Describing the Appearance and Flavor Profiles of Fresh Fig (*Ficus carica* L.) Cultivars

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Abstract: Twelve fig cultivars, including cultivars destined for the fresh and dried markets, were harvested from 6 locations and evaluated by a trained panel using descriptive sensory analysis. Instrumental measurements were taken at harvest and also during sensory analysis. Each fresh fig cultivar had a characteristic appearance and flavor sensory profile regardless of the source. The primary flavor attributes used to describe the fig cultivars were "fruity," "melon," "stone fruit," "berry," "citrus," "honey," "green," and "cucumber." Maturity levels significantly affected the chemical composition and sensory profiles of the fig cultivars. Less mature figs had a higher compression force, a thicker outer skin, and higher ratings for "green" and "latex" flavors, firmness, graininess, bitterness, tingling, and seed adhesiveness. Meanwhile, more mature figs had higher soluble solids concentration, and were perceptibly higher in "fruit" flavors, juiciness, stickiness, sliminess, and sweetness. The specific sensory terminology used for fig appearance and flavor profiles will assist with communication between marketers and consumers, which can increase fresh fig consumption.

Keywords: canonical variate analysis, fig cultivar, fruit maturity, sensory analysis

Practical Application: The development of a unique set of descriptors for each fresh fig cultivar allows better communication between fig growers, retailers, and consumers. Consumers who are able to correctly anticipate how a particular fig variety tastes are more likely to be satisfied and purchase more figs. This work also demonstrates the need to develop and select cultivars with high flavor attributes for future fresh fig production.

Introduction

The common fig tree (*Ficus carica* L.) is grown on approximately 454,000 hectares worldwide, with an annual fruit production of over 1.3 million tons (Food and Agriculture Organization 2007). The majority of fig growing areas have moderate climates, exhibiting low relative humidity (lower than 25%), intense luminosity, high summer temperatures around 32 to 37 °C, and moderate winters with temperatures above −1 °C (Obenauf and others 1978). The United States of America ranks 7th in the world's fig production after Turkey, representing approximately 3.3% of total production, and California accounts for approximately 98% of production in the U.S., due to its favorable climate. The main cultivars planted in California are "Calimyrna," "Mission," "Brown Turkey," and "Kadota" (Stover and others 2007). Most fig production in California is used for the dried market; only a small percentage is harvested for fresh fig consumption (Stover and others 2007). Until recently, fresh figs represented less than 5% of total fig production (Stover and others 2007). However, after 2002, fresh fig production experienced nearly a 4-fold increase, reaching 16% of California's fig production in 2006 (U.S. Dept. of Agriculture 2007). Most of the fig cultivars currently grown in California have been selected for their favorable characteristics in the dried fig market. Therefore, it is necessary for breeding programs to select new fig cultivars with favorable traits for fresh fruit consumption, such as intense fruity flavors, an adequate balance of sweetness and sourness, and good postharvest performance (Stover and others 2007). It is necessary to evaluate cultivars grown in California for fresh fig instrumental quality parameters, since no studies have yet been performed on this subject. Previous studies evaluating fig cultivars have mostly been performed on those native to Turkey (Caliskan and Polat 2008; Polat and Caliskan 2008), which are not presently grown; however, these cultivars are different from those currently grown or tested in California (Crisosto and others 2010).

One approach to promote and increase fresh fig consumption is to identify the sensory attributes of fresh fig cultivars and use this information to group cultivars based on similar sensory profiles. This can be achieved using descriptive sensory analysis with a trained panel. Cultivar classification will help match consumer preferences, and enhance current promotion and marketing programs. Also, this sensory technique will create a terminology to describe their diverse sensory attributes.

The use of sensory methods to characterize foods and beverages is well documented in the literature. Descriptive sensory analysis techniques have been applied to products in order to characterize sensory properties of different cultivars, growing regions, production methods, and so on. So far, descriptive sensory analysis of figs has been related to dried figs and fig jam (Levaj and others 2010; Haug's personal communication). For fresh fruit, descriptive sensory analyses have been used to characterize cultivars of peaches, nectarines, plums, pluots, apples, and kiwifruits (Crisosto and others 2006; Swahn and others 2010; Jaeger and others 2011).

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An "in-store" consumer acceptance test was used to investigate consumer preferences for 4 commercial California fresh fig cultivars at both the commercial mature and the tree ripe stages (Crisosto and others 2010). The results indicated that consumers are able to perceive differences between fresh fig cultivars and preferred late harvested fresh figs (tree ripe maturity compared with commercial ripe maturity) (Crisosto and others 2010). This indicates that there is a market potential to target consumer groups that prefer different fig cultivars and sensory attributes.

In order for the United States and other countries to develop and/or select cultivars for a viable fresh fig industry, research initiatives need to be established to develop flavorful fig cultivars with favorable traits for fresh fruit production. The aim of this study was to create a terminology and characterize the sensory properties of California-grown fresh fig cultivars using a descriptive sensory analysis of 12 fresh fig cultivars, grown in California, from 6 different sources.

Materials and Methods

Plant materials

Thirty-nine fresh fig samples consisting of 11 cultivars and one selection, hereafter called cultivars, were assessed (Figure 1). The fig cultivars were collected from 6 sources in California: commercial growers' orchards in Fresno, Madera, and Merced counties (Sources A, B, C, and D), the fig plot at the Kearney Agricultural Research and Extension Center (KAC) in Parlier, CA (Source E) and the USDA, ARS National Clonal Germplasm Repository (NCGR) for Fruit & Nut Crops in Davis, CA (Source F) during the 2011 season (Table 1). All fig samples were packed in labeled, single-layer boxes with trays. The fig samples of each cultivar-source-replicate consisted of 100 fruits. The figs were stored at 0 °C for an average of 2 d (±SD 1.3) prior to analysis.

Fruit selection and preparation

Prior to evaluation, the most representative fruits of each cultivar-source-replicate were selected based on appearance, maturity, and freedom from defects: 12 whole fruits for initial fruit instrumental quality measures and photos; and 48 fruits for sensory analysis, divided into 3 presentation replicates of 16 fruits each. It should be noted that although there was some variation in maturity stages within each source replicate, the same proportions of maturities were distributed evenly among the samples for fruit instrumental quality analysis and sensory analysis, based on nondestructive visual and firmness cues. At the time of analysis, figs were simultaneously removed from cold storage and warmed to room temperature, approximately 20 °C, under a fan for approximately 1 h.

