

DEVELOPMENT AND APPLICATION OF A LEXICON TO DESCRIBE THE FLAVOR OF POMEGRANATE JUICE

K. KOPPEL¹⁻³ and E. CHAMBERS IV^{1,4}

¹*The Sensory Analysis Center, Kansas State University
Justin Hall, Manhattan, KS 66506-1407*

²*Department of Food Processing, Tallinn University of Technology*

³*Competence Center of Food and Fermentation Technologies
Tallinn, Estonia*

Accepted for Publication June 28, 2010

ABSTRACT

A lexicon for describing the sensory flavor characteristics of pomegranate juices was developed. Thirty-three pomegranate juices, including concentrated products, products from concentrate, and freshly squeezed and pasteurized products, were studied. More than 30 sensory attributes were identified, defined, and referenced by a highly trained descriptive sensory panel. The lexicon that was established includes attributes to describe a range of flavors associated with pomegranates, such as brown spice, fermented, molasses, vinegar, wine-like, woody, apple, berry, cranberry, cherry and grape. Generally, pomegranate juice can be described by the flavor characteristics of sour, sweet, musty/earthy, fruity aromatics and an astringent mouthfeel. The flavor characteristics of pomegranate juices are reminiscent of a combination of concord grapes, cranberries, blackberries, cherries, currants and raspberries, but there also are vegetable notes such as beets and carrots. The lexicon provides attribute descriptors, definitions and references that were previously lacking in literature on pomegranates.

PRACTICAL APPLICATIONS

The manufacturing and consumption of pomegranate and pomegranate-based products has increased. Many products use pomegranate as a main flavor component or as an addition to other flavors in juices, yoghurts, jams and

⁴ Corresponding author. TEL: (785) 532-0156; FAX: (785) 532-0176; EMAIL: eciv@ksu.edu

supplements. This research provides sensory terms that can be used to describe the flavor characteristics of pomegranate juices. This information is useful to product developers, researchers and technologists in understanding the characteristics of pomegranate flavor and using those attributes to create new products, adapt other products, and study quality-control and shelf-life issues.

INTRODUCTION

The health benefits of pomegranates are becoming widely known (Basu and Penugonda 2009). Pomegranate juice may improve stress-induced myocardial ischemia in patients who have coronary heart disease (Sumner *et al.* 2005), help fight diabetes-related conditions (Rosenblat *et al.* 2005) and carry anticarcinogenic properties (Adams *et al.* 2006; Pantuck *et al.* 2006). Research on pomegranates, the chemical composition of pomegranate juices, and the antioxidant properties of pomegranate juices have shown that commercial pomegranate juices have high antioxidant content and a high total phenolic content (Tezcan *et al.* 2009).

Researchers have also shown that there can be considerable variations in the antioxidant properties between different pomegranate cultivars (Ozgen *et al.* 2008). Different components of pomegranate juice, such as punicalagin and ellagic acid, have a positive synergistic effect on health (Seeram *et al.* 2004). Because of the health benefits, demand has increased production and consumption of pomegranate products. There are numerous pomegranate juices, concentrates and mixtures of juices available, providing the consumer with many options from which to choose.

Despite the popularity and considerable health benefits of pomegranate, little research on the descriptive sensory attributes of pomegranate juices was found. Data showing differences in chemical composition among pomegranate cultivars suggests that pomegranates may vary in their flavor properties as well. Martinez *et al.* (2006) described five new pomegranate varieties using attributes like seed hardness, visual color, taste, and overall quality appreciation. The aroma, taste, firmness, visual appearance, color, browning and dehydration of pomegranates were evaluated by López-Rubira *et al.* (2005) when studying the shelf life of pomegranate arils, which cover the pomegranate seeds and are edible. Singh and Sethi (2003) evaluated the mouthfeel of pomegranates in addition to the color and flavor in the sensory analysis of anardana – dried pomegranate seeds. Vardin and Fenercioglu (2003) studied the clarification of pomegranate juices and evaluated attributes like color, turbidity, overall appearance, bitterness and overall quality. Consumer acceptability was important for the studies of Hayaloglu and Vardin (2001) and Riaz and Elahi (1992) in the research of fruit punch with watermelon/pomegranate juice mixtures and carbonated pomegranate drink, respectively.

None of the studies included a detailed lexicon for the classification of the flavor attributes of pomegranate juice, although differences clearly exist. Thus, the objectives of this study were to (1) identify and define the sensory flavor attributes that characterize pomegranate juices and (2) describe and group different flavor profiles of commercially available pomegranate juice.

MATERIALS AND METHODS

Samples

Thirty-three pomegranate juice samples (Table 1) were used in this study. Twenty-seven of the juices were available in the U.S.A., although some were manufactured in other countries (predominately Turkey and Azerbaijan). One sample was obtained in Spain (Granavida Pomegranate Juice 100% Natural, #618), two samples were purchased from Estonia (4U Pomegranate Juice #115 and 100% Pomegranate Juice #175), and three samples were bought in Thailand (Brighty Pomegranate Juice #501, AC Fresh 100% Pomegranate Juice #289, and Dimes 100% Pomegranate Juice #416). Pomegranate juice with other added juices were excluded from the study in order to focus on the attributes of pomegranate specifically. However, nine of the samples contained natural flavors, nine were concentrated, and 15 were made from concentrate. One sample was enriched with fructose and two samples were made from organic pomegranates. All of the samples were assigned random three-digit codes. The products were obtained 3–4 weeks before testing and were stored according to the instructions given on the packages.

