Sensory Profiles for Dried Fig (*Ficus carica* L.) Cultivars Commercially Grown and Processed in California

Megan T. Haug, Ellena S. King, Hildegarde Heymann, and Carlos H. Crisosto

Abstract: A trained sensory panel evaluated the 6 fig cultivars currently sold in the California dried fig market. The main flavor and aroma attributes determined by the sensory panel were "caramel," "honey," "raisin," and "fig," with additional aroma attributes: "common date," "dried plum," and "molasses." Sensory differences were observed between dried fig cultivars. All figs were processed by 2 commercial handlers. Processing included potassium sorbate as a preservative and SO_2 application as an antibrowning agent for white cultivars. As a consequence of SO_2 use during processing, high sulfite residues affected the sensory profiles of the white dried fig cultivars. Significant differences between dried fig cultivars and sources demonstrate perceived differences between processing and storage methods. The panel-determined sensory lexicon can help with California fig marketing.

Keywords: descriptive sensory analysis, dried fig, processing methods, quality attributes, sulfite residue

Practical Application: A set of dried fig sensory descriptors was established to provide more information for processors, marketers, and consumers in the dried fig market. Additionally, our results demonstrate at which levels sulfite residues can be perceived in dried figs.

Introduction

Figs (*Ficus carica* L.) are mainly grown in the Mediterranean region (Stover and others 2007). U.S. production increased 20% between 2005 and 2010 (Food and Agriculture Organization 2010). The San Joaquin Valley of California accounts for 98% of the total U.S. production, with 38600 tons of figs produced in 2011 (U.S. Dept. of Agriculture 2011). The fig market is divided into fresh and processed sectors (U.S. Dept. of Agriculture 2011). The fresh fig market consists of fresh fruit harvested and taken to market. While the processed market refers to whole dried figs sold in retail consumer packages (destined for direct consumption) or in bulk for manufacturing (such as, fig paste or fig juice concentrate). The bulk industrial items are sold to bakeries and to food processing companies (mainly cookie and energy bar companies) that use them to produce value-added items such as cookies, pastries, sauces, jams, and so on (Crisosto and others 2011; Iowa State Univ. 2011).

After figs mature and ripen on the tree, they can be dried in 2 manners; commonly referred to as tray-dried or sun-dried. Tray-dried figs are harvested at the tree-ripe maturity stage (Crisosto and others 2010), the white cultivars receive SO_2 application, and then all figs are laid on trays to dry in the sun. As these figs receive SO_2 application when they are fresh, they have a greater surface area to absorb SO_2 (California Environmental Protection Agency 2012). In contrast, sun-dried figs are fully ripened on the tree, and partially dry prior to abscising and dropping to the ground. They are collected and fully dried to the growers' preferences (California Fig Advisory Board 2012). White cultivars receive SO_2 application during postharvest storage. The desired final dried fig moisture content is around 17% (Crisosto and others 2011). The maximum moisture content allowed at retail is 24% without the use of a mold inhibitor, and 30% with a mold inhibitor (such as, potassium sorbate) (U.S. Dept. of Agriculture 2001). Sun-dried figs are sold domestically, while tray-dried figs are sold as a specialty item to Asian markets (Matt Jura's personal communication).

During postharvest storage, dried fruit of white cultivars commonly receive SO_2 application to inhibit enzymatic and nonenzymatic browning as a result of the Maillard reaction (Nichols and Cruess 1932; Roos and Himberg 1994; Karadeniz and others 2000). "Black Mission," the only dark cultivar used for dried fig processing, does not receive SO_2 application because the purple/black skin conceals any darkening. Color maintenance is an important commercial factor, as was demonstrated by a sensory evaluation regarding dried figs and fig paste that showed color was the major factor determining the acceptance level (Şen and others 2010). Meanwhile, potassium sorbate is used as a preservative for all dried cultivars (Perera 2007). This antimycotic agent is necessary in dried figs due to their high moisture content, which continues to increase after drying and during storage. Potassium sorbate application between 200 and 600 ppm has an antifungal effect, while levels greater than 600 ppm can be detected by the taster (Nury and Bolin 1962).

In addition to darkening, another postharvest issue with dried figs is the formation of fruit sugaring on the exterior of the fig (Meyvaci and others 2003). Fruit sugaring occurs when sugars from inside the fruit crystallize on the exterior surface of the fruit, which increases with time and high storage temperatures. To prevent sugaring, dried figs can receive a gentle heat treatment (Sen and others 2010).

MS 20130218 Submitted 2/15/2013, Accepted 4/30/2013. *Authors Haug and Crisosto are with Dept. of Plant Sciences, Univ. of California, Mail Stop 2 One Shields Ave., Davis, CA 95616, U.S.A. Authors King and Heymann are with Dept. of Viticulture and Enology, Univ. of California, One Shields Ave., Davis, CA 95616, U.S.A. Direct inquiries to author Haug (E-mail: mthaug@ucdavis.edu).*

doi: 10.1111/1750-3841.12196

S: Sensory & Food Quality

Journal of Food Science A Publication of the Institute of Food Technologists

In California, the 6 fig cultivars grown for the dried market are "Calimyrna," "Conadria," "Kadota," "Black Mission," "Sierra," and "Tena." "Calimyrna" and "Black Mission" figs are both sold at the consumer level and in processed products, while the other 4 cultivars are mainly used for processing. When sent for further processing, the different colors and flavors of the fig cultivars are important in determining how much of which cultivars will be combined. Thus, predetermined visual and sensory attributes presented in a dried fig flavor code would be beneficial for the fig industry.