Figure 1–A visual representation of the 12 California fresh fig cultivars used in the descriptive sensory analysis.

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Table 1– Details of the California-grown fresh fig cultivars, sources, number of source-replicates and cultivar-source codes (numbers indicating order of assessment) evaluated in this study.

Fig cultivar	Source[a]	# of source replicates	Cultivar-Source Code[b]
"Black Mission"	A	1	BM8A
	B	2	BM7B
			BM22B
	C	2	BM10C
			BM21C
	D	2	BM32D
			BM36D
"Brown Turkey"	A	4	BT1A
			BT13A
			BT16A
			BT17A
	B	1	BT6B
	D	3	BT20D
			BT23D
			BT25D
"Calimyrna"	B	1	CAL3B
	C	3	CAL11C
			CAL12C
			CAL19C
"Ischia Black"	E	1	IB29E
"Kadota"	A	1	KAD4A
	B	3	KAD5B
			KAD24B
			KAD27B
	D	1	KAD33D
"Panachee"	A	1	PAN26A
	E	1	PAN34E
	F	1	PAN39F
"Sequoia"	E	1	SEQ30E
"Sierra"	A	5	SI2A
			SI9A
			SI14A
			SI15A
			SI18A
	C	1	SI31C
"Tina"	E	1	TIN35E
"UCR 200–43"	F	1	UCR38F
"Violette de Bordeaux"	F	1	VDB37F
"Zidi"	E	1	ZID28E

[a]Sources A, B, C, and D—commercial growers' orchards located in Fresno, Madera, and Merced counties; Source E—Kearney Agricultural Research and Extension Center, Parlier, CA; Source F—USDA, ARS National Germplasm Repository, Davis, CA.
[b]Number corresponds to the order of assessment (1 = 1st fig cultivar-source assessed; 39 = last fig cultivar-source assessed).

Initial fruit instrumental quality assessment

Initial fruit instrumental quality was measured on 10 figs per source replicate prior to sensory analysis. This included fruit weight, ostiole diameter, skin color, compression force, compression distance, visual maturity stage, flesh color, skin thickness, soluble solids concentration (SSC), and titratable acidity (TA). Individual fresh weight was measured with a digital scale (model PM 4000, Mettler Instrument Corp., Hightstown, N.J., U.S.A.). Ostiole diameter and skin thickness were measured with calipers (SPI 2000, dial caliper). Fruit compression force was measured using a Texture Analyzer (TAXT) (model TA.XT *plus*, Texture Technologies Corp., Scarsdale, N.Y., U.S.A.) fitted with an aluminum 5 cm diameter × 20 mm high cylinder probe (TA-25).

Each whole fig was oriented on the stage on its side with the ostiole facing the operator, and then the fig was compressed on the cheek with the probe at a speed of 1 mm per second until the fig split and the maximum value of force (compression force) was recorded.

Visual maturity was assessed on each cut fig half as commercial mature (CM), tree ripe (TR), or overripe (OR). A fig was considered commercial mature when the fruit was physiologically mature and the flesh gave a little to the touch; tree ripe maturity was riper and softer than commercial maturity with translucent flesh; while a fig was considered overripe when the flesh was very soft, completely translucent and the skin was beginning to thin and deteriorate.

Skin color was measured on both cheeks of the fruit perpendicular to the widest diameter and flesh color was measured on the flesh of both halves of the fig cut longitudinally along the split that resulted from the compression, using a Minolta colorimeter (model CR-300, Osaka, Japan). For SSC and TA, 3 composite juice samples were obtained by pressing the flesh of 3 or 4 figs through cheesecloth with a hand press. The juice was used for the determination of SSC with a temperature compensated digital refractometer (model PR 32α, Atago Co., Tokyo, Japan). Four grams of each composite juice sample were used for determination of TA with an automatic titrator (model TIM 850, Radiometer Analytical, Lyon, France), reported as a percentage of citric acid.

Sensory analysis

A descriptive sensory analysis was conducted on 12 fresh fig cultivars in August and September 2011. Twelve panelists (8 females) were recruited from the Univ. of California, Davis campus, aged 20 to 32 y old (mean age of 24 y), most with previous experience in descriptive sensory analyses. Panelists were selected based on having no allergic reactions to figs and being available at the necessary times. All panelists participated in three 1-h training sessions.

Sensory descriptors were generated through panel consensus, using fresh figs and pictures of figs (for appearance), and also from documented and anecdotal evidence, as not all fig cultivars were available for tasting in the training sessions. Some of the published sources used included (McEachern 1996; IPGRI and CIHEAM 2003; Polat and Caliskan 2008; Gozlekci 2010; Oliveira and others 2010; Podgornik and others 2010). Panelists practiced the formal testing procedure and use of the rating scales, prior to formally rating the figs.

Panelists rated 5 appearance attributes on the same whole fig in a grey-background light box (GretagMacbeth, Chicago) under sodium light. In isolated, ventilated tasting booths, also under sodium lighting, panelists were each given one whole fruit, which they assessed for 3 texture attributes. Then, they cut the fig in half lengthwise from the stem end to the ostiole using a small paring knife, to assess 5 internal appearance attributes, 25 aroma attributes (including "other"), 6 in-mouth texture attributes, 4 taste attributes, 25 flavor attributes (including "other"), and 3 aftertaste attributes. One half of each of the fruits assessed was returned to organizers for half-fruit instrumental quality assessment. Panelists were required to taste the skin and expectorate all samples.

Panelists were presented with 9 figs per session, 3 fig cultivar-sources in triplicate, in a randomized and balanced order across the panelists. All figs were served at room temperature, on paper plates, with 3 digit random codes that differed for each panelist. Panelists cleansed their palates with water in between samples. For appearance, 2 whole fruits of each presentation replicate were placed adjacent to one another in the light box—one fruit positioned vertically, and the other oriented on its side with the ostiole facing panelists. The presentation replicates were each given 3 digit

Table 2–Fresh fig appearance and flavor sensory attributes, definitions and reference standards used in the descriptive sensory analysis.