Sample Preparation

All of the samples were served at room temperature. Juices were shaken and poured into odor-free, disposable 92 mL plastic cups (Sweetheart Cup Co., Inc., Owings Mills, MD) covered with lids for the evaluation. Concentrated samples were prepared according to the instructions given on the packaging. The samples were prepared 30 min to 1 h prior to the testing. Each panelist received 57–85 mL of each product for evaluation. Additional sample was available if the panelists requested it.

Panelists

Five highly trained panelists from the Sensory Analysis Center, Kansas State University (Manhattan, KS) participated in this study. All of these panelists had completed 120 h of general descriptive analysis panel training with a variety of food products. This training included techniques and practice in

TABLE 1.
 PRODUCT NAMES, TYPES AND ABBREVIATIONS OF THE EVALUATED POMEGRANATE JUICES

Sample #	Product name	Ingredients	Producer/country of origin
115	4U pomegranate juice	Pomegranate juice of first direct pressing	Gouzay-Stud ASC, Gousay, Azerbaijan
143	L&A all pomegranate	Pomegranate juice from concentrate (filtered water, pomegranate juice concentrate), natural flavors	Langer Juice Company Inc., City of Industry, CA
175	100% pomegranate juice	Pomegranate juice	ARAZ Imishli, Azerbaijan
190	Avesa pomegranate juice	Fresh pressed pomegranate juice from whole ripe pomegranates. Potassium sorbate is added as preservative.	Avesa LLC, Rutherford, NJ, Azerbaijan.
197	Jarrow pomegranate juice concentrate	Pomegranate Juice Concentrate	Jarrow Formulas, Los Angeles, CA
225	Puritan's pride pomegranate concentrate	Pomegranate concentrate, purified water, potassium benzoate, potassium sorbate	Puritans Pride Inc., Oakdale, NY
256	Pomegranate juice ziyad	Water, 100% pomegranate concentrate	Ziyad Brothers Importing, Cicero, IL, Turkey.
279	Lakewood organic pure pomegranate fresh pressed 100% juice	Fresh pressed juice from whole ripe certified pomegranates	Lakewood, Florida Family Trust, Miami, FL
289	AC fresh 100% pomegranate juice	100 % Pomegranate juice from concentrate	Thailand
324	RW knudsen family just pomegranate 100% premium pomegranate juice from concentrate, unsweetened, pasteurized	Pomegranate juice, filtered water (sufficient to reconstitute), pomegranate juice concentrate	Knudsen & Sons, Inc., Chico, CA
328	Langers pure 100% all pomegranate juice	Pomegranate juice from concentrate (filtered water, pomegranate juice concentrate), natural flavors	Langer Juice Company Inc., City of Industry, CA
331	Pomegranate concentrate by culinary traditions	Pomegranate juice concentrate, filtered water	The Perfect Puree of Napa Valley, Culinary Traditions, Napa, CA
334	Heirloom farms 100% pomegranate juice	Pomegranate juice (pomegranate juice concentrate, filtered water), natural flavor	Opal International Ltd, Columbus, OH, Turkey.

TABLE 1.
CONTINUED

Sample #	Product name	Ingredients	Producer/country of origin
367	Elite Naturel: 100% organic natural pomegranate juice	100% Organic pomegranate juice	Elite Naturel Icecek, Ankara, Turkey. Organicjuiceusa.com
373	Northland 100% pomegranate juice pure pomegranate	100% Pomegranate juice (filtered water juice concentrate), natural flavors, vegetable color	Northland Products Ltd, U.S.A.
388	Tree of life pomegranate concentrate	Pomegranate concentrate	Tree of Life Inc., St Augustine, FL
403	Earthly delights all natural pure pomegranate high in antioxidants; pomegranate juice from concentrate with natural flavours, gently pasteurized	Pomegranate juice concentrate, natural flavours, grape seed extract	Global Juices and Fruits, Eagle, ID
411	Lakewood pure pomegranate concentrate	Pomegranate Juice Concentrate, Vitamin C (ascorbic acid)	Lakewood, Florida Family Trust, Miami, FL
416	Dimes 100% pomegranate juice	100 % Juice from concentrated pomegranate juice (water 77,08%)	Thailand
442	Woodstock farms juice concentrate	Pomegranate juice concentrate	Woodstock Farms, Dayville, CT
488	Life extension pomegranate juice concentrate	Pomegranate juice concentrate, purified water	Quality Supplements and Vitamins Inc., Fort Lauderdale, FL
501	Brightly pomegranate juice	Pomegranate 85%, fructose 15%	Thailand
520	Elite naturel: 100% natural pomegranate juice	100% Pomegranate juice	Elite Naturel Icecek, Ankara, Turkey. Organicjuiceusa.com
555	RW knudsen pomegranate juice concentrate	Pomegranate juice concentrate	Knudsen & Sons Inc., Chico, CA

