000 mL water = 3.0

Slimy: Degree to which a thick, mucous-like substance is perceived in the mouth during mastication.

เป็นเมือก ระดับความเป็นเมือกของตัวอย่างที่รู้สึกได้ขณะเคี้ยว

Reference: Trappey's Cut Okra (canned) = 7.5
Fresh Okra = 11.0

Preparation: Drain canned okra and place okra in 92.1 g cups.
Slice fresh okra across into 1.27 cm slices.

Slickness: Ease with which a product slides around in the mouth during mastication (2.46 mL of product).

ความลื่น ความสามารถในการลื่นไหลของตัวอย่างภายในปากซึ่งรู้สึกได้ขณะเคี้ยว (2.46 มล.)

Reference: Kraft Miracle Whip Light = 7.5

Fiber Awareness: The degree to which fiber are present. Evaluated during mastication after 5 to 8 chews (excluding skin).

เส้นใย ปริมาณเส้นใยของตัวอย่างที่รู้สึกได้หลังจากเคี้ยวตัวอย่าง 5-8 ครั้ง ทั้งนี้ไม่รวมเปลือกหรือผิวนอกของตัวอย่าง

Reference: Creative Gourmet Frozen Whole Strawberries = 2.0
Dole Canned Pineapple Rings = 10.0 (evaluating 1 piece)

Preparation: Weigh 230 g of strawberries then cook in microwave 2.50 min.
Cut Canned Pineapple Rings into 1 in. chunks.

Pulpy Residue: A soft moist residue.

กาก กากเนื้อในที่นุ่มและชุ่มน้ำของตัวอย่างที่เหลืออยู่หลังเคี้ยว

Reference: Del Monte Lite Peaches = 2.0
Preparation: Cut into 2.54 cm chunks.

Throat Irritation: An irritating feeling in the throat that causes one to feel like coughing. This may result from the taste or texture of the sample after swallowing. Two pieces are evaluated at a time.

ระคายคอ ความรู้สึกคัน ระคายเคือง แสบคอ ซึ่งอาจเกิดจากรสชาติหรือเนื้อสัมผัสของตัวอย่างหลังกลืน

Reference: Tong Garden Salted Peanuts = 5.0

Tongue burn: A burning feeling, prickling, and/or numbness of the tongue. However, it does not cover heat burn.

แสบลิ้น ความรู้สึกทิมแทง แสบ ชา บริเวณลิ้น ทั้งนี้ไม่รวมความรู้สึกเผ็ดร้อน

Reference: Heinz White Vinegar in water (1:8) = 8.0

Definitions and references used in Thailand to evaluate mango purée

Mango Identity: A sweet, fruity, green, somewhat woody, and piney aromatic associated with mango that sometimes may include aromatics similar to other specific fruits, such as peach, orange, grapefruit, and/or pineapple.

มะม่วง กลิ่นรสเฉพาะตัวของมะม่วง

Reference: Jumex Mango Nectar = 6.5
Reese Sliced Mango in Mango Juice = 7.5
Preparation: Cut Sliced Mango into 2.54 cm chunks and serve without juice in 92.1 g cups.

Fruity: An aroma blend which is sweet and reminiscent of a variety of different fruits. When possible, specific fruits were described.

ผลไม้ กลิ่นรสที่ผสมผสานกันของความหอมหวาน ซึ่งทำให้ระลึกถึงผลไม้ต่างๆ ถ้าเป็นไปได้ให้ระบุชนิดของผลไม้ด้วย

Reference: Heinz Smooth Summer Fruit Gel = 6.0

Peach: Aromatic associated with ripe peach which includes floral, perfumy, sweet, sometimes woody, and green notes, and can have a hint of fermented note.

พีช กลิ่นรสเฉพาะตัวของพีชที่สุกแล้ว

Reference: Fresh Peach Pit = 8.0
Preparation: Remove flesh from pit and place pit in medium snifter, covered.

Orange: A natural, sweet, fruity, floral, slightly sour and citrus-like aromatic associated with oranges.