Attribute	Definition	Reference standard
Appearance of exterior		
Size	Small, medium, large	
Colors and percentage	White, yellow, gold, light green, dark green, orange, pink, red, doark red, maroon, brown, blue, violet, purple, black	
Color variation	Striped, spotted	
Texture of skin	Smooth, powdery/white coating, matte, glossy, hairy, waxy, furry	
Position of ostiole	Closed, open	
Texture of exterior		
Firmness-exterior	Low anchor (not firm) High anchor (very firm)	
Skin smoothness	Low anchor (not smooth) High anchor (very smooth)	
Skin hairiness	Low anchor (not hairy) High anchor (very hairy)	
Appearance of interior		
Colors and percentage of pith	White, off-white, yellow, pink, red, green	
Colors and percentage of pulp	White, yellow, pink, red, dark red, maroon, brown, green, purple	
Colors and percentage of seeds	White, yellow, pink, red, brown	
Size of internal fruit cavity	None, small, medium, large	
Percentage of seeds and pulp		
Aroma		
Overall aroma intensity	Low anchor (low) High anchor (high)	
Intensity of fig aroma	Low anchor (low) High anchor (high)	$\frac{1}{2}$ dried Mission fig (Trader Joe's)
Fruity	Includes generic fruit and grape	1 piece canned yellow papaya + 1 piece canned orange, no juice (Dole tropical fruits)
Apple		2 × 1 cm^2 pieces of fresh apple, including peel
Banana		2 × 2 mm^2 pieces of fresh banana, no peel
Melon		2 cm x 1 cm piece of fresh honeydew melon, without peel
Stone fruit	Includes peach and plum	2 cm slice of fresh peach, including peel + 2 cm slice of fresh plum, including peel
Berry	Includes raspberry, strawberry, and dark berries	1 frozen blueberry + 1 frozen blackberry (Best Yet naturally sweet berry medley) + 1 frozen raspberry (Cascadian Farm Organic raspberries) + 1 frozen strawberry (Best Yet naturally sweet strawberries)
Floral	Includes generic floral, rose perfume, violet	$\frac{1}{2}$ tsp. of rose water (Sadaf)
Citrus		2 cm slice of fresh lime peel + 2 cm slice of fresh lemon peel + 2 cm slice of fresh orange peel
Honey	Includes sweet aromas	1 tsp. Clover honey (SueBee)
Toffee	Includes butterscotch, caramel and brown sugar	1 tsp. Butterscotch caramel topping (Mrs. Richardson's)
Coconut		$\frac{1}{2}$ tsp. sweetened coconut (Angel Flake, Baker's)
Chocolate		$\frac{1}{4}$ square of unsweetened baking chocolate (Baker's)
Nutty		$\frac{1}{2}$ tsp. unsalted, dry toasted slivered almonds (Trader Joe's) + $\frac{1}{2}$ tsp. walnut baking pieces (Trader Joe's)
Spicy		$\frac{1}{2}$ tsp. ground allspice (McCormick)
Green	Includes generic green, vegetal, herbal, leafy and fruit peel	3 frozen cut green beans (Birds Eye) + 4 frozen sweet peas (Birds Eye)
Cucumber		4 mm slice halved of fresh cucumber
Grassy		2 tsp. fresh cut grass
Minty		$\frac{1}{2}$ tsp. mint jelly (Reese)
Earthy	Includes dirt and soil	1 tsp. all-purpose potting soil (Black Gold)
Woody		1 tsp. pine shavings (Nature's Care, Alfalfa Hay mini-bales)
Latex		–
Sulfur	Includes garlic, onion and meaty	$\frac{1}{2}$ tsp. 10% SO_2 solution
Vinegar		$\frac{1}{2}$ tsp. white vinegar (Best Yet)
Flavor		
Overall flavor intensity	Low anchor (low) High anchor (high)	
Intensity of fig flavor	Low anchor (low) High anchor (high)	
In-mouth perception of the same attributes as aroma, without standards		

Continued.

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Table 2–Continued.

Attribute	Definition	Reference standard
Taste		
Skin thickness	Low anchor (thin) High anchor (thick)	
Sweetness	Low anchor (not sweet) High anchor (very sweet)	
Sourness	Low anchor (not sour) High anchor (very sour)	
Bitterness	Low anchor (not bitter) High anchor (very bitter)	
Texture in-mouth		
Pith firmness	Low anchor (not firm) High anchor (very firm)	
Sliminess	Low anchor (not slimy) High anchor (very slimy)	
Seed crunchiness	Low anchor (not crunchy) High anchor (very crunchy)	
Juiciness	Low anchor (not juicy) High anchor (very juicy)	
Stickiness	Low anchor (not sticky) High anchor (very sticky)	
Graininess	Low anchor (not grainy) High anchor (very grainy)	
Aftertaste		
Astringency	Low anchor (not astringent) High anchor (very astringent)	
Seed adhesiveness	Amount of product packed in teeth surfaces after chewing Low anchor (not adhesive) High anchor (very adhesive)	
Tingling	Low anchor (not tingly) High anchor (very tingly)	

random codes that were the same for each panelist, in which the computer session forced panelists to rate the appearance of each replicate in a randomized and balanced order. Panelists were given food at the end of each session, as well as a moderately priced gift card upon completion of the sensory analysis.

All attributes, reference standards, and descriptions are listed in Table 2. The intensity of some attributes, such as texture, taste, and aftertaste were rated using an unstructured 15 cm line scale anchored by wordings of "absence" or "low" to "extreme" or "high." Two aroma and flavor attributes ("overall aroma/flavor intensity" and "intensity of fig aroma/flavor") were also rated using scales. All other aroma, flavor, and appearance attributes were assessed using the "check all that apply" (CATA) method, used by Campo and others (2010). This method was used, as it was thought that figs have subtle aromas and flavors that would be better assessed on a "present" or "absent" basis.

The vocabulary used by panelists to describe certain parts of the fig were as follows: the "skin" was the outer most layer of the fruit; the "pith" was the layer inside the fruit directly beneath the skin; the "pulp" was the fleshy layer, located in the middle of the fruit, surrounding the seeds; the "seeds" were the hard, circular parts in the middle of the pulp; the "internal fruit cavity" was the size of the hole where the seeds are found, and the percentage of seeds and pulp was the total area of seeds and pulp (colored area) in relation to the whole fruit.

Half-fruit instrumental quality assessment

Each panelist returned a half of each fig sample to organizers after sensory analysis and placed them in labeled, lidded 5.5 oz. soufflé cups (Solo® Cup Co., Lake Forest, Ill., U.S.A.). Half-fruit instrumental quality assessment included visual maturity stage, skin thickness, compression distance, SSC, and TA, following the methods previously described, except for compression distance. The compression distance of the individual half fig was measured by placing it flesh side down on the stage and measuring the distance to compress the fig half with a compression force of 10 N at a speed of 1 mm per second.