TABLE 1.
CONTINUED

Sample #	Product name	Ingredients	Producer/country of origin
566	POM Wonderful 100% pomegranate juice from concentrate with added natural flavours, flash pasteurized	Pomegranate juices from concentrate and natural flavours	POM Wonderful, LLC, Los Angeles, CA
618	Granavida pomegranate juice 100% natural	100% Elche pomegranate extract, direct extract (not derived from a concentrate)	Granadas de Elche, SLU, Las Bayas Elche, Alicante, Spain
655	Swanson pomegranate juice	Reconstituted pomegranate fruit concentrates, purified water, potassium benzoate and potassium sorbate (to retard spoilage)	Swanson Health Products, Fargo, ND
707	Old orchard premium pomegranate juice	Pomegranate Juice from concentrate (filtered wter, pomegranate juice concentrate), natural flavours, ascorbic acid (vitamin C), vitamin E acetate	Old Orchard Brands, LLC, Sparta, MI
739	Archer Farms Pomegranate 100% juice from concentrate with natural flavor	Pomegranate juice from concentrate (filtered water, pomegranate juice concentrate), natural flavor.	Target Brands Inc., Target Corp., Minneapolis, MN
843	Indo-European Pomegranate Juice	Pure pomegranate juice and pomegranate concentrated blend	Indo-European Foods, Inc., Glendale, CA
846	Whole foods 365 100% juice pomegranate	Pomegranate juice from concentrate (filtered water, pomegranate juice concentrate), natural flavor	Whole Foods Market, Austin, TX
943	Hyson pomegranate juice	Fresh squeezed pomegranate juice, potassium sorbate	Hyson USA Inc., Arlington Heights, IL. Pomegranate origin = Turkey.
981	Dynamic health pomegranate concentrate	Pomegranate juice concentrate	Dynamic Health Laboratories, Inc., Brooklyn, NY

attribute identification, terminology development, and intensity scoring. Each of the panelists had more than 1,000 h of testing experience with a variety of food products. For this study the panelists also received further orientation on fresh and processed pomegranates.

Terminology Development and Description

The descriptive terminology for this study was developed initially using only seven of the pomegranate juice samples. Various descriptive references were provided for the panelists. While some references were proposed by the panelists and were based on previous work and experience, others were added to the lexicon during this initial lexicon development phase. Five 1.5 h orientation sessions were held to establish the initial attributes and descriptive references for pomegranate juices. Recent studies by Hongsoongnern and Chambers (2008a, 2008b); Talavera and Chambers (2009); Thompson *et al.* (2009); Dooley *et al.* (2009) and Civille *et al.* (2010), have used similar attribute determination and description procedures as the ones used in this study.

Sample Evaluation Procedure

Twenty-one 1.5 h sessions were held for evaluation of the samples. Only one to two samples were evaluated during each session in order to reduce the carryover of flavors. All samples were evaluated once, although multiple servings of the sample could be served during that one time period. All of the samples were coded with three-digit random numbers and the order in which the products were evaluated was randomized. The panelists were allowed to add attributes to the descriptive terminology if new flavors were found in samples they tested.

A modified flavor profile method used by Talavera and Chambers (2009) and Hongsoongnern and Chambers (2008b), using a scale with 0.5 increments where 0 represents none and 15 extremely strong, was used to measure intensity. This consensus profile method is particularly useful in lexicon development studies because new attributes can be easily added, defined, and referenced when they appear in products the panel is seeing for the first time.

Each sample was evaluated for the flavor attributes that were present in the sample and each panelist individually assigned intensities to the attributes according to the flavor references included in the lexicon. All of the recorded attributes and their intensities were discussed by the panel. Often the evaluation of the sample would continue into the next session because of strong carryover. In cases where a new attribute emerged, a discussion between the panel leader and the panelists, using the consensus approach, would focus on the appropriateness, definition, references and evaluation technique of that attribute.

Data Analysis

The Statistical Analysis System version 8.2 (SAS, Cary, NC, 2001) was used for clustering the samples and for the correlation analysis, using Pearson correlation coefficients. The Unscrambler version 9.7 (Camo Software, Norway) was used for principal component analysis (PCA). Clustering of the samples was done by using the CLUSTER procedure (Ward's Minimum Variance Cluster Analysis). The number of clusters was set according to the eigenvalues of the correlation matrix (>1). Attributes that were scored in seven or fewer products (approximately 20% of products, 22 of 36 attributes) were excluded from the analysis because they tend to force the multivariate statistics into separating unique attributes rather than the overall pattern of attributes and intensities. Using these criteria means that the overall pattern of common pomegranate flavors is evaluated, but potentially characterizing attributes must be examined further by the researchers on a case by case basis. This points to a problem when using PCA: it can be overly sensitive to attributes that are unique to only a few products and can lose the overall structure of the data. It is critical for papers to explain the impact of decisions related to attribute selection. In addition, it is crucial to examine the other attributes to determine what they may add to understanding of the unique properties of the products.

RESULTS AND DISCUSSION

The initial lexicon based on the small initial set of juices included 15 attributes: sweet, sour, bitter, astringent, umami, toothetch, fruity, tomato, cranberry, grape, beet, fruity-dark, green-viney, musty/earthy and fermented. Tomato and umami, included in the initial lexicon, were not scored during the evaluations and hence these attributes are not included in the final lexicon. Several attributes were added to the lexicon during the testing: apple, berry, brown spice, brown sweet, carrot, candy-like, cherry, floral, molasses, sweet overall, vinegar, wine-like, woody, metallic, metallic mouthfeel, chalky mouthfeel, pungent, tongue tingle, tongue numb and throat burn (Table 2).

Most of the attributes are self-explanatory using the information in Table 2. However, several attributes may need further explanation. For example, the berry attribute was added to the lexicon because the panelists needed an attribute to describe a general, unidentifiable berry flavor. This attribute describes sweet, sour, and sometimes darker aromatics associated with a variety of berries. Thus, a general berry term was added to describe this overarching flavor.