Most people in the United States associate figs with fig cookies (Stover and others 2007). California growers and marketers are trying to change this perception. They are trying to expand the fig market in California, with emphasis on expanding the fresh market. As a result, a fresh fig sensory study was completed to help with fresh fig marketing (King and others 2012). Although this market has expanded in recent years, only 10% of the figs produced in 2011 were used in the fresh market (U.S. Dept. of Agriculture 2011). Therefore, it is necessary to further aid the marketing of dried and processed figs, since this comprises the majority of the California fig industry sales. Previous studies have investigated the consumer acceptance of fig jams and preserves (Levaj and others 2010; Şen and others 2010). There are also flavor and odor descriptors for dried fig cultivars in the USDA Standards for Grades of Dried Figs (U.S. Dept. of Agriculture 2001), but no descriptive sensory panels or consumer tests have been performed. This study involved conducting a descriptive sensory analysis on dried figs, in order to develop a lexicon for dried fig cultivars, to compare the effects of both cultivar and processing source, and to evaluate the effect of sulfite concentration on sensory perception.

Materials and Methods

Plant materials

Twelve dried fig samples, consisting of 6 cultivars from 2 sources (processors), were evaluated: "Black Mission," "Calimyrna," "Conadria," "Kadota," "Sierra," and "Tena." These samples were collected from 2 different commercial dried fig processors located in Fresno, California. Each source handled and processed their dried fig samples as if they were to be sold commercially, and sent their top quality to be assessed. These practices included the application of potassium sorbate (as a preservative) and sulfur dioxide to white cultivars (to prevent exterior browning). Eleven of the 12 cultivar-sources were sun-dried, while Kadota source 2 was tray-dried. Upon arrival to UC Davis, there were approximately 200 fruit samples of each cultivar source packaged into sealed 2 gallon Ziploc bags. The dried fig samples were stored at room temperature (20°C) for 1 wk prior to the initiation of the sensory analysis, and then were maintained at room temperature for the 3 wk duration of the experiment.

Fruit selection and preparation

When picking out fruit material, the most representative dried figs of top quality were chosen. For the sensory analyses, 12 of each cultivar source were used each day. For initial fruit quality assessment, 5 of each cultivar source were selected for the single day of analysis.

Sulfite residue testing

To measure the sulfite content of the fruit samples, 200 g samples of each cultivar source were sent to the Dried Fruit Association of California Laboratory in Fresno, Calif., U.S.A. The sulfite residue (resulting from the SO_2 application during processing) was measured using the gravimetric Monier–Williams technique (Nury and others 1959).

Initial fruit quality assessment

Initial fruit quality was measured on 5 fruit per cultivar-source. This included whole fruit weight, ostiole size, skin and flesh color, skin thickness, compression force, soluble solids concentration (SSC), titratable acidity (TA), and moisture content.

Skin color was measured on both cheeks of the whole fruit, using a Minolta colorimeter (model CR-300, Osaka, Japan). After cutting the fruit longitudinally in half through the ostiole, flesh color was measured on the pulpy flesh of both halves of the fig. All measurements were recorded as hue values, which describe the primary colors using measurements from 0 (red) to 360 (magenta), with yellow at 60, green at 120, and so on. Digital calipers (SPI 2000, dial caliper) measured ostiole size and skin thickness (including the skin and the pith).

The compression force was measured with a Texture Analyzer (model TA.XT *plus*, Texture Technologies Corp., Scarsdale, N.Y., U.S.A.), using a 5 cm wide × 2 cm high aluminum cylinder probe (TA-25). One of the cut fig halves per fruit was oriented on its flesh side on the stage (with the ostiole facing the operator), and the cheek of the fig was compressed by the probe to a set distance of 5 mm. The value reached at the distance of 5 mm was recorded as the compression force.

The compressed fruit halves were then used to determine SSC and TA. A composite juice sample of each cultivar-source was obtained using 5 g of randomly selected fruit material from the 5 fruit per cultivar source, added to 35 mL of distilled water, homogenized (Janke and Kunkel Ultra-Turrax homogenizer, Germany), and kept on ice prior to testing. The SSC was measured using a temperature-compensated digital refractometer (model PR 32α, Atago Co., Tokyo, Japan), and 4 g of each composite juice sample were used to measure the TA with an automatic titrator (model TIM 850, Radiometer Analytical, Lyon, France), expressed as the citric acid percentage.

The whole and half fruit weight was measured with a digital scale (model PM 4000, Mettler Instrument Corp., Hightstown, N.J., U.S.A.). The other half of each fruit used for the initial quality analysis was weighed at the time of the initial fruit quality measurements, and then every 24 h for the following 4 d of dehydration (NESCO Snackmaster® Encore Food Dehydrator, model FD-61, Milwaukee, WI, U.S.A.) to record the final stabilized weight, which determined the initial dry weight of each cultivar-source (Crisosto and others 2008).

Sensory analysis

A descriptive sensory analysis was conducted at UC Davis in January of 2012. Twenty-four panelists (11 males), with an average age of 36 y, were recruited from the campus and surrounding community. Panelists were selected based on having previously consumed fresh and/or dried figs, having no known allergies to figs, and being available to attend all training and tasting sessions. All panelists participated in 3 d of training and 6 d of tasting, lasting for a total of 3 wk.

The 24 panelists were trained as a group using the quantitative descriptive analysis (QDA) method (Lawless and Heymann 1999). During the training sessions, the group of panelists assessed all samples (except the tray-dried Kadota figs—Kadota-source 2) to create and agree upon terminology used to describe the sensory profiles of the dried figs. Reference standards were generated from

Table 1–A comparison of the sulfite residue levels found in the dried fig samples between each cultivar-source, using the Monier–Williams method.