Data analysis

FIZZ software (Version 2.1, Biosystemes, France) was used for the collection of all sensory data. All data were analyzed per fig cultivar, source, and source replicate (also known as order of assessment) (that is, the 39 samples separately) (see Table 1 for more details), as not all fig cultivars were assessed an equal number of times, and it was hypothesized that there would be differences in maturity stages between figs assessed at the start and at the end of the study.

The scaled sensory data and physicochemical data were analyzed separately from the CATA data. For the scaled sensory data, missing values were imputed using mean presentation replicate values, and the data were analyzed using a three-way analysis of variance (ANOVA) with two-way interactions for judge, presentation replicate, and fig cultivar-source, using a pseudo-mixed test, with mean square (judge*fig cultivar-source) as the error. Variance was assessed using the Tukey HSD order of comparison. A canonical variate analysis (CVA) was performed on the raw data, when the Wilks' Lambda P value was less than 0.05. The 95% confidence interval bubbles were calculated and fig cultivars were grouped. The CATA data were statistically analyzed using the methods of Campo and others (2010). In summary, the number of checks or citations was summed and frequency tables were created. Missing data were not imputed. The frequency data were then used for correspondence analysis using symmetrical analysis. Two correspondence analyses were performed, one for all appearance attributes, and the other for all categorical aroma and flavor attributes.

Table 3–Initial fruit instrumental quality measurements for each cultivar, source, and source replicate, averaged across 10 replicates, and an average of each cultivar (in boldface, see Table 1 for details of study design), standard deviation italicized in parentheses.

Cultivar-source	Weight (g)	SSC (%)	TA (% citric acid)	Skin thickness (mm)	Ostiole size (mm)	Compression force (N)
BM7B	27.0 *(4.84)*	15.3 *(1.76)*	0.12 *(0.01)*	2.8 *(0.35)*	3.8 *(0.90)*	8.8 *(0.42)*
BM8A	40.5 *(4.89)*	14.6 *(0.78)*	0.23 *(0.04)*	3.3 *(0.57)*	5.1 *(1.30)*	22.5 *(0.52)*
BM10C	35.8 *(5.72)*	14.9 *(0.31)*	0.11 *(0.01)*	3.1 *(0.33)*	5.7 *(0.79)*	7.8 *(0.17)*
BM21C	32.9 *(4.92)*	18.1 *(1.21)*	0.14 *(0.01)*	3.0 *(0.41)*	4.8 *(0.82)*	7.8 *(0.35)*
BM22B	47.1 *(9.78)*	20.9 *(2.14)*	0.18 *(0.01)*	2.9 *(0.46)*	6.9 *(1.26)*	7.8 *(0.19)*
BM32D	30.3 *(4.94)*	18.5 *(4.27)*	0.15 *(0.02)*	3.2 *(0.47)*	5.8 *(1.00)*	8.8 *(0.17)*
BM36D	29.7 *(8.89)*	20.9 *(1.12)*	0.23 *(0.00)*	3.1 *(0.55)*	5.4 *(1.01)*	11.8 *(1.02)*
Black Mission	**34.8 *(9.07)***	**17.6 *(3.04)***	**0.17 *(0.05)***	**3.1 *(0.47)***	**5.4 *(1.33)***	**10.8 *(0.68)***
BT1A	58.7 *(9.65)*	14.3 *(0.81)*	0.19 *(0.05)*	4.8 *(0.92)*	9.6 *(1.13)*	23.5 *(1.49)*
BT6B	52.1 *(8.63)*	18.6 *(1.64)*	0.12 *(0.02)*	5.5 *(1.05)*	7.5 *(1.99)*	9.8 *(0.35)*
BT13A	46.8 *(11.52)*	18.4 *(0.75)*	0.09 *(0.01)*	5.0 *(1.21)*	5.5 *(0.91)*	13.7 *(0.72)*
BT16A	52.1 *(7.99)*	15.9 *(1.18)*	0.13 *(0.02)*	4.7 *(0.82)*	6.6 *(1.15)*	13.7 *(0.56)*
BT17A	42.3 *(11.48)*	19.8 *(2.10)*	0.14 *(0.02)*	4.3 *(0.97)*	5.2 *(0.75)*	12.7 *(0.79)*
BT20D	63.6 *(8.05)*	19.4 *(0.62)*	0.14 *(0.03)*	4.9 *(0.79)*	7.7 *(1.48)*	12.7 *(0.80)*
BT23D	57.9 *(9.10)*	20.4 *(0.69)*	0.12 *(0.02)*	5.1 *(0.66)*	8.2 *(1.91)*	14.7 *(0.64)*
BT25D	70.6 *(7.52)*	22.5 *(0.89)*	0.16 *(0.01)*	4.2 *(0.66)*	10.3 *(1.19)*	13.7 *(0.22)*
Brown Turkey	**55.5 *(12.38)***	**18.6 *(2.63)***	**0.14 *(0.03)***	**4.8 *(0.95)***	**7.6 *(2.14)***	**14.3** *(0.84)*
CAL3B	62.3 *(15.72)*	16.9 *(1.39)*	0.23 *(0.03)*	3.1 *(0.81)*	7.8 *(1.59)*	17.6 *(0.56)*
CAL11C	77.1 *(8.60)*	16.3 *(0.06)*	0.17 *(0.03)*	3.9 *(0.41)*	9.5 *(1.12)*	13.7 *(0.46)*
CAL12C	74.8 *(9.45)*	16.0 *(1.77)*	0.23 *(0.06)*	4.2 *(0.81)*	9.6 *(1.90)*	14.7 *(0.48)*
CAL19C	75.1 *(5.09)*	18.2 *(1.01)*	0.21 *(0.04)*	3.7 *(0.67)*	10.6 *(1.47)*	11.8 *(0.28)*
Calimyrna	**72.3 *(11.67)***	**16.9 *(1.31)***	**0.21 *(0.04)***	**3.7 *(0.78)***	**9.4 *(1.81)***	**14.5 *(0.49)***
IB29E	31.1 *(9.16)*	22.0 *(1.36)*	0.30 *(0.05)*	2.6 *(0.60)*	4.2 *(0.55)*	10.8 *(0.37)*
KAD4A	58.6 *(10.07)*	17.9 *(1.23)*	0.27 *(0.04)*	6.2 *(0.87)*	9.3 *(0.92)*	41.2 *(1.52)*
KAD5B	45.4 *(10.13)*	19.1 *(2.34)*	0.13 *(0.01)*	5.3 *(1.28)*	8.5 *(1.21)*	22.5 *(1.11)*
KAD24B	31.5 *(4.31)*	18.1 *(0.64)*	0.14 *(0.03)*	3.9 *(0.80)*	8.5 *(0.99)*	12.7 *(0.48)*
KAD27B	29.3 *(4.51)*	18.9 *(0.17)*	0.12 *(0.02)*	3.7 *(0.62)*	9.3 *(1.21)*	13.7 *(0.63)*
KAD33D	30.9 *(5.02)*	16.4 *(1.37)*	0.14 *(0.01)*	3.9 *(0.83)*	9.2 *(0.79)*	15.7 *(0.89)*
Kadota	**39.1 *(13.43)***	**18.0 *(1.50)***	**0.16 *(0.06)***	**4.6 *(1.32)***	**9.0 *(1.07)***	**21.2 *(1.44)***
PAN26A	55.8 *(10.44)*	18.1 *(0.89)*	0.42 *(0.08)*	3.2 *(0.86)*	9.8 *(1.95)*	20.6 *(0.52)*
PAN34E	40.9 *(9.64)*	21.9 *(2.70)*	0.55 *(0.05)*	2.8 *(0.35)*	6.1 *(1.49)*	14.7 *(0.45)*
PAN39F	31.4 *(4.08)*	17.9 *(1.27)*	0.50 *(0.01)*	2.6 *(0.47)*	6.4 *(1.76)*	19.6 *(0.97)*
Panachee	**36.2 *(8.70)***	**20.1 *(2.76)***	**0.52 *(0.04)***	**2.7 *(0.42)***	**6.3 *(1.59)***	**18.3 *(0.77)***
SEQ30E	48.6 *(9.36)*	19.7 *(0.78)*	0.34 *(0.04)*	3.8 *(0.59)*	3.6 *(0.28)*	24.5 *(0.95)*
SI2A	45.0 *(13.16)*	16.5 *(0.99)*	0.14 *(0.02)*	3.5 *(0.90)*	5.9 *(1.17)*	20.6 *(1.24)*
SI9A	41.5 *(9.64)*	15.5 *(0.75)*	0.22 *(0.01)*	3.3 *(0.53)*	3.9 *(0.49)*	19.6 *(0.84)*
SI14A	46.7 *(6.50)*	14.9 *(5.20)*	0.17 *(0.01)*	3.5 *(0.80)*	3.8 *(0.53)*	32.3 *(2.63)*
SI15A	52.5 *(11.82)*	17.5 *(3.20)*	0.19 *(0.01)*	4.0 *(1.00)*	2.8 *(0.53)*	17.6 *(0.80)*
SI18A	57.7 *(8.84)*	18.7 *(1.71)*	0.21 *(0.05)*	3.5 *(0.64)*	3.4 *(0.40)*	17.6 *(0.51)*
SI31C	38.1 *(8.05)*	15.9 *(3.67)*	0.31 *(0.04)*	2.4 *(0.52)*	4.5 *(0.40)*	16.7 *(0.72)*
Sierra	**46.9 *(11.58)***	**16.4 *(2.82)***	**0.21 *(0.06)***	**3.4 *(0.86)***	**4.0 *(1.17)***	**20.7 *(1.39)***
TIN35E	29.7 *(3.78)*	18.1 *(1.01)*	0.14 *(0.02)*	2.3 *(0.49)*	6.8 *(0.78)*	13.7 *(0.36)*
UCR38F	45.6 *(9.48)*	16.2 *(0.72)*	0.32 *(0.03)*	3.3 *(0.79)*	5.7 *(0.46)*	9.8 *(0.21)*
VDB37F	29.5 *(8.87)*	17.5 *(1.79)*	0.52 *(0.00)*	3.2 *(0.58)*	7.3 *(1.61)*	9.8 *(0.41)*
ZID28E	53.6 *(9.45)*	21.4 *(1.80)*	0.27 *(0.03)*	3.0 *(0.46)*	8.0 *(1.75)*	10.8 *(0.38)*