The attribute vinegar often was accompanied by the mouthfeel attributes tongue tingle, tongue numb or throat burn. These may have been the result of

TABLE 2.
POMEGRANATE JUICE ATTRIBUTES, DEFINITIONS, REFERENCES AND INTENSITIES ON A 15-POINT SCALE

Attribute	Definition	Reference
Apple	A sweet, light, fruity, somewhat floral aromatic commonly associated with processed apple juice and cooked apples.	Gerber applesauce = 6.0 (flavor)
Beet	The damp, musty/earthy, slightly sweet aromatics commonly associated with canned/cooked beets.	Diluted kroger canned beet juice (1:2) = 4.0 (flavor)
Berry	The sweet, sour, sometimes dark aromatics associated with a variety of berries such as blackberries, currants, raspberries etc, excluding cranberries.	Blackwell red currant jelly = 8.5 (flavor)
Brown Spice	Aromatics associated with a range of brown spices such as cinnamon, nutmeg, cloves and allspice.	McCormick spices, mixed = 13.0 (aroma). Preparation: combine 1/4 tsp of cinnamon, 1/4 of ground cloves, 1/4 of ground nutmeg and 1/4 of allspice in a vial, shake well to combine. Serve 1/4 tsp of this mixture in a medium snifter, cover.
Brown sweet	Sweet brown aromatics that may include the character notes identified as caramelized and commonly associated with honey, brown sugar, caramel, or other products that have been non-enzymatic browning.	Dark Karo syrup = 10.5 (flavor) C&H golden brown Sugar = 8 (flavor) C&H dark brown sugar = 9.5 (flavor)
Carrot	The aromatics commonly associated with canned, cooked carrots.	Del monte sliced canned carrots = 7.0 (flavor)
Candy-like	A sweet aromatic often associated with processed essential oils and usually found in candy products such as Jell-O and Kool-Aid.	Jell-O strawberry gelatin (powder) = 7.5 (flavor)
Cranberry	The sweet, fruity, slightly sour and sharp aromatics commonly associated with cranberries.	Ocean spray dried cranberries = 9.0 (flavor) Old Orchard's frozen cranberry concentrate = 7.5 (flavor) old orchard's frozen cranberry conc diluted (1:1) = 3.5 (flavor)
Cherry	The sour, fruity, slightly bitter aromatics commonly associated with cherries.	RW knudsen cherry juice diluted (1:2) = 4.0 (flavor)
Fermented	Pungent, sweet, slightly sour, sometimes yeasty/alcohol like aromatics characteristic of fermented fruits or sugars or over-proofed dough	Frank's Sauerkraut (juice only, diluted + 6.5 (flavor). Preparation: Drain juice from solids and mix 1 part juice to 2 parts water
Floral	Sweet, light, slightly perfumey impression associated with flowers.	Humco artificial rose/water diluted 1:10 = 6.0 (aroma) (1 drop on cotton ball in medium snifter, covered); Geraniol (10,000 ppm = 7.5 (aroma) 2 drops on cotton ball in lg. snifter, covered)

TABLE 2.
CONTINUED

Attribute	Definition	Reference
Fruity	A general term used to describe the sweet, floral, fruity aromatics associated with a blend of fruits.	DeMonte lite chunky mixed fruits, preparation: drain fruits, mix juice with water 1:1, juice = 5.5 (flavor). Jello mixed fruit, prepared according to package. Instructions = 8.0 (flavor). Fruit mixture = 10 (aroma). Preparation: mix in a medium snifter, cover: 1 strawberry from Kellogg's special K red berry cereal; mariani dried cherry; ocean spray dried cranberry; sun maid raisin; and 1/3 piece sunmaid mission
Fruity-dark	The sweet, brown honey/caramel-like aromatics commonly associated with dark fruits such as raisins and prunes that have been cooked.	Mixture of sun maid raisins, prunes, ocean spray cranberries and water: juice = 5.0. Preparation: mix of 1/4 cup raisins, 1/3 cup dried cranberries and 1/4 cup of prunes (chopped), add 3/4 cup of water and cook on high for 2 min. Pour juice into 1 ounce cups, cover with lid.
Grape	The sweet, brown, fruity, musty aromatics commonly associated with grapes.	Welch's concord grape juice = 9.5 (flavor) Welch's concord grape juice diluted (1:1) = 5.0 (flavor) Welch's white grape juice diluted (1:1) = 5.0 (flavor)
Green-viney	A green aromatic associated with green vegetables and newly cut vines and stems; characterized by increased bitter and musty/earthy character.	Trans-2-hexen-1-ol 5,000 ppm = 4.0 (aroma). Fresh sliced tomatoes = 10.0 (flavor), 9.0 (aroma)
Honey	Sweet, light brown, slightly spicy aromatics associated with honey.	2 Teaspoons busy bee honey in 250 mL water = 6.5 (flavor).
Metallic	The impression of slightly oxidized metal, such as iron, copper and silver spoons.	Dole canned pineapple juice, unsweetened = 6.0 (flavor)
Molasses	Dark, caramelized top notes that are slightly sharp and characteristic of molasses.	Grandmas molasses = 6.5 (flavor) Mix 2 teaspoons of molasses in 250 mL water
Musty/earthy	Humus-like aromatics that may or may not include damp soil, decaying vegetation, or cellar-like characteristics.	Raw potatoes = 3.0 (aroma). 100 ppm geosmin = 8.5(a) (Dip perfumer strips in geosmin solution and place in individual test tubes for each panelist).
Pungent	A sharp, physically penetrating sensation in the nasal cavity.	Heinz white vinegar : water 1:8 dilution = 8.0 (aroma)