Cultivar	Source	Sulfites (ppm)
Black Mission	1	0
Black Mission	2	0
Calimyrna	1	352
Calimyrna	2	243
Conadria	1	641
Conadria	2	471
Kadota	1	538
Kadota	2	3712
Sierra	1	750
Sierra	2	0
Tena	1	628
Tena	2	711

a previous fresh fig sensory panel (King and others 2012), flavor and odor descriptors listed in the USDA Standards for Grades of Dried Figs (U.S. Dept. of Agriculture 2001), and terminology advertised by the California Fig Advisory Board (2012).

Panelists assessed the dried figs in separate, ventilated, well-lit tasting booths. Each panelist received 6 figs per tasting session, served on paper plates with different 3-digit codes used to identify each sample. The 12 cultivar-sources were served in a randomized and balanced order, with each panelist receiving 3 replicates of each cultivar-source throughout the 6 d of tasting. Panelists assessed the appearance and texture of the whole dried samples in individual booths, and then individually cut their fruit sample lengthwise through the ostiole to evaluate the appearance, aroma, flavor, texture, and aftertaste of the half pieces. Panelists were encouraged to expectorate all samples and consume water between samples. Food was provided at the end of each tasting session, and upon completion of the project, each panelist received a moderately priced gift card.

Two different methods were used to score the attributes: line scales and "check all that apply" (CATA) frequency data, also used by Campo and others (2010) and King and others (2012). The unstructured 15 cm line scales were anchored from "low" to "high," and were used to rate the exterior texture, some aroma and flavor descriptors, taste, aftertaste, and in-mouth texture of the samples. The CATA method was used to determine the appearance, aroma, and flavor attributes present in the dried fig samples. Frequency data were used in place of line scales because the sensory profiles of dried figs often contain multiple aromas, which can be difficult to score using line scales (Lawless and Heymann 1999; Campo and others 2010).

Data analysis

All sensory data were collected using FIZZ software (Version 2.1, Biosystémes, Couternon, France) and were analyzed per cultivar-source. Both chemical and sensory data were analyzed with source separate from cultivar due to the different processing methods used. The categorical (CATA) data were organized in frequency tables and were included in the analysis if at least 37% of the panelists rated the attributes as being present in a given cultivar-source. This number was determined given that Campo and others (2010) used a 15% rating with 33 participants, while King and others (2012) used 40% with 14 participants.

A three-way analysis of variance (ANOVA) of sensory data was conducted using cultivar-source, replicate and judge as the main effects, with all possible 2-way interactions. The ANOVA and all correlations between initial fruit quality and sensory measurements, according to Pearson's pairwise correlations, were performed with JMP (Version 8.0, SAS Inst., Cary, N.C., U.S.A.). All significant differences were determined using Tukey's multiple comparisons test (least significant difference *t*-test). A canonical variate analysis (CVA) biplot was generated in XLSTAT (Version 2009.3.01 Addinsoft, N.Y.) using the raw-scaled sensory data, to determine the interaction between cultivar and source.

Results and Discussion

Sulfite residue testing

The Monier–Williams test established the sulfite residue levels, ranging from 0 to 3712 ppm between cultivar-sources (Table 1). This could be caused by different application rates used by the 2 processors. Sulfite oxidizes and degrades over time, even more so under higher temperature conditions, so the storage duration following SO_2 application could have also influenced the levels of sulfite residue (Nichols and Cruess 1932; Stadtman and others 1945; Joslyn and Braverman 1954; Lydakis and others 2003). No SO_2 was applied to both Black Mission cultivar sources, due to the dark skin color. All of the other cultivars received SO_2 application, except for Sierra-source 2. All white cultivars, except for Kadota-source 2, were sun-dried and the white cultivars received SO_2 application after drying was completed. Meanwhile, Kadota-source 2 was tray-dried, and thus, is likely to contain more SO_2 because the application was made when the figs were fresh, larger in size, and contained more surface area to absorb SO_2 (California Environmental Protection Agency 2012).

S: Sensory & Food Quality

Table 2–The initial dried fruit chemical and physical measurements per cultivar-source measured during postharvest handling; numbers in parentheses indicate standard deviation (n = 5).

Cultivar	Source	Weight (g)	Ostiole size (mm)	Skin color (Hue)	Flesh color (Hue)	Skin thickness (mm)	Compression force (N)	SSC (%)	TA (% citric acid)	Dry weight (%)
Black Mission	1	9.3 (1.14)	4.4 (0.89)	42.0 (6.53)	64.5 (1.90)	2.2 (0.27)	16.7 (9.69)	9.8	0.1	76.2 (0.65)
Black Mission	2	11.7 (1.28)	3.6 (0.55)	39.8 (2.65)	62.1 (2.39)	2.8 (0.57)	15.0 (11.88)	9.6	0.1	77.0 (0.54)
Calimyrna	1	18.3 (2.00)	6.6 (0.55)	78.2 (2.41)	63.0 (3.93)	2.3 (0.27)	10.4 (2.76)	8.9	0.1	79.8 (0.67)
Calimyrna	2	13.8 (1.41)	7.0 (0.79)	77.9 (1.55)	66.1 (1.49)	2.5 (0.61)	9.6 (5.20)	11.4	0.1	79.9 (1.43)
Conadria	1	11.5 (1.77)	5.0 (0.94)	73.0 (3.06)	64.3 (2.19)	2.0 (0.00)	12.2 (5.00)	8.5	0.1	78.4 (0.46)
Conadria	2	11.0 (1.49)	4.5 (0.94)	73.3 (1.95)	64.1 (1.94)	1.9 (0.89)	14.3 (6.50)	10.8	0.2	70.7 (1.52)
Kadota	1	15.2 (1.91)	6.6 (0.89)	72.9 (4.14)	62.9 (2.53)	3.0 (0.35)	15.8 (18.46)	8.6	0.1	82.4 (0.43)
Kadota	2	9.6 (1.03)	6.4 (0.65)	94.3 (0.94)	78.4 (4.70)	2.6 (0.42)	37.4 (16.22)	11.4	0.2	80.8 (0.86)
Sierra	1	13.2 (3.18)	4.1 (0.42)	75.6 (3.45)	66.9 (2.85)	2.4 (0.42)	12.6 (5.02)	9.2	0.1	80.9 (0.64)
Sierra	2	15.3 (2.90)	3.7 (0.45)	72.0 (4.07)	64.4 (1.55)	2.2 (0.84)	7.6 (3.23)	10.7	0.1	78.0 (1.13)
Tena	1	12.9 (1.18)	5.5 (0.50)	75.4 (1.67)	66.8 (1.44)	2.4 (0.42)	10.0 (5.61)	9.9	0.1	80.5 (0.71)
Tena	2	15.5 (2.58)	5.3 (1.10)	73.6 (1.55)	66.0 (1.39)	2.2 (0.57)	9.8 (5.21)	9.3	0.1	77.6 (1.49)