ส้ม กลิ่นรสเฉพาะตัวของส้ม

Reference: Majestic Mountain Sage Orange Valencia Essential Oil = 6.5
Majestic Mountain Sage Orange 5-Fold Essential Oil = 8.5
Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Guava: A green, sweet aromatic associated with ripe guava.

ฝรั่ง กลิ่นเขียว หวาน ซึ่งสัมพันธ์กับกลิ่นฝรั่งสุก

Reference: Guava Juice (Tipco) = 6.0

Grapefruit: A natural, sour, slightly sweet, fruity, somewhat musty, woody, pungent, citrus-like aromatic associated with grapefruit.

เกรปฟรุต กลิ่นรสเฉพาะตัวของเกรปฟรุต

Reference: Grapefruit Essential Oil (Aura Cacia) = 6.0
Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Pineapple: A sweet, woody, slightly sharp, floral aromatic associated with pineapple.

สับปะรด กลิ่นรสเฉพาะตัวของสับปะรด

Reference: Dole Canned Pineapple Juice and water (1:1 dilution) = 6.0

Cooked: An aromatic impression associated with a cooked fruit rather than fresh, uncooked fruit.

สุกผ่านความร้อน กลิ่นรสของผลไม้ที่ผ่านความร้อน

Reference: Jumex Mango Nectar = 6.0
Reese Sliced Mango in Mango Juice = 7.0
Preparation: Cut Sliced Mango into 2.54 cm chunks and serve without juice in 92.1 g cups.

Caramelized: A round, full bodied, medium brown aromatic.

น้ำตาลเคี่ยว

กลิ่นรสของน้ำตาลที่เคี่ยวด้วยความร้อนจนเปลี่ยนเป็นสีน้ำตาลทอง

Reference: C&H golden Brown Sugar = 9.0

Chemical: A general term associated with many different types of compounds generally known as chemicals.

เคมี กลิ่นรสที่ให้ความรู้สึกเสมือนมีสารเคมี

Reference: Borneol (10,000 ppm) = 2.5
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Green: Slightly sour aromatic commonly associated with under-ripe fruit.

เขียว (ดิบ) กลิ่นรสเฉพาะของผลไม้ที่ยังไม่สุก ซึ่งมีกลิ่นเปรี้ยวเล็กน้อย และให้ความรู้สึกว่าฝาด

Reference: Green Granny Smith = 7.0
Preparation: Remove peel. Core and slice 1 apple into 10 slices using apple cutter. Cut each slice into 3 pieces. Serve in 92.1 g cups.

Green-viney: Green, fresh aromatic associated with newly cut vines and stems. It sometimes relates to cucumber.

เขียวสด กลิ่นรสเขียวแบบสดของเถาวัลย์หรือกิ่งไม้ที่ตัดใหม่ๆ บางครั้งมีกลิ่นคล้ายกับกลิ่นของแตงกวา

Reference: 2-Isobutylthiazole (Givaudan; 10,000 ppm) = 9.0
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Fermented: A combination of aromatics that are sweet, slightly brown, overripe, and somewhat sour.

หมัก กลิ่นรสที่ผสมผสานกันของกลิ่นรสหวาน สุกงอม อาจเจือกลิ่นรสเปรี้ยว

Reference: Blackberry WONF 3RA654 (Full Strength) = 7.0
Preparation: 1 drop oil on a cotton ball in a medium snifter, covered.

Floral/ Perfumy: A sweet, heavy aromatics blend of a combination of flowers which can be somewhat chemical and perfume-like.

ดอกไม้/น้ำหอม กลิ่นหอมรุนแรงของดอกไม้นานาพันธุ์ ซึ่งอาจคล้ายกลิ่นสารเคมีบางชนิดหรือกลิ่นน้ำหอม

Reference: Jasmine Flavor (Winner's) = 4.5
Preparation: Place 1 drop in 200 mL water.

Musty: An aromatic that has a damp, earthy character similar to fresh mushrooms.

อับชื้น กลิ่นอับชื้นหรือกลิ่นดินชื้นคล้ายกับกลิ่นของเห็ดสด

Reference: Fresh Button Mushroom = 10.5
Geosmin (20 ppm) = 12.0
Preparation: Cut mushroom into thin slices (about 0.64 cm).
Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Peel-like: Slightly sharp aromatic that can be described as slightly sour and bitter. It is commonly associated with citrus peel.