TABLE 2.
CONTINUED

Attribute	Definition	Reference
Sweet, overall	The perception of the combination of sweet taste, sweet aromatics, caramelized, brown sugar, honey, and maple.	White pear grape juice diluted (1:1) = 4.0 (flavor). Lorna doone cookie = 5.5 (flavor) C&H pure cane golden brown sugar = 9.0 (flavor). 12 C&H golden brown sugar solution = 11 (flavor). Torani sugar free classic caramel flavoring syrup = 14 (flavor) Heinz white vinegar diluted (1:12) = 8.0 (flavor)
Vinegar	Sour, astringent, slightly pungent aromatics associated with vinegar.	Regina cooking wine = 10.0 (aroma) Forster craft stick = 7.5 (aroma)
Wine-like	Sharp fruity alcohol-like aromatics associated with red wine.	2% sucrose solution = 2.0 4%. sucrose solution = 4.0
Woody	The aromatics associated with dry freshly cut wood.	0.025% Citric acid solution = 2.5 0.05% Citric acid solution = 3.5
Sweet	The fundamental taste factor associated with a sucrose solution.	0.08% Citric acid solution = 5.0 0.1% Citric acid solution = 7.0
Sour	A fundamental taste factor of which citric acid in water is typical.	0.01% Caffeine solution = 2.0 0.02% Caffeine solution = 3.5
Bitter	The fundamental taste factor of which caffeine or quinine is typical.	0.035% Caffeine solution = 5.0 0.05% Caffeine solution = 6.5
Astringent	The dry puckering mouthfeel associated with an alum solution.	0.05% alum solution = 2.5 0.1% alum solution = 5.0 0.15% alum solution = 7.5
Toothetch	A sensation of abrasion and drying of the surface of the teeth.	Welch's grape juice diluted (1:1) = 6.0 (flavor)
Metallic	A mouthfeel and aromatics associated "tin" cans, iron copper, or oxidized silver.	Silver spoon placed in the mouth = 7.0 (flavor). 0.01 g ferrous sulfate in 1,000 mL water = 5.0 (mouthfeel)
Chalky	A dry, powdery sensation and an aromatic associated with mineral salts such as chalk. Can be on mouth and /or teeth.	Corn starch solution = 3.0 Mix 1 g of corn starch in 100 mL water. Pour in 1 ounce cups, cover with lid.
Tongue tingle	A feeling of an increased sensation on the tongue that may be due to intense carbonation or other causes. Evaluate during first 3-5 s after sample is placed in the mouth.	7-Up = 8.5
Tongue numbing	Loss of sensation on tongue evaluated after swallowing the sample	7-Up = 5.5
Throat burn	The chemical feeling factor described as a burning sensation perceived in the throat.	Heinz white vinegar diluted (1:12) = 4.0

organic acids present in the product. One difficulty with the vinegar attribute was that the panelists initially defined the vinegar attribute as including pungency, which is part of the overall impression when smelling vinegar. However, during evaluation, the panelists had difficulty agreeing on vinegar intensities because in many cases the vinegar flavor was present in the samples but the pungent aromatics were lacking. Thus, “vinegar” flavor aromatics and “pungent” need to be separate attributes in the lexicon when conducting further research on pomegranate juice. The definition of vinegar was modified in the lexicon and the term pungent was added to reflect this necessary change.

The wine-like attribute was added to the lexicon as there was a need to describe aromatics associated with red wines. There was a discussion among the panelists whether the attribute wine-like could be distinguished from the attribute fermented, which was already in the lexicon. It was decided that the fermented attribute described the aromatics associated with yeasty over-proofed dough or fermented vegetables or fruits as opposed to the overall “wine-like” note found in red wines.

The overall fruit complex attribute was used as a general term to describe the sweet, floral and fruity aromatics associated with a variety of fruits. This term was used in the case of three samples (739, 403 and 256) to express the overall fruitiness combining different notes that could not be distinguished otherwise. Although the panelists indicated that a fruity complex and fruitiness were different attributes, they were not able to describe the difference well enough to propose separate definitions that could be used by others. Thus, we chose not to include fruity complex as a separate term.

Three samples (225, 175 and 416) were noted to be “watery”, which the panel initially described as a weak non-descript flavor. However, such an attribute is not necessary to add because it can be inferred from low scores on other attributes.

The attribute chalky mouthfeel often is considered a textural property. In this study, it was first noted in a product that also had large flakes, resulting in high amounts of residuals in the cup. However, two other samples that did not have residue were noted as chalky, and the panelists indicated they felt it was aromatic in nature and different from a textural characteristic. This suggests that the aroma of certain compounds may provide a chalkiness that is part of flavor. Thus, it appears that chalky can be either a texture (physical particulate) or flavor (aromatic).

Some attributes were characteristic for only a small number of samples (Table 3). These attributes represent a variety of flavor notes and mouthfeel attributes that may result from processing conditions, pomegranate variety, or the age of the fruit and the product. Attributes such as green-viney, cherry, apple, carrot, floral, candy-like, brown sweet, brown spice and molasses indicate the range of different flavors that are available to consumers of pome-

TABLE 3.
ATTRIBUTES, THAT WERE NOTED IN 7 OR FEWER POMEGRANATE JUICE SAMPLES

Sample #	Attributes
175	Candy-like
190	Chalky mouthfeel, vinegar, woody
197	Astringent, chalky mouthfeel, molasses, woody
225	Apple, metallic, throat burn, tongue tingle, vinegar
289	Astringent, carrot, woody
324	Carrot, green-viney, metallic, metallic mouthfeel
331	Astringent
367	Carrot
373	Brown spice, floral, throat burn
388	Throat burn, vinegar, woody
411	Brown sweet, molasses, vinegar, woody
416	Candy-like, floral, woody
442	Brown sweet, molasses, woody
488	Astringent, bitter
501	Brown sweet, candy-like, cherry, floral
520	Carrot, chalky mouthfeel
555	Throat burn
566	Astringent, floral
618	Metallic, metallic mouthfeel
655	Throat burn, tongue tingle, tongue numb, vinegar
707	Astringent, bitter, floral, metallic, metallic mouthfeel
739	Apple
843	Metallic
846	Apple, cherry, floral
981	Candy-like

granate juice. The attributes chalky mouthfeel, metallic mouthfeel, throatburn, woody, vinegar and tongue tingle also were not detected in most of the pomegranate juices, but were found in a few.