Table 3–Lexicon of all the panelist-rated attributes, and the descriptions and reference standards used.

Attribute	Description	Reference standard
Appearance of exterior		
Colors and percentage of skin	Crème, Blonde, Golden Brown, Dark Brown Sugar, Burnt Orange, Amber, Maroon, Burgundy, Dark Purple, Black, Light Gray, Dark Gray	
Texture of skin	Moist, Matte, Glossy, Waxy, Rubbery, Leathery, Sticky, Sugary	
Position of ostiole	Closed, Open	
Texture of exterior		
Firmness of fruit	low → high anchor (not firm → very firm)	
Wrinkliness of fruit	low → high anchor (not wrinkly → very wrinkly)	
Wetness of skin	low → high anchor (not wet → very wet)	
Sugaring of skin	low → high anchor (no sugaring → high sugaring)	
Appearance of interior		
Colors and percentage of pith	Crème, Blonde, Golden Brown, Dark Brown Sugar, Dark Purple	
Colors and percentage of pulp	Golden Brown, Dark Brown Sugar, Burnt Orange, Amber, Maroon, Burgundy, Dark Purple	
Color of seeds	Blonde, Golden Brown	
Percentage of seeds and pulp		
Percentage of seeds within the pulp		
Percentage of cilia	Dried hair-like structures located inside the fruit near the ostiole	
Aroma		
Overall aroma intensity	low → high anchor (low overall aroma → high overall aroma)	
Intensity of fig aroma	low → high anchor (low fig aroma → high fig aroma)	
Apricot (dried)		Dried apricots (sulfured)
Black licorice		1 star anise
Caramel		1 tsp. Mrs. Richardson's Butterscotch Caramel Topping
Cinnamon		1/2 tsp. cinnamon sugar
Common date		1 Medjool dried date, chopped and mixed with water
Asian date		4 dried dates, chopped and mixed with water
Dried plum (prune)		3 Pitted Prunes (Sunsweet)
Fermented		*no reference used – panelists all agreed to the smell/taste
Fig		1 Mission Fig, cut in 1/2 (Sunmaid CA Mission Figs)
Floral (citrus)		7 orange flavored dried cranberries (cranberries, sugar, sunflower oil, natural orange flavor)
Fruity		1″ slice each of chopped Granny Smith and Fuji apples
Honey		1 tsp. Valley Blossom Honey
Molasses		1/2 tsp. unsulfured molasses (Grandma's Gold Standard All Natural Original)
Nutty		3 almonds + 1 walnut, chopped and mixed with water
Papaya		9 2 cm chopped slices of dried papaya spears (low sugar)
Raisin		14 Monukka Raisins (organic, no sulfur) cut in 1/2 and mixed with water
Spicy		1 clove + 15 Fennel seeds + 20 pieces crushed red pepper + 7 pieces Peppercorn Medley (grounded black pepper)
Tamarind		1/2″ chunk of wet tamarind, chopped and mixed with water
Flavor		
Overall flavor intensity	low → high anchor (low overall flavor → high overall flavor)	
Intensity of fig flavor	low → high anchor (low fig flavor → high fig flavor)	
Apricot (dried)		Dried apricots (sulfured)
Black licorice		1 star anise
Caramel		1 tsp. Mrs. Richardson's Butterscotch Caramel Topping
Cinnamon		1/2 tsp. cinnamon sugar
Common date		1 Medjool dried date, chopped and mixed with water
Asian date		4 dried dates, chopped and mixed with water
Dried plum (prune)		3 Pitted Prunes (Sunsweet)
Fermented		*no reference used—panelists all agreed to the smell/taste
Fig		1 Mission Fig, cut in 1/2 (Sunmaid CA Mission Figs)
Floral (citrus)		7 orange flavored dried cranberries (cranberries, sugar, sunflower oil, natural orange flavor)
Fruity		1″ slice piece of chopped Granny Smith and Fuji apples
Honey		1 tsp. Valley Blossom Honey
Molasses		1/2 tsp. unsulfured molasses (Grandma's Gold Standard All Natural Original)
Nutty		3 almonds + 1 walnut, chopped and mixed with water

(Continued)

Table 3–Continued.