For the initial fruit instrumental quality data, a two-way ANOVA was performed with one-way interactions for each measurement replicate and fig cultivar-source.

The means of scaled sensory and chemical data, and sums of categorical data were correlated using Pearson's pairwise correlations. A multiple factorial analysis was performed using Pearson's correlation matrix on the mean scaled sensory data, all mean physicochemical data, and the standardized coefficients of the 1st 2 of the correspondence analyses for the appearance, aroma and flavor CATA factors data.

SAS (Version 9.2, SPSS Inc. IBM, Ill., U.S.A.), JMP (Version 8.0, SAS Inst., Cary, N.C., U.S.A.), and XLSTAT (Version 2009.3.01 Addinsoft, N.Y., U.S.A.) software were used for all data analysis.

Results and Discussion

Initial fruit instrumental quality measures for each fig cultivar from each source and order of assessment, as well as an average of each fig cultivar are summarized in Table 3. The SSC, TA, and other initial fruit instrumental quality measurements correlated well ($r < 0.77$, $P < 0.05$) to their corresponding half fruit instrumental quality measures. The instrumental quality measurements also correlated well with the associated sensory attributes, such as ostiole size and "position of ostiole" ($r = 0.70$, $P < 0.05$), TA and "sourness" ($r = 0.71$, $P < 0.05$), weight and whole fruit "size" ($r = 0.82$, $P < 0.05$), and compression force and "firmness-exterior" ($r = 0.69$, $P < 0.05$).

All scaled sensory attributes were significantly different for the fig cultivar-sources ($P < 0.05$). There were also significant interactions between presentation replicate and fig cultivar-source ($P < 0.05$), using the pseudo-mix test for "intensity of fig aroma," "seed adhesiveness," "stickiness," "graininess," "bitterness," and "overall flavor intensity." When an ANOVA was performed testing for the effects of judge, presentation replicate and fig cultivar only (without source or order of assessment), the same sensory attributes were significantly different for fig cultivar and presentation replicate (data not shown). It should be noted that there were very low scores (less than 10% of scale) for "bitterness" and "tingling."