The bitter attribute was present in all of the samples and usually was sensed at the end of tasting the sample. However, for some samples (488 and 707) the bitter taste also was noted in the beginning of tasting. These bitter taste scores are also given in Table 3.

Molasses was used to describe the dark, caramelized, sharp notes. The concentration technology of the pomegranate juice is of high importance in terms of the final quality of the product as it greatly influences the flavor, aroma, color, appearance and mouthfeel of the product (Jiao *et al.* 2004). Five of the concentrated samples were a brown color and two were a brown/red color. The brown color can be associated with the attribute molasses as that note is related to highly concentrated, heated plant products containing sugars. The attribute molasses was noted three times and only in the case of concentrated products. In addition to molasses, the panel determined that an attribute

other than molasses that described brown, sweet aromatics without the dark, almost burnt and sulphury character of molasses was needed. Thus, "brown sweet" was included.

The aromatics of honey and caramel were noted when evaluating one sample. The panelists discussed whether it is necessary to introduce these two new attributes to the lexicon. Although references were proposed for these attributes, the panelists decided not to include these aromatics as separate attributes because they were already covered in attributes such as dark fruit and brown sweet. However, in hindsight we believe that honey is a distinctly different attribute and should be included as a separate term in the lexicon. Thus, we have included honey as an attribute in the lexicon, but it was not scored for any of the products in this test.

During the evaluation, the panelists occasionally did not agree on the flavor notes present in the samples. This occurred for six attributes: wine-like, beet, floral, brown spice, fermented and molasses for specific products. Such an occurrence suggests that the attribute was not be as well defined or referenced as it should have been because some panel members interpreted the attribute differently from other panelists. When this happened, the panel re-defined or re-referenced the attributes and re-evaluated samples to ensure consensus was reached.

Correlation and PCA of Pomegranate Juices

Figures 1 and 2 present principal components (PC) 1–4. The first four PCs explain 70% of the variation in the flavor attributes. PC1 differentiates between the dark-fruity characteristics versus those associated with grapes and berries. PC2 separates samples according to the higher overall sweetness of the samples versus the lower or less sweet samples. The berry attribute versus the grape attribute is differentiated by PC3 and PC4 distinguishes between the fermented characteristics and the musty/earthy, beet-like notes.

Most of the correlations among attributes for the pomegranate juices were low indicating that the attributes were describing different characteristics in the pomegranate juices. Few correlations exceeded a moderate level of approximately 0.50. Candy-like was positively correlated to sweet overall ($r = 0.79$) and negatively to sour ($r = -0.64$) and sweet and sour were negatively correlated ($r = -0.69$). Both of these attributes also were negatively correlated with bitterness and astringency.

Attributes that were measured in dual ways or were measured twice (early and late in the profile) tended to be more highly correlated than other attributes. For example, metallic mouthfeel and metallic flavor were highly correlated ($r = 0.87$). In most of the samples where metallic flavor was noted, a metallic mouthfeel was scored as well. This indicates the possibility of

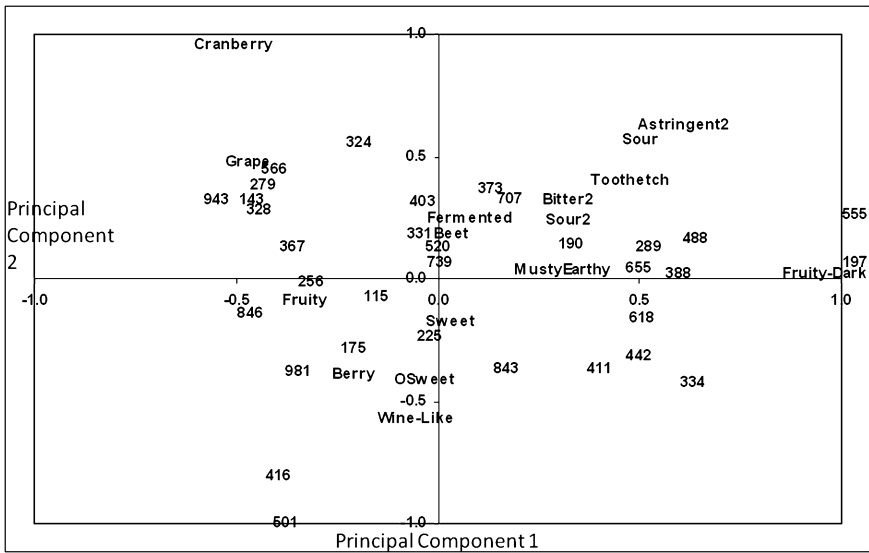


FIG. 1. PRINCIPAL COMPONENTS MAP OF PRODUCTS ON DIMENSION 1 (EXPLAINS 29% OF THE VARIATION) AND DIMENSION 2 (EXPLAINS 18% OF THE VARIATION)
 Note: Astringent2 – astringent mouthfeel noted in the end of sample tasting. Bitter2 – bitter taste noted in the end of sample tasting.

recording similar impressions twice. However, as the panelists differentiated between these two attributes and there were two samples that were scored for metallic flavor, but not metallic mouthfeel, both of these attributes probably should be kept in the lexicon. Similarly, there was a high correlation of 0.78 between the first sour impression (noted rarely) and the astringent mouthfeeling found at the end of tasting. The same was also true for the bitterness and astringency found at the end of tasting the sample (0.89). A correlation of 0.72 is present between the sourness and bitterness scored at the end of sample tasting. All of the samples were scored for the attributes sour and bitter and only two of the samples were not scored for astringency. These correlations and the initial scores indicate that sourness, bitterness and astringency are part of the nature of pomegranate juices and likely are found in tandem with each other.