เหมือนเปลือก กลิ่นรสเปรี้ยวเล็กน้อยและขมของเปลือกโดยทั่วไปเป็นเปลือกของผลไม้สกุลส้ม

Preparation: Lime peel = 13.0
Preparation: In medium covered snifter. Measure out 3.2 g.

Piney: A slightly sharp resinous aromatic that may be medicinal or chemical in character. It is associated with green pine needles or pine pitch.

ยางสน กลิ่นรสของยางสนจากใบสนหรือลำต้นสน ซึ่งอาจมีกลิ่นคล้ายยาหรือสารเคมี

Reference: Isobornyl propionate (IFF) (10,000 ppm) = 6.5
Preparation: Cut 1.27 cm off perfumer strip and dip in the solution until it reaches 2nd line, put in test tube, lid.

Spicy: A sweet brown, slightly musty aromatics reminiscent of cinnamon.

เครื่องเทศ กลิ่นรสหอมของเครื่องเทศอย่างอบเชย

Reference: McCormick Ground Allspice = 9.5
Preparation: A 2.46 mL in a medium snifter, covered.

Starchy: A bland, cooked vegetable-like aromatics associated with the meat of a baked sweet potato or squash.

แป้ง กลิ่นรสอ่อนๆ ของผักที่ทำให้สุกด้วยความร้อนอย่างกลิ่นของเนื้อมันฝรั่งอบหรือผักจำพวกแตงหรือน้ำเต้า

Reference: Baked Sweet potato = 8.0
Preparation: Microwave a scrubbed baking potato on high for 8 min on high. Only meat portion (no skin) is cut into 1.27 cm cubes.

Sulfur: Reference: Durian Flavor (Winner's) in water = 6.5

ซัลเฟอร์ กลิ่นฉุน แสบจมูก คล้ายกลิ่นที่เกิดขึ้นขณะจุดไม้ขีดไฟ และพบได้ในไข่ต้ม ทุเรียนสุกงอม

Preparation: Add 1 drop of durian flavor to 100 mL water.

Vegetable (yellow squash-like): Sweet, musty, earthy aroma characteristic of yellow squash.

ผัก (คล้ายสคอชสีเหลือง) กลิ่นเฉพาะของสคอชสีเหลืองซึ่งมีลักษณะหอมหวานและอับชื้น

Reference: Gerber squash baby food = 7.5

Overall Sweet: Aromatics and flavor notes associated with the impression of all sweet substances.

หวานโดยรวม กลิ่นรสที่ให้ความรู้สึกหวานหอม

Reference: Lorna Doone Cookie = 4.5
6% C&H Brown Sugar in water = 9.0

Overall Sour: Aromatics and flavor notes associated with the impression of all sour substances.

เปรี้ยวโดยรวม กลิ่นรสที่ให้ความรู้สึกเปรี้ยว

Reference: Highland Sour Cream = 4.5
Heinz White Vinegar in water (1:8 dilution) = 8.0

Fundamental Tastes:

Sweet: The fundamental taste sensation of which sucrose is typical.

หวาน การรับรู้รสพื้นฐานของลิ้นเมื่อถูกกระตุ้นด้วยน้ำตาลซูโครส

Reference: 2% Sucrose Solution = 2.0
4% Sucrose Solution = 4.0
6% Sucrose Solution = 6.0

Bitter: The fundamental taste sensation of which caffeine or quinine are typical.

ขม การรับรู้รสพื้นฐานของลิ้นเมื่อถูกกระตุ้นด้วยคาเฟอีน

Reference: 0.02% Caffeine Solution = 3.5

Sour: The fundamental taste sensation of which citric acid is typical.

เปรี้ยว การรับรู้รสพื้นฐานของลิ้นเมื่อถูกกระตุ้นด้วยกรดซิตริก

Reference: 0.015% Citric Acid Solution = 1.5
0.050% Citric Acid Solution = 3.5

Metallic: The chemical feeling factor on the tongue described as flat, associated with iron, copper, and silver spoons.