A number of sensory attributes were closely related, as shown by their proximity to one another in Figure 2. "Stickiness" and "sliminess" were strongly positively correlated (r = 0.88, $P < 0.05$), as were "astringency" and "graininess" (r = 0.76, $P < 0.05$), and "seed adhesiveness," to a lesser extent (r = 0.57, $P < 0.05$). "Crunchiness" was moderately associated with "firmness-exterior" (r = 0.40, $P < 0.05$), whereas "pith firmness" and "juiciness" were moderately negatively correlated (r = −0.53, $P < 0.05$), despite their close location in Figure 2. "Intensity of fig flavor" was driving ratings of "overall flavor intensity" (r = 0.88, $P < 0.05$).

The main sensory attributes of the 12 fresh fig cultivars tested are presented in Table 4. For the CATA data, these were the attributes rated by more than 40% of panelists, and for the scaled sensory data, these attributes were those significantly different between cultivars based on the Tukey HSD order of comparison. Each of the fresh fig cultivars studied had a different appearance and sensory flavor profile (Table 4), however, there were commonalities among sensory attributes used to describe the fresh fig cultivars. The main categorical aroma attributes rated by the panelists were: "fruity," "melon," "green," "cucumber," and "grassy." The main categorical flavor attributes rated were: "fruity," "melon," "stone fruit," "berry," "citrus," "honey," "green," and "cucumber." There were moderate to strong correlations between the same aroma and flavor attributes, however, more flavor attributes were used to describe the fresh fig cultivars than aroma attributes. This suggests that the in-mouth flavors of fresh figs are more intense and/or complex than the aromas. Panelists were required to assess both the skin and pith of the fresh fig during the descriptive sensory analysis, which might have contributed to the intensity of the flavors.

The results of a CVA of the scaled sensory data for fig cultivar-source and order of assessment are shown in the biplot in Figure 2. The center of each circle represents the mean of the fig cultivar-source, and the circle represents the 95% confidence interval. Overlapping circles signify that the fig cultivar-sources are not significantly different from each other. The CVA biplot in Figure 2 explains 43% of the variance, with an equal amount explained by the 1st 2 axes. CV3 explains an additional 15% (data not shown).

The 12 fresh fig cultivars studied are grouped by color in Figure 2. Most of the fig cultivars are spatially separated on the biplot and do not overlap other cultivars, indicating that the fresh fig cultivars studied had characteristic appearance and flavor sensory profiles, described in Table 4. The fig cultivars with multiple sources in this study are generally located close together on the biplot, indicating that source is not affecting the sensory properties of the figs to a large degree. Other tree fruits have also been shown to differ more between cultivars than growing locations (Crisosto and others 2006).

There are, however, a number of outlier cultivar-sources in Figure 2. All "Brown Turkey" (BT) figs are located in the bottom

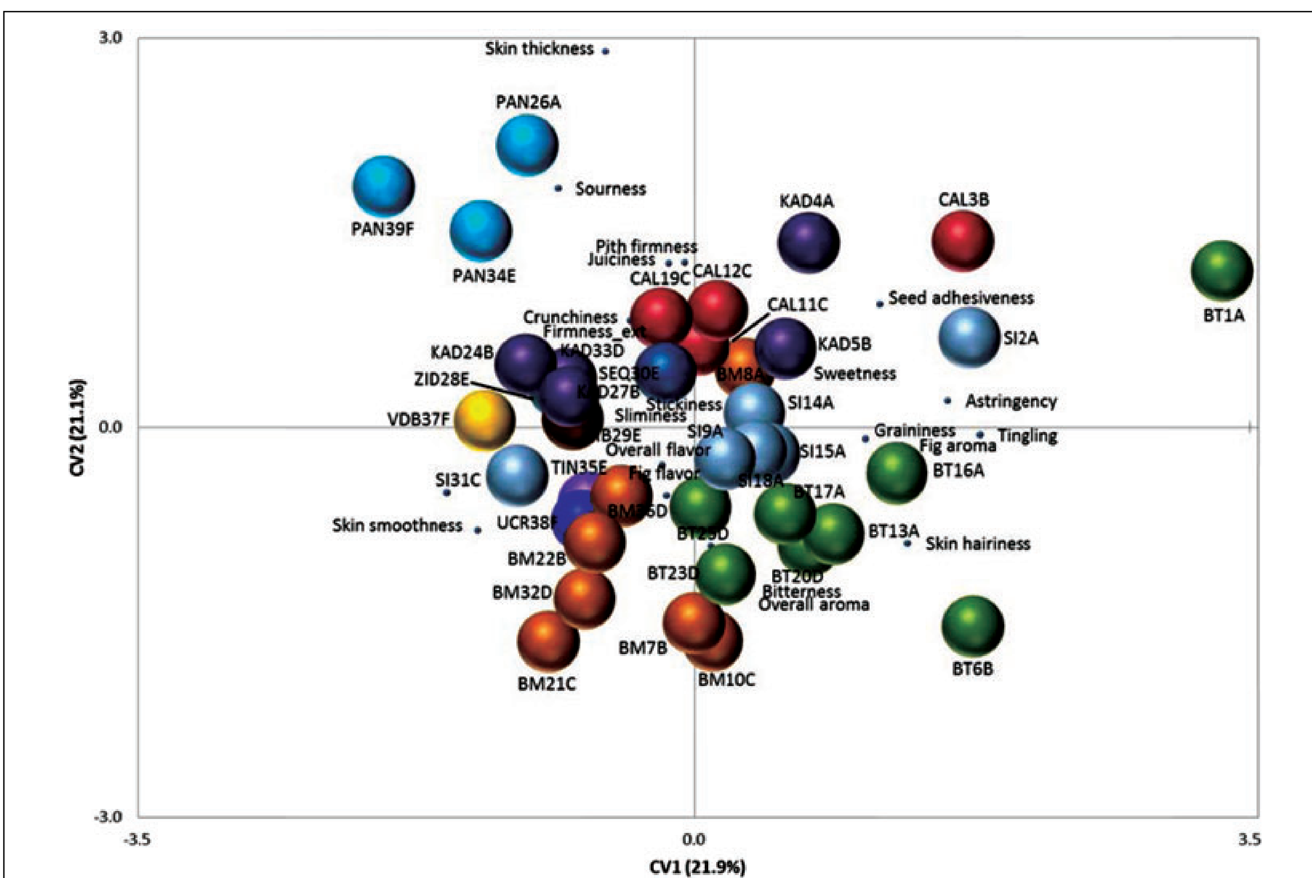

Figure 2–A canonical variate analysis (CVA) biplot of the scaled sensory data for fig cultivar-source and source replicate. The center of the circle represents the mean of each of the fig cultivar-sources, and the circle represents a 95% confidence interval. "Black Mission" (orange); "Brown Turkey" (green); "Calimyrna" (red); "Ischia Black" (brown); "Kadota" (purple); "Panachee" (light blue); "Sequoia" (dark blue); "Sierra" (grey); "Tina" (light purple); "Violette de Bordeaux" (yellow); "UCD 200–43" (blue); "Zidi" (light blue). See Table 1 for cultivar-source codes.