Clustering Pomegranate Juices

Some of the samples in cluster 1 (Table 4, samples 334, 442, 403, 289, 331, 388, 843, 618, 115 and 411) are characterized by berry and fruity-dark (Fig. 1) attributes. According to PC2, these samples could be described as

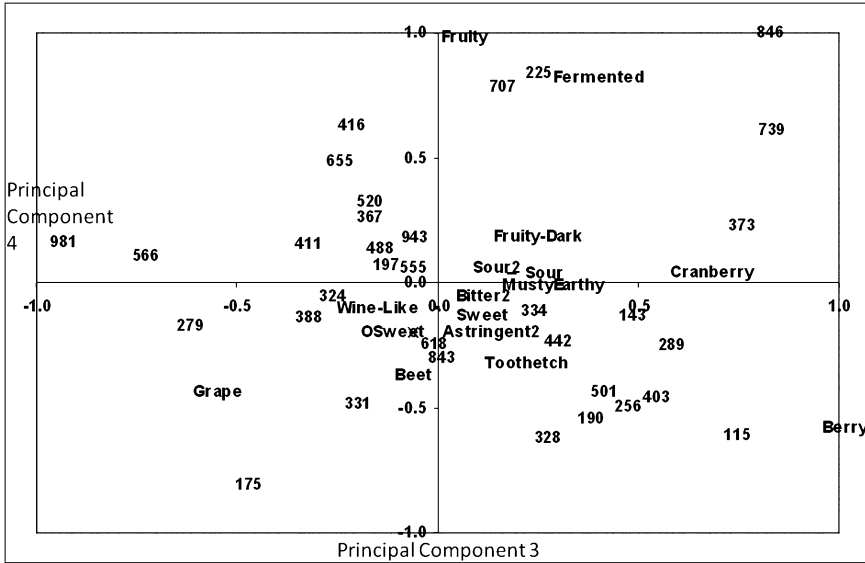


FIG. 2. PRINCIPAL COMPONENTS MAP OF PRODUCTS ON DIMENSION 3 (EXPLAINS 13% OF THE VARIATION) AND DIMENSION 4 (EXPLAINS 10% OF THE VARIATION)
 Note: Astringent2 – astringent mouthfeel noted in the end of sample tasting. Bitter2 – bitter taste noted in the end of sample tasting.

TABLE 4.
 CLUSTER ANALYSIS RESULTS OF POMEGRANATE JUICES (SEMI-PARTIAL R SQUARED <0.05)

Cluster no	Sample no	Differentiating attributes
1	115, 289, 331, 334, 388, 403, 411, 442, 618, 843	Berry, dark-fruity, toothtetch mouthfeel
2	143, 256, 279, 324, 328, 367, 520, 566, 943	Grape, cranberry, wine-like
3	225, 373, 655, 707, 739, 846	Fermented, toothtetch mouthfeel
4	190, 197, 488, 555	Brown color, musty/earthy
5	175, 416, 501, 981	Candy-like, sweet overall

sweet and also overall sweet when fruity-dark and berry notes are added to the sweet flavor. Cluster 2 (samples 328, 256, 143, 943, 279, 324, 520, 367 and 566) is composed of samples that are characterized by grape and cranberry (Fig. 2) attributes and were colored red or purple. Fermented and toothtetch properties are characteristics of samples in cluster 3 (samples 739, 846, 655, 225, 707 and 373). This group of samples cannot be related to certain attributes like grape, fruity-dark, sweetness or berry according to Fig. 1. However, Fig. 2

suggests that the fermented attribute explains the similar traits of these samples. The samples in cluster 4 (samples 197, 555, 488 and 190) were brown in color and had low intensities of the musty/earthy attribute. Three of these samples (all except 190) were products of concentrate, suggesting they were heated extensively before being made into juice, which might explain the brown color. Cluster 5 (samples 501, 416, 981 and 175) is composed of samples that are candy-like. The sweet overall values of these samples are in the moderate range (scores 6–8). Samples that are in this cluster are located close to the overall sweet (OSweet) attribute in Fig. 1. No scores of cranberry, dark-fruity or fermented attributes were given to these samples and this could explain the separation into an extra cluster.

The clustering results suggest that the pomegranate juices can be divided into groups that are characterized by distinctive sensory attributes. In general, those seem to be driven by processing. However, differences in original solids content, cultivar, or location might become more important if a more focused set of samples or known original fruit were chosen. Most of these groups appear logical based on the PCA results. It is clear that pomegranate juices are sweet, sour, bitter, astringent, and have toothetch. Although the flavors can be complex, the major components are grape, cranberry, berry, fruity-dark, musty/earthy and beet.

CONCLUSION

A sensory lexicon for pomegranate juice evaluation was developed. The 34 referenced and defined attributes can be helpful for scientists, technologists and product developers in working with and understanding pomegranate or pomegranate-based products. However, all of these attributes might not be necessary when studying a certain product and a selection should be made accordingly. Some of the attributes found in several samples in this study might not be appealing from a consumer's point of view and this information could be helpful in developing production technologies, clarification and the concentration methods of pomegranate juices.