โ ล ห ะ ค ว า ม ร ู ้ ส ึ ก ท า ง เ ค ม ี บ น ล ิ ้ น
ซึ่งเกิดจากกลิ่นรสที่รับรู้ได้หลังจากที่ดึงช้อนที่ทำจากของโลหะพวกเหล็ก ทองแดง หรือเงินออกจากปาก

Reference: 0.10% Potassium Chloride Solution = 1.5

Astringent: The complex of drying, puckering, shrinking sensations in the oral cavity.
ฝาด ความรู้สึกแห้ง ฝืด ขืน ปร่าหรือเฝื่อน ในช่องปาก

Reference: 0.05% Alum Solution = 2.5
0.1% Alum Solution = 5.0

Texture:

Viscosity: The measure of flow as the product moves on the tongue when pressed between the tongue and the palate (2.46 mL of product).
ความหนืด ความสามารถในการไหลของตัวอย่างบนลิ้น เมื่อกดตัวอย่างระหว่างลิ้นกับเพดานปาก (ใช้ตัวอย่าง 2.46 มล.)

Reference: Gerber Applesauce Stage 1 = 9.0
Musselman's Natural Applesauce = 11.0

Mealy: The perception of fine, soft particles distributed within the product.
ร่วน / ซุย ความรู้สึกว่ามีชิ้นตัวอย่างขนาดเล็กและอ่อนนุ่มกระจายอยู่ในมวลตัวอย่าง

Reference: Gerber Applesauce Stage 1 = 2.0
Musselman's Natural Applesauce = 14.0

Chalky Mouthfeel: A dry, powdery sensation in the mouth.
เหมือนผงชอล์ก ความรู้สึกแห้ง เป็นผงละเอียดภายในปาก

Reference: 10 g Argo cornstarch in 1,000 mL water = 3.0

Slimy: Degree to which a thick, mucous-like substance is perceived in the mouth during mastication.
เป็นเมือก ระดับความเป็นเมือกของตัวอย่างที่รู้สึกได้ขณะเคี้ยว

Reference: Trappey's Cut Okra (canned) = 7.5
Fresh Okra = 11.0
Preparation: Drain canned okra and place okra in 92.1 g cups.

Slickness: Ease with which a product slides around in the mouth during mastication (2.46 mL of product).
ความลื่น ความสามารถในการลื่นไหลของตัวอย่างภายในปากซึ่งรู้สึกได้ขณะเคี้ยว (2.46 มล.)

Reference: Kraft Miracle Whip Light = 7.5

Mouthcoating: The perception of coating in the mouth after swallowing (2.46 mL swallowed after 3 manipulations).

เคลือบปาก ความรู้สึกถึงตัวอย่างที่เคลือบภายในปากหลังกลืน ประเมินโดยใช้ตัวอย่าง 2.46 มล. เคี้ยว 3 ครั้ง แล้วกลืน

Reference: Dillon's Whipping Cream = 8.0
Karo Light Syrup = 10.0

Fiber Awareness: The degree to which fiber are present. Evaluated during mastication after 5 to 8 chews (excluding skin).

เส้นใย ปริมาณเส้นใยของตัวอย่างที่รู้สึกได้หลังจากเคี้ยวตัวอย่าง 5-8 ครั้ง ทั้งนี้ไม่รวมเปลือกหรือผิวนอกของตัวอย่าง)

Reference: Creative Gourmet Frozen Whole Strawberries = 2.0
Preparation: Weigh 230 g of strawberries then cook in microwave 2.50 min.

Pulpy Residue: A soft moist residue.

กาก กากเนื้อในที่นุ่มและชุ่มน้ำของตัวอย่างที่เหลืออยู่หลังเคี้ยว

Reference: Del Monte Lite Peaches = 2.0
Preparation: Cut into 2.54 cm chunks.