Table 4–Summary of the main appearance and flavor sensory descriptors for the 12 California fresh fig cultivars studied, averaged across judges ($n = 12$), presentation replicates ($n = 3$), source and source replicate (see Table 1 for study design).

Fig cultivar	Appearance descriptors	Sensory descriptors
Black Mission	Small to medium size Exterior: Violet, purple, black Spotted Smooth, powdery Closed ostiole Interior: Pith color: white, off-white Pith thickness: thin Pulp color: white, pink Seed color: yellow Small internal cavity	Thin skin, soft pith Aroma: High intensity Fig, green, cucumber, grassy Flavor: Fig, fruity, melon, stone fruit, honey, cucumber Low sourness Low graininess
Brown Turkey	Large size Exterior: Light green, purple Striped Hairy Open ostiole Interior: Pith color: white, off-white Pith thickness: thick Pulp color: white, pink, red Seed color: yellow Large internal cavity	Aroma: High intensity Fig, melon, green, cucumber, grassy Flavor: Fig, fruity, stone fruit, honey, cucumber Low sourness Grainy, astringent Low seed crunchiness Tingling
Calimyrna	Large size Exterior: Light green, yellow Striped Hairy Open ostiole Interior: Pith color: white, off-white, yellow Pith thickness: moderate Pulp color: white, yellow, pink, red Seed color: brown Minimal internal cavity	Firm exterior, firm pith Aroma: Cucumber, grassy Flavor: High intensity Fig, fruity, melon, stone fruit, berry, honey, cucumber Sweet, low bitterness Grainy, juicy Crunchy, high seed adhesiveness Tingling
Ischia Black	Small size Exterior: Violet, purple Spotted Smooth, powdery Open ostiole Interior: Pith color: off-white Pith thickness: thin Pulp color: white, pink, dark red, maroon Seed color: yellow Small internal cavity	Soft exterior Aroma: Cucumber Flavor: Fig, fruity, stone fruit, berry, honey Bitter Grainy, astringent
Kadota	Small size Exterior: Light green, dark green Spotted Smooth, glossy, waxy Open ostiole Interior: Pith: white, off-white Pith thickness: thick Pulp color: white Seed color: yellow Minimal internal cavity	Thick skin, firm pith Aroma: Low intensity Green, cucumber, grassy Flavor: Low intensity Honey, green, cucumber Low sweetness and sourness Low juiciness, sliminess and stickiness Low seed crunchiness
Panachee	Medium size Exterior: Yellow, light green Striped Smooth Open ostiole	Thick skin, firm exterior, firm pith Aroma: Cucumber Flavor: High intensity Fruity, stone fruit, berry, citrus, honey

Continued.

Table 4–Continued.

Fig cultivar	Appearance descriptors	Sensory descriptors
	Interior: Pith color: white, yellow Pith thickness: thin Pulp color: white, dark red Seed color: yellow Minimal internal cavity	Sour, low bitterness Crunchy seeds
Sequoia	Medium size Exterior: Light green, dark green Spotted Smooth Closed ostiole Interior: Pith color: white Pith thickness: thick Pulp color: white, pink Seed color: yellow Minimal internal cavity	Thick skin, firm exterior, firm pith Aroma: Cucumber, grassy Flavor: Fruity, cucumber Low juiciness, sliminess and stickiness
Sierra	Medium size Exterior: Light green, dark green Striped, spotted Hairy Closed ostiole Interior: Pith color: white Pith thickness: moderate Pulp color: white, yellow, pink Seed color: yellow, brown Minimal internal cavity	Firm exterior Aroma: Low intensity Green, cucumber, grassy Flavor: Low intensity Honey, cucumber Bitter, low sweetness Grainy, astringent Moderate seed adhesiveness Tingling
Tina	Medium size Exterior: Light green, dark green Striped Smooth, waxy Open ostiole Interior: Pith color: white, off-white Pith thickness: thin Pulp color: white, yellow, pink Seed color: yellow Minimal internal cavity	Soft exterior, soft pith Aroma: High intensity Fig, cucumber, grassy Flavor: Honey, cucumber Low sourness and bitterness Slimy, sticky Low tingling
UCR 200–43	Large size Exterior: Yellow, light green, dark green Striped, spotted Smooth, powdery Closed ostiole Interior: Pith color: white Pith thickness: moderate Pulp color: white, pink, red Seed color: yellow Medium to large internal cavity	Thin skin, soft exterior, soft pith Aroma: Fig, green, cucumber, grassy Flavor: Berry, honey Bitter Grainy, juicy Low astringency Low sliminess and stickiness
Violette de Bordeaux	Small to medium size Exterior: Violet, purple Spotted Smooth, powdery Open ostiole Interior: Pith color: off-white, pink Pith thickness: thin Pulp color: white, dark red Seed color: yellow Minimal internal cavity	Thin skin, soft pith Aroma: Cucumber Flavor: Fruity, stone fruit, berry, citrus honey Sweet, sour Juicy, slimy, sticky Astringent Low tingling

Continued.

Table 4–Continued.