ACKNOWLEDGMENTS

The authors thank Foundation Archimedes for funding for the author and to staff of the Sensory Analysis Center for their help in conducting the study.

REFERENCES

ADAMS, L.S., SEERAM, N.P., AGGARWAL, B.B., TAKADA, Y., SAND, D. and HEBER, D. 2006. Pomegranate juice, total pomegranate ellagi-

- tannins, and punicalagin suppress inflammatory cell signaling in colon cancer cells. *J. Agric. Food Chem.* *54*, 980–985.
- BASU, A. and PENUGONDA, K. 2009. Pomegranate juice: A heart-healthy fruit juice. *Nutri. Rev.* *67*, 49–56.
- CIVILLE, G.V., LAPSLEY, K., HUANG, G., YADA, S. and SELTSAM, J. 2010. Development of an almond lexicon to assess the sensory properties of almond varieties. *J. Sensory Studies* *25*, 146–162.
- DOOLEY, L.M., ADHIKARI, K. and CHAMBERS, E. IV. 2009. A general lexicon for sensory analysis of texture and appearance of lip products. *J. Sensory Studies* *24*, 581–600.
- HAYALOGLU, I. and VARDIN, H. 2001. Sensory evaluation of fruit punch including watermelon and pomegranate juices at various levels. *Gida.* *26*, 267–270.
- HONGSOONGNERN, P. and CHAMBERS, E. IV. 2008a. A Lexicon for green odor or flavor and characteristics of chemicals associated with green. *J. Sensory Studies* *23*, 205–221.
- HONGSOONGNERN, P. and CHAMBERS, E. IV. 2008b. A Lexicon for texture and flavor characteristics of fresh and processed tomatoes. *J. Sensory Studies* *23*, 583–599.
- JIAO, B., CASSANO, A. and DRIOLI, E. 2004. Recent advances on membrane processes for the concentration of fruit juices: A review. *J Food Eng.* *63*, 303–324.
- LÓPEZ-RUBIRA, V., CONESA, A., ALLENDE, A. and ARTÉS, F. 2005. Shelf life and overall quality of minimally processed pomegranate arils modified atmosphere packaged and treated with UV-C. *Postharvest Biol. Technol.* *37*, 174–185.
- MARTINEZ, J.J., MELGAREJO, P., HERNANDEZ, F., SALAZAR, D.M. and MARTINEZ, R. 2006. Seed characterisation of five new pomegranate (*Punica granatum* L.) varieties. *Sci. Hort.* *110*, 241–246.
- OZGEN, M., DURGAC, C., SERCE, S. and KAYA, C. 2008. Chemical and antioxidant properties of pomegranate cultivars grown in the Mediterranean region of Turkey. *Food Chem.* *111*, 703–706.
- PANTUCK, A.J., LEPPERT, J.T., ZOMORODIAN, N., ARONSON, W., HONG, J., BARNARD, R.J., SEERAM, N., LIKER, H., WANG, H., ELASHOFF, R., HEBER, H., AVIRAM, M., IGNARRO, L. and BELLDEGRUN, A. 2006. Phase II study of pomegranate juice for men with rising prostate-specific antigen following surgery or radiation for prostate cancer. *Clin. Cancer Res.* *12*, 4018–4026.
- RIAZ, R.A. and ELAHI, M. 1992. Studies on the preparation and storage stability of carbonated pomegranate drink. *Pak. J. Sci. Ind. Res.* *35*, 467–470.

- ROSENBLAT, M., HAYEKA, T. and AVIRAM, M. 2005. Anti-oxidative effects of pomegranate juice (PJ) consumption by diabetic patients on serum and on macrophages. *Atherosclerosis*. *187*, 363–371.
- SEERAM, N.P., ADAMS, L.S., HENNING, S.M., NIU, Y., ZHANG, Y., NAIR, M.G. and HEBER, D. 2004. *In vitro* antiproliferative, apoptotic and antioxidant activities of punicalagin, ellagic acid and a total pomegranate tannin extract are enhanced in combination with other polyphenols as found in pomegranate juice. *J. Nutri. Biochem.* *16*, 360–367.
- SINGH, D. and SETHI, V. 2003. Screening of pomegranate genotypes for the preparation of quality grade Anardana. *J. Food Sci. Technol.* *40*, 236–238.
- SUMNER, M.D., ELLIOTT-ELLER, M., WEIDNER, G., DAUBENMIER, J.J., CHEW, M.H., MARLIN, R., RAISIN, C.J. and ORNISH, D. 2005. Effects of pomegranate juice consumption on myocardial perfusion in patients with coronary heart disease. *Am. J. Cardiol.* *96*, 810–814.
- TALAVERA, M. and CHAMBERS, D.H. 2009. Simplified lexicon to describe flavor characteristics of western European cheeses. *J. Sensory Studies* *23*, 468–484.
- TEZCAN, F., GULTEKIN-OZGUVEN, M., DIKEN, T., OZCELIK, B. and ERIM, F.B. 2009. Antioxidant activity and total phenolic, organic acid and sugar content in commercial pomegranate juices. *Food Chem.* *115*, 873–877.
- THOMPSON, K.R., CHAMBERS, D.H. and CHAMBERS, E.I. 2009. Sensory characteristics of ice cream produced in the U.S.A and Italy. *J Sens. Stud.* *24*, 396–414.
- VARDIN, H. and FENERCIOGLU, H. 2003. Study on the development of pomegranate juice processing technology: Clarification of pomegranate juice. *Nahrung/Food.* *47*, 300–303.