Attribute	Description	Reference standard
Papaya		9 2 cm chopped slices of dried papaya spears (low sugar)
Raisin		14 Monukka Raisins (organic, no sulfur), cut in 1/2 and mixed with water
Spicy		1 clove + 15 Fennel seeds + 20 pieces crushed red pepper + 7 pieces Peppercorn Medley (grounded black pepper)
Tamarind		1/2″ chunk of wet tamarind, chopped and mixed with water
Taste		
Chewiness of skin	low → high anchor (not chewy → very chewy)	
Sweetness	low → high anchor (not sweet → very sweet)	
Sourness	low → high anchor (not sour → very sour)	
Bitterness	low → high anchor (not bitter → very bitter)	
Texture in-mouth		
Thickness of skin	low → high anchor (not thick → very thick)	
Sliminess	low → high anchor (not slimy → very slimy)	
Gumminess	low → high anchor (not gummy → very gummy)	
Fibrousness	low → high anchor (not fibrous → very fibrous)	
Mealiness	low → high anchor (not mealy → very mealy)	
Crunchiness of seeds	low → high anchor (not crunchy → very crunchy)	
Aftertaste		
Astringency	low → high anchor (not astringent → very astringent)	
Adhesiveness of seeds	low → high anchor (not adhesive → very adhesive)	
Caramelized	low → high anchor (not caramelized → very caramelized)	
Sourness	low → high anchor (not sour → very sour)	
Common after dried fruit taste	low → high anchor (no common feeling → high common feeling)	

These 2 methods of processing dried figs are comparable to raisin processing. The Sultana raisins are treated with SO_2 after the drying process, while the golden bleached and sulfur bleached raisins receive SO_2 prior to drying (Lydakis and others 2003).

Initial fruit quality assessment

The initial fruit quality measurements varied by cultivar and source (Table 2). The commercial dried fruit weight varied from 9.3 g (Black Mission-source 1) to 18.3 g (Calimyrna-source 1). The ostiole size varied per cultivar, with "Black Mission" and "Sierra" having the smallest ostiole, and "Calimyrna" having the largest. As expected, "Black Mission," the only dark cultivar, had a lighter hue value for skin color compared to the white cultivars. The 2 Kadota cultivar-sources demonstrated source differences, with Kadota-source 2 containing the highest hue value (Table 2). This same situation also occurred with the flesh color, where all cultivars (including "Black Mission") had similar hue values, while Kadota-source 2 had the highest value. Thus, it is probable that the high SO_2 levels in Kadota-source 2 (Table 1) had a bleaching effect on both the flesh and the skin color. Sulfite residue might have also influenced the firmness of the fruit, as Kadota-source 2 had a higher compression force than the other dried fig cultivar-sources (Table 2). The skin thickness, SSC, and TA were similar among cultivars, as was the dry weight percentage of the fruit, showing that the figs were dried to have approximately 20% water weight.

Sensory analysis

The panelists determined a lexicon for describing the dried fig sensory attributes, consisting of interior and exterior appearance, texture, aroma, flavor, taste, and aftertaste (Table 3). The categorical data are reported by cultivar, except "Kadota," due to similarities between sources when the data were analyzed by cultivar and source (Table 4). Thus, the data between cultivar-sources were combined and analyzed per cultivar to present a sensory lexicon that would be more helpful for marketing purposes, which was our main objective. The few differences, most likely due to processing, are discussed later. However, both "Kadota" sources are presented separately, as panelists perceived large differences between these samples.

The key categorical flavor attributes used to describe dried figs by over 37% of panelists included "caramel," "honey," "raisin," and "fig." Whereas the common aroma attributes described by the panelists were "caramel," "honey," "fig," "raisin," "common date," "dried plum," and "molasses." There were a greater number of aroma descriptors rated in comparison to flavor characteristics for the dried figs, which contradicts the sensory findings from a previous fresh fig sensory panel. King and others (2012) found that the flavor of fresh figs was more intense than the aroma, whereas the opposite is true for dried figs in this study. This might be due to less flavor release with dried figs due to the smaller surface area.

The flavor and aroma ratings for some of the same attributes were positively correlated, including "cinnamon" flavor and aroma ($r = 0.66$, $P < 0.05$), "dried plum" flavor and aroma ($r = 0.69$, $P < 0.05$), "fig" flavor and aroma ($r = 0.87$, $P < 0.01$), "floral (citrus)" flavor and aroma ($r = 0.69$, $P < 0.05$), "honey" flavor and aroma ($r = 0.64$, $P < 0.05$), "molasses" flavor and aroma ($r = 0.91$, $P < 0.0001$), "papaya" flavor and aroma ($r = 0.63$, $P < 0.05$), and "raisin" flavor and aroma ($r = 0.70$, $P < 0.05$).

All scaled sensory data were analyzed by cultivar and by source, due to the significant interaction between cultivar sources. Out of the 23 scaled sensory attributes, 20 attributes were significant ($P < 0.05$) and are presented in the form of a CVA biplot (Figure 1). Each circle represents a 95% confidence interval for each cultivar source (Figure 1). The first 2 principal components (PCs) explain 70.9% of the total variability between cultivar and source (Figure 1).

"Black Mission" was the only cultivar that did not demonstrate significant differences between sources on all scaled measurements. Although the bubbles on the CVA biplot do not overlap for "Calimyrna," "Sierra," and "Tena" (Figure 1), all 3 cultivars are only significantly different between sources, with source 1 having a greater amount of "fruit sugaring." Thus, storage conditions

Table 4–The main appearance and flavor descriptors of dried figs, rated by trained panelists (n = 24), using categorical data, including a representative image of each cultivar (with both sources combined, except for the 2 Kadota sources).