Fig cultivar	Appearance descriptors	Sensory descriptors
Zidi	Medium size Exterior: Violet, purple Spotted, striped Hairy, furry Open ostiole Interior: Pith color: off-white, yellow Pith thickness: thin Pulp color: white, red, dark red Seed color: yellow, brown Minimal internal cavity	Aroma: Fruity, cucumber Flavor: Fruity, melon, stone fruit, berry, honey Sweet, low bitterness Juicy, sticky, slimy Crunchy seeds Low tingling

right quadrant of Figure 2, except for BT1A, which is located in the far right of the quadrant. BT1A was rated higher in "firmness," "graininess," "sourness," "astringency," "seed adhesiveness," and "tingling" than the other "Brown Turkey" figs. "Black Mission" figs are located mostly in the bottom half of the biplot, however, one sample, BM8A, is located in the top half of the quadrant, being rated higher in "seed adhesiveness," "astringency," and "bitterness" than the other "Black Mission" figs, and lower in "sweetness." The "Sierra" figs are mainly clustered in the center of the biplot, being moderately rated in most of the sensory attributes. One "Sierra" sample, SI2A, located to the right of the cluster, was rated high in "tingling" and "astringency," while fig SI31C, located to the left of the cluster, was rated high for "skin smoothness" and low for "graininess." The "Calimyrna" figs are located in the center of the top quadrant, whereas fig CAL3B, located to the right of the cluster, had higher ratings for "seed adhesiveness," "astringency," and "tingling" than the other "Calimyrna" samples. The "Kadota" figs are mostly clustered slightly to the left of the central axis. In contrast, 2 "Kadota" samples, KAD4A and KAD5B, are positioned to the right of the cluster, and are rated high in those attributes found low in the other "Kadota" samples, in particular, "astringency," "tingling," "graininess," "intensity of fig aroma," and "seed adhesiveness." All of the outliers, except SI31C, were located to the right of their cultivar groups, in the right-hand quadrant of the biplot, associated with increased ratings of "astringency," "seed adhesiveness," "graininess," and "tingling" (Figure 2). These outliers can be explained by the differences in initial fruit instrumental quality measurements (Table 3). All the outliers, except SI31C, were assessed in the 1st 3 d of analysis (order of assessment 1 to 9, see Table 1 for details), indicating that they were harvested early in the growing season.

Of those outliers harvested early in the season (BT1A, SI2A, CAL3B, KAD4A, and BM8A), the initial instrumental quality parameters indicated that they were harvested earlier, commonly with a lower maturity rating and SSC, and a higher compression force compared to the other sources harvested as the season progressed (Table 3). While the outlier harvested later in the season, SI31C, was the last of the "Sierra" figs to be assessed, and had, as expected, the lowest "firmness" rating of the "Sierra" figs (Table 3), exhibiting characteristics of an overripe fig. It should be noted that "Sierra" is a new fig cultivar with young trees just coming into production and growers have yet to understand the optimal harvest maturity for this cultivar.

All fresh figs were harvested between maturity stages "commercial mature" and "tree ripe," with a number of figs at the "overripe" stage toward the end of the study. There was a moderately positive correlation between the maturity stage and SSC ($r = 0.62$, $P < 0.05$) and compression force ($r = 0.68$, $P < 0.05$), indicating, as expected, that the SSC and compression force increased as figs matured (Crisosto and others 2010). In contrast, there was a moderate negative correlation between maturity and "skin thickness" ($r = -0.53$, $P < 0.05$), where "skin thickness" decreased as maturity increased.

There were a number of sensory attributes associated with maturity levels. As maturity increased, the following sensory aroma attributes decreased: "green" ($r = -0.67$, $P < 0.05$), "cucumber" ($r = -0.61$, $P < 0.05$), "grassy" ($r = -0.54$, $P < 0.05$), "earthy" ($r = -0.61$, $P < 0.05$), "woody," ($r = -0.72$, $P < 0.05$), and "latex" ($r = -0.40$, $P < 0.05$) (only 20% of panelists rated the "latex" attribute). Whereas "stone fruit" ($r = 0.45$, $P < 0.05$), "berry" ($r = 0.52$, $P < 0.05$), and "honey" ($r = 0.49$, $P < 0.05$) aromas increased with maturity, maturity was also related to some of the in-mouth texture attributes, including "juiciness" ($r = 0.62$, $P < 0.05$), "stickiness" ($r = 0.68$, $P < 0.05$), and "sliminess" ($r = 0.78$, $P < 0.05$). In contrast, "graininess," "tingling," and "seed adhesiveness" were found to decrease with increasing maturity. "Tingling" was moderately associated with "skin hairiness" ($r = 0.47$, $P < 0.05$), possibly due to the allergic reactions associated with plants in the *Ficus* family. As expected, maturity was positively related to "sweetness" ($r = 0.63$, $P < 0.05$), and negatively related to "bitterness" ($r = -0.62$, $P < 0.05$) and "astringency" ($r = -0.74$, $P < 0.05$).

These data demonstrate that the level of maturity affects the sensory properties of fresh figs, irrespective of fig cultivar. Fresh figs harvested earlier in the season (less mature) are more likely to exhibit unripe sensory profiles, such as green characters, "earthy," "woody," "latex," "bitter," "astringent," "grainy," "tingling," and "adhesive seeds." Ripe fresh figs are characterized more by "fruity" characters, "honey," "juicy," "sticky," "slimy," and "sweet." To our knowledge, no previous studies have indicated that "green" characters and "latex" flavor in fresh figs are associated with lower levels of ripeness. It may be that the skin, stem, and/or pith of the fresh figs contributed to the green characters and "latex" flavor. "Skin thickness" was somewhat positively associated with "green" flavor ($r = 0.38$, $P < 0.05$) and "latex" flavor ($r = 0.42$, $P < 0.05$). As "skin thickness" was found to decrease as figs ripen, this suggests that the "green" characters and "latex" flavor in ripe figs may decrease not as a result of changing sensory profiles, but of changing amounts of components in the fresh figs containing these characters. Therefore, a ripe fresh fig with a thicker skin, such as "Kadota" or "Sequoia," will retain some of the "green" characters (Table 4). A detailed study is being prepared to further answer the questions regarding harvest maturity and the resulting sensory attributes.

Conclusions

Fig cultivars vary in appearance and flavor sensory profiles, which, in general, were not affected by source. Specific sensory descriptor terminology for fig appearance and flavor profiles are being proposed based on the results of the trained sensory panel. We believe this terminology will assist with communication between marketers and consumers, which can increase fresh fig consumption. Maturity levels had a large effect on the fresh fig sensory profiles. Fresh figs harvested at lower maturity are perceived as having "green" and "latex" flavors, and high "astringency," "seed adhesiveness," "graininess," and "tingling," while mature-ripe fresh figs are associated with "fruity" flavors and higher "sweetness," "juiciness," and "sliminess." The results of this study highlight the importance of selecting cultivars and genotypes with strong flavors, not dependent on maturity stage, and which will remain firm as they mature.

Based on this sensory descriptors study and our previous "in-store" consumer test (Crisosto and others 2010), it would be of interest for the fresh fig industry to follow up these sensory studies with a large-scale consumer test, to identify the flavor characteristics driving consumer liking of fresh fig cultivars for promising, new fresh fig cultivars.

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