Appendix D - SAS code for data analysis

To calculate analysis of variance for each flavor attribute across all samples:

```
proc mixed data=work.cl covtest cl;
class sample rep panelist;
model attribute = sample/ddfm=satterth;
random rep(sample) panelist sample*panelist;
lsmeans sample/pdiff = all;
run;
```

To calculate analysis of variance for physicochemical measurements:

```
proc glm data = work.cl;
class sample;
model TSS--pH = sample;
lsmeans sample/pdiff lines;
run;
```

Appendix E - PCA results comparing fresh mango, mango purée, and mango sorbet

Table E.1 Correlation loadings for fresh mango, mango purée, and mango sorbet using U.S. cultivars.

	PC1 (48%)	PC2 (30%)
Product		
Haden Fresh	-0.400	-0.060
Haden Purée	0.230	0.272
Haden Sorbet	0.226	-0.345
Kent Fresh	-0.322	-0.154
Kent Purée	0.313	0.445
Kent Sorbet	0.224	-0.318
Manila Fresh	-0.324	-0.204
Manila Purée	0.263	0.204
Manila Sorbet	0.286	-0.315
Tommy Fresh	-0.544	0.145
Tommy Purée	-0.083	0.561
Tommy Sorbet	0.131	-0.231
Attribute		
Mango Identity	-0.333	-0.299
Fruity	-0.753	-0.338
Peach	0.092	0.046
Orange	0.030	-0.559
Grapefruit	-0.320	0.303
Pineapple	-0.018	-0.088
Cooked	0.930	0.348
Animalic	-0.595	0.359
Black Pepper	-0.452	-0.007
Caramelized	0.654	-0.407
Clove	-0.093	-0.617
Chemical	-0.856	0.294
Cumin	-0.124	-0.197
Green	-0.588	0.277
Green-viney	-0.717	0.175
Fermented	-0.520	0.291
Floral/Perfumy	-0.668	-0.251
Musty	-0.861	0.384
Peel-like	-0.526	0.413
Piney	0.119	-0.488
Spicy	0.099	-0.058
Starchy	0.879	0.249
Vegetable	0.687	0.462

	PC1 (48%)	PC2 (30%)
Woody	0.666	0.003
Overall Sweet	0.741	-0.526
Overall Sour	-0.668	0.684
Sweet	0.752	-0.477
Bitter	-0.566	0.431
Sour	-0.794	0.554
Astringent	-0.065	0.945
Metallic	0.791	-0.067

Table E.2 Correlation loadings for fresh mango and mango purée using Thai cultivars.

	PC1 (78%)	PC2 (14%)
Product		
Chok Anun Fresh	-0.325	-0.307
Chok Anun Purée	0.290	0.210
Kaew Leam Rung Fresh	-0.318	-0.274
Kaew Leam Rung Purée	0.322	-0.193
Nam Dok Mai Fresh	-0.248	0.603
Nam Dok Mai Purée	0.314	-0.142
Nung Klang Won Fresh	-0.334	-0.308
Nung Klang Won Purée	0.280	-0.205
Ok Rong Fresh	-0.277	0.490
Ok Rong Purée	0.313	0.263
Thongdam Fresh	-0.302	-0.094
Thongdam Purée	0.283	-0.044
Attribute		
Mango Identity	0.352	0.900
Fruity	-0.154	0.600
Grapefruit	-0.134	-0.401
Guava	0.523	0.156
Peach	-0.162	0.492
Orange	0.223	0.507
Pineapple	0.065	0.328
Caramelized	0.797	0.361
Chemical	0.063	-0.775
Cooked	0.997	-0.070
Green	-0.464	-0.397
Green-viney	0.249	-0.392
Fermented	0.219	0.557
Floral/Perfumy	0.063	0.939
Musty	-0.129	0.127
Peel-like	-0.611	-0.365
Piney	-0.509	-0.466
Spicy	-0.775	0.196
Starchy	0.718	-0.408
Sulfur	0.227	0.091
Vegetable	0.687	-0.487
Overall Sweet	0.400	0.810
Overall Sour	-0.078	0.189
Sweet	0.535	0.541
Bitter	-0.237	-0.619
Sour	0.122	0.084
Astringent	-0.136	-0.722
Metallic	0.103	-0.436
Throat Irritation	-0.967	0.016

	PC1 (78%)	PC2 (14%)
Tongue Burn	-0.986	0.088