Cultivar	Appearance descriptors	
Black Mission	**Exterior** Skin Color: Black, Burgundy, Dark Purple Skin Texture: Glossy, Leathery, Moist, Rubbery, Sticky Closed Ostiole **Interior** Pith Color: Dark Purple, Dark Brown Sugar Pulp Color: Dark Purple, Maroon Seed Color: Golden Brown **Aroma** Dried Plum, Fig, Honey, Molasses, Raisin, Tamarind **Flavor** Dried Plum, Fig, Honey, Raisin	
Calimyrna	**Exterior** Skin Color: Blonde, Crème, Dark Brown Sugar, Golden Brown Skin Texture: Leathery, Matte, Moist, Rubbery, Sticky, Sugary Open Ostiole **Interior** Pith Color: Blonde, Crème, Golden Brown Pulp Color: Amber, Burnt Orange, Dark Brown Sugar, Golden Brown Seed Color: Blonde, Golden Brown **Aroma** Caramel, Common Date, Dried Plum, Fig, Honey, Molasses, Raisin **Flavor** Caramel, Fig, Honey, Raisin	
Conadria	**Exterior** Skin Color: Blonde, Dark Brown Sugar, Golden Brown Skin Texture: Glossy, Leathery, Moist, Rubbery, Sticky, Sugary, Waxy Closed Ostiole **Interior** Pith Color: Blonde, Crème, Golden Brown Pulp Color: Amber, Burnt Orange, Dark Brown Sugar Seed Color: Golden Brown **Aroma** Common Date, Dried Plum, Fig, Honey, Molasses, Raisin **Flavor** Fig, Honey, Raisin	
Kadota1	**Exterior** Skin Color: Blonde, Burnt Orange, Crème Dark Brown Sugar, Golden Brown Skin Texture: Glossy, Leathery, Matte, Rubbery Sugary, Waxy Open Ostiole **Interior** Pith Color: Blonde, Crème, Golden Brown Pulp Color: Amber, Burnt Orange, Dark Brown Sugar, Golden Brown Seed Color: Golden Brown **Aroma** Apricot, Caramel, Dried Plum, Fig, Honey, Raisin **Flavor** Caramel, Fig, Honey, Raisin	
Kadota2	**Exterior** Skin Color: Blonde, Crème Skin Texture: Glossy, Leathery, Matte, Rubbery, Waxy Open Ostiole **Interior** Pith Color: Blonde, Crème Pulp Color: Amber, Golden Brown Seed Color: Blonde	

(Continued)

Table 4–Continued.

Cultivar	Appearance descriptors	
	Aroma Apricot, Fig, Honey **Flavor** Apricot, Fig, Floral (citrus), Fruity, Papaya	
Sierra	**Exterior** Skin Color: Blonde, Crème, Dark Brown Sugar, Golden Brown Skin Texture: Leathery, Matte, Rubbery, Sugary **Interior** Pith Color: Blonde, Crème, Golden Brown Pulp Color: Amber, Burnt Orange, Dark Brown Sugar Seed Color: Blonde, Golden Brown **Aroma** Caramel, Common Date, Dried Plum, Fig, Honey, Molasses, Raisin **Flavor** Caramel, Dried Plum, Fig, Honey, Raisin	
Tena	**Exterior** Skin Color: Blonde, Crème, Dark Brown Sugar, Golden Brown Skin Texture: Glossy, Leathery, Matte, Rubbery, Sticky, Sugary **Interior** Pith Color: Blonde, Crème, Golden Brown Pulp Color: Amber, Burnt Orange, Dark Brown Sugar, Golden Brown Seed Color: Blonde, Golden Brown **Aroma** Caramel, Dried Plum, Fig, Honey, Molasses, Raisin **Flavor** Caramel, Fig, Honey, Raisin	

should be regulated to prevent fruit sugaring for longer storage periods because the difference in exterior appearance can be perceived.

The different Conadria and Kadota cultivar-sources are in different areas of the biplot, with different defining characteristics (Figure 1). For "Conadria," source 1 had a significantly higher "fibrous" texture and "chewy" taste, and a significantly lower "wet fruit" and "sour" taste. The high "wet fruit" of Conadria-source 2 appears to be the main cause of separation between the sources (Figure 1).

The 2 "Kadota" sources are widely separated in the biplot (Figure 1), with Kadota-source 1 displaying similar sensory profiles to other dried fig cultivars in the bottom quadrant, while Kadota-source 2 is on the outskirts of the biplot being characterized by "sour" taste and aftertaste. The segregation of both "Kadota" samples in the CVA biplot (Figure 1) is thought to be due to the large differences in sulfite residues between the 2 samples (Table 1). The 2 "Kadota" sources were scored as significantly different for the following 12 attributes: "fruit firmness," "fruit sugaring," "overall" aroma, "fig" aroma, "wet fruit," "gummy" texture, "sweet" taste, "sour" taste, "fig" flavor, "adhesive" aftertaste, "sour" aftertaste, and "caramelized" aftertaste. All attributes were significantly greater for Kadota-source 1, except "fruit firmness," "sour" taste, and "sour" aftertaste all rated significantly greater for Kadota-source 2. This supports the idea that the high sulfite residues are altering flavor perception.

The 2 "Sierra" samples were the only ones that had either none (0 ppm) or the normal (750 ppm) levels of sulfite residues in this study (Table 1). The CVA shows the 2 cultivar-sources as significantly different from one another, but in the same quadrant (Figure 1). The only significantly different attribute between the 2 samples was the higher "fruit sugaring" for Sierra-source 1 (Figure 1), which is a result of different storage conditions. With the sulfite ranges provided, this study demonstrated that only sulfite residue levels above 750 ppm were found to affect the sensory characteristics of dried figs, with our 1 example above 750 ppm (Kadota-source 2) impacting both the color of dried figs (Table 2 and 4) and the taste (Figure 1). Although sulfite levels begin to decrease after 6 mo of storage (Nichols and Cruess 1932; Joslyn and Braverman 1954) and can lose up to 65% of the initial application (Stadtman and others 1945), it seems that the bleaching effect on the skin and flesh color, as well as changes in sensory attributes, are irreversible if excessive levels of SO_2 are applied. More research is required to investigate the effect of SO_2 application on dried fruit sensory profiles.

The panelist-rated sensory attributes correlated well with the initial fruit quality measurements (Table 2). For example, skin thickness (in mm) and "skin thickness" ($r = 0.70$, $P < 0.05$), skin thickness (in mm) and "gummy" texture ($r = 0.60$, $P < 0.05$), TA and "sour" taste ($r = 0.95$, $P < 0.0001$), and TA and "sour" aftertaste ($r = 0.93$, $P < 0.0001$). Future research should include a dried fig consumer test to evaluate which cultivars are preferred. The combined results of this descriptive analysis and a consumer test would provide plant breeders with the knowledge of which attributes to select for in future cultivars.

Differences between the cultivar-sources can be related to the different postharvest handling methods used by each dried fig processor. Although there are significant differences between sources, the majority of flavor and aroma attributes remain the same among

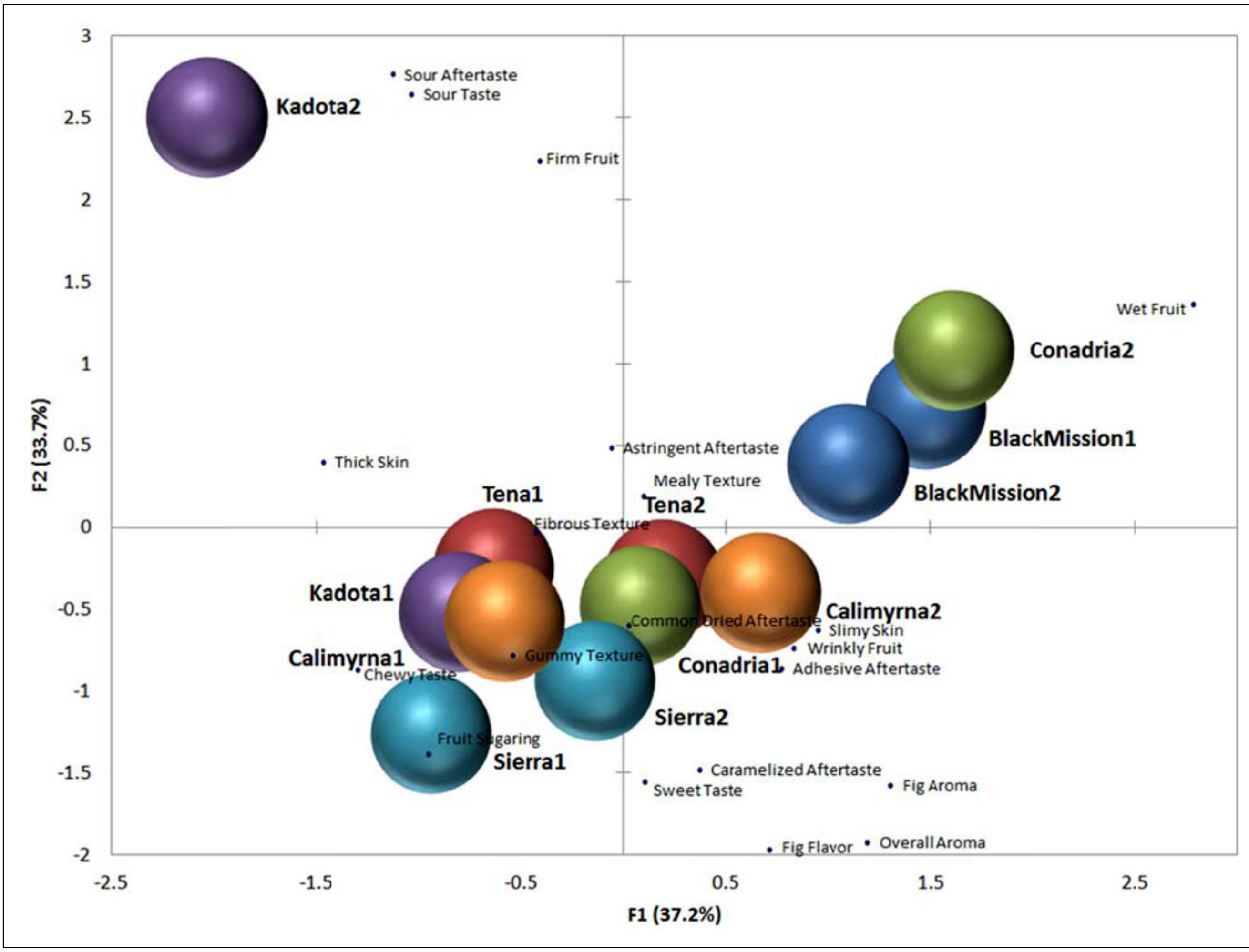

Figure 1–A CVA biplot demonstrating the 95% confidence intervals ($n = 3$) for each dried fig cultivar-source, based on the panelist-scaled sensory descriptors. The number after the cultivar indicates the source.

S: Sensory & Food Quality

cultivars, except when uncommon levels of sulfite residues were found within the fruit samples.

Conclusion

Dried figs remain the largest production of the fig market. Thus, it is important to maintain the quality of dried figs, both for those destined for direct consumption and those which will receive further processing. Based on our sensory findings, all 6 cultivars currently used in the dried fig market have predominant sensory characteristics. The panel-generated terminology can assist in marketing endeavors for both dried and processed dried fig products. This terminology and future consumer preference studies can help plant breeders to expand the fig industry.

In addition to cultivar differences, processors should maintain sulfite residue levels below 750 ppm in order to preserve the light colors of the white figs, without altering the sensory characteristics. Storage conditions should also be monitored to prevent fruit sugaring because the difference in exterior appearance can be perceived.

Acknowledgments

We thank the California Fig Assoc. for their continued financial support, and for supplying the fruit material. We acknowledge Gayle Crisosto for helping gather initial fruit and descriptor samples, and Kevin Scott for helping with data collection.

References

California Environmental Protection Agency: Office of Environmental Health Hazard Assessment [Internet]. Consumption of Sulfur Dioxide in Dried Fruits, CA.gov. 2012. Available from: http://oehha.ca.gov/prop65/law/pdf_zip/SO2driedfruitIG.pdf. Accessed 2012 August 20.

California Fig Advisory Board: California Figs [Internet]. Dried Figs. 2012. Available from: http://californiafigs.com/home. Accessed 2012 August 20.

Campo E, Ballester J, Langlois J, Dacremont C, Valentin D. 2010. Comparison of conventional descriptive analysis and a citation frequency-based descriptive method for odor profiling: an application to Burgundy Pinot noir wines. Food Qual Pref 21:44–55.

Crisosto CH, Bremer V, Ferguson L, Crisosto GM. 2010. Evaluating quality attributes of four fresh fig (*Ficus carica* L.) cultivars harvested at two maturity stages. HortScience 45:707–10.

Crisosto CH, Ferguson L, Bremer V, Stover E, Colleli G. 2011. Fig (*Ficus carica* L.). In: Yahia EM, editor. Postharvest biology and technology of tropical and subtropical fruits. Volume 3: Cocona to mango. Oxford: Woodhead Publishing Limited. p 134–58.

Crisosto CH, Hasey J, Cantin CM, Crisosto GM. 2008. New kiwifruit dry weight protocol. UC Cooperative Extension Central Valley Postharv Newslett 17:11–5.

Food and Agriculture Organization [Internet]. Data archives, Food and agriculture organization of the United Nation (FAO). 2010. Available from: http://faostat.fao.org/site/567/DesktopDefault.aspx#ancor. Accessed 2012 August 20.

Iowa State Univ.: Agricultural Marketing Resource Center [Internet]. Fig Profile, AgMRC. 2011. Available from: http://www.agmrc.org/commodities__products/fruits/fig-profile/. Accessed 2012 August 20.

Joslyn MA, Braverman JBS. 1954. The chemistry and technology of the pretreatment and preservation of fruit and vegetable products with sulfur dioxide and sulfites. In: Mrak EM, Stewart GF, editors. Advances in food research. Volume V. New York: Academic Press Inc. p 97–147.

Karadeniz F, Durst RW, Wrolstad RE. 2000. Polyphenolic composition of raisins. J Agric Food Chem 48:5343–50.

King ES, Hopfer H, Haug MT, Orsi JD, Heymann H, Crisosto GM, Crisosto CH. 2012. Describing the appearance and flavor profiles of fresh fig (*Ficus carica* L.) cultivars. J Food Sci 77(12):419–29.

Lawless H, Heymann H. 1999. Sensory evaluation of food: principles and practices. NY: Chapman and Hall. 848 p.

Levaj B, Bunić N, Dragović-Uzelac V, Kovačević DB. 2010. Gel strength and sensory attributes of fig (*Ficus carica*) jams and preserves as influenced by ripeness. J Food Sci 75: S120–4.

Lydakis D, Fysarakis I, Papadimitriou M, Kolioradakis G. 2003. Optimization study of sulfur dioxide application in processing of sultana raisins. Intl J Food Prop 6(3):393–403.

Meyvaci KB, Sen F, Aksoy U, Ö zdamar F, Çakir M. 2003. Research on prolonging the marketing period of dried and ready-to-eat type figs *(Ficus Carica)*. Acta Hort 628:439–45.

Nichols PF, Cruess WV. 1932. Sulfur dioxide as dried fruit preservative. Ind Eng Chem 24:649–50.

Nury FS, Bolin HR. 1962. Colorimetric assay for potassium sorbate in dried fruits. J Food Sci 27(4):370–2.

Nury FS, Taylor DH, Brekke JE. 1959. Modified direct colorimetric method for determination of sulfur. Dioxide Dried Fruits 7:351–2.

Perera C. 2007. Selected quality attributes of dried foods. Drying Technol 23(4):717–30.

Roos YH, Himberg MJ. 1994. Nonenzymatic browning behaviour, As related to glass transition, of a food model at chilling temperatures. Food Chem 42(4):893–8.

Şen F, Meyvacı KB, Aksoy U, Koç S, Sarılar S, Kocatürk R. 2010. Changes in quality of dried fig fruit and processed fig products under cold and ambient storage conditions. Acta Hort 877:853–60.

Stadtman ER, Barker HA, Mrak EM, Mackinney G. 1945. Storage of dried fruit. Ind Eng Chem 38:99–104.

Stover E, Aradhya M, Crisosto CH, Ferguson L. 2007. Overview of the California fig industry and new interest in varieties for fresh fruit. In: Proceedings of the california plant and soil conference; 6–7 February. Sacramento, CA: California Chapter, American Society of Agronomy.

U.S. Dept. of Agriculture: Noncitrus Fruits and Nuts. 2011. summary [Internet]. National Agricultural Statistics Service, U.S. Department of Agriculture; 2011. Available from: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1113. Accessed 2012 August 20.

U.S. Dept. of Agriculture: United States Standards for Grades of Dried Figs [Internet]. Processed Products Branch, U.S. Department of Agriculture. 2001. Available from: http://www.agmrc.org/media/cms/dried_figs_4389B86E01EC4.pdf. Accessed 2011 December 15.