Journal of the American Pomological Society 71(2): 66-81 2017

Determination of Chemical, Physical and Sensory Characteristics of Apricot Jam from Winter-Hardy Genotypes

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Additional index words: Fruit jams, chemical characterization, flavor, color, sensory evaluation, texture analysis, *Prunus armeniaca.*

Abstract

Apricots are highly desirable aromatic fresh fruits, although their high respiration rates as climacteric fruit limits their shelf life. Thus, they are often preserved as dried fruits or jams for enjoyment throughout the year. Winter hardy apricots that survive in USDA Zone 4 have never been tested for physicochemical properties and sensorial profiles of their jams; this was the objective for the present study. Fresh fruit from eight winter hardy apricot genotypes were harvested and made into jam; these apricot jams, along with three comparative jam controls were tested for soluble solids, pH, titratable acidity, and L*a*b* CIELAB chromaticity coordinates, hue angle, and chrome values. Sensorial profiles were determined in a sensory evaluation panel using the following traits: color, spreadability, texture, fruit pieces, flavor, off flavor, sweetness, bitterness, overall quality, and desire to purchase. 'Sungold', 'Westcott' and the tart cherry jam control had greater than 60% soluble solids (°Brix). MN 604, MN203, 'Brookcot' and 'Sungold' apricot jams had the lowest pH levels. The lightest color jam (L*) was 'Brookcot' with 'Debbie's Gold' having the yellowest color (b*). The darkest jams were made from MN206 and MN203 similar to the tart cherry control. Panelists were able to discern differences among apricot jams for spreadability, texture, fruit pieces, flavor, off-flavor and overall quality but could not distinguish differences in sweetness and bitterness across cultivars. Results from this study provided much-needed information on sensorial profiles and physicochemical qualities of apricot jams made from these winter-hardy genotypes. We concluded that the best apricot for use in jam making is 'Sungold'.

Along with a number of other fruit and nut crops the apricot (*Prunus armeniaca* L.) belongs to the large, economically important genus, *Prunus* L., part of the Rosaceae family (Potter, 2012). *Prunus armeniaca* are native to Asia (China) and have been bred and adapted for cultivation in areas that fulfills the chilling requirements (Touati et al., 2014). World production of apricots was 4.04 M metric tonnes in 2012 and ranked 16th in cultivated fruit worldwide (FAOSTAT 2013).

Apricots are aromatic, nutritionally rich fruits (Gutierrez-Martinez et al., 2007; Mehlenbacher et al., 1991) with a high fiber content, and a source of vitamins, minerals and sugars (Sartaj et al., 2011) as well as carotenoids and phytochemicals, e.g. ferulic, caffeic, chlorogenic and *p*-coumaric acids (Dragovic-Uzelac et al., 2007; Rababah et al., 2011). However, since apricots are climacteric fruit, high respiration rates, fast ripening and soft texture limit shelf life (Touati et al., 2014). Thus, apricots are frequently processed into dried fruits, jams, marmalades, jellies or nectars (Touati et al., 2014).

The production of jellies and jams is a method used to preserve perishable fruits, which allows for consumption during periods of the year when fresh fruit is not available (Touati et al., 2014). Jams are classified as intermediate moisture foods, created by boiling whole fruit or pulp with pectin, acid, and sugars to a thick but spreadable consistency (Touati et al., 2014; Vidhya and Nara-

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in, 2011; Kurz et al., 2008; Wicklund et al., 2005). Today, jam is a common and popular food product with 92% of households consuming jams, jellies, and preserves (Agriculture and Agri-Food Canada, 2012).

Consumers' perception of jam quality is affected by a number of physical, chemical, and sensory characteristics (Grujić et al., 2007). Sensory attributes perceived by the consumer during purchasing and consumption influence whether or not the product will be bought. According to Lawless and Heymann (2010), color is one of the most important sensory factors that consumers perceive when evaluating a food product's quality. Other important sensory characteristics that have been examined when evaluating jam quality include taste, sweetness, sourness, spreadability, and overall quality (Culetu et al., 2014; Sandulachi and Tatarov, 2012; Touati et al., 2014). Previous studies examining *Prunus* jam quality have also analyzed chemical and physical characteristics such as pH, soluble solids, titratable acid, and color parameters (Culetu et al., 2014; Sandulachi and Tatarov, 2012). Gelation, flavor, and shelf life of a jam are all affected by pH, which measures the amount of organic acid present in the sample (Culetu et al., 2014). The amount of sugar present in a jam is quantified via soluble solid content, which affects the gelation and stability of a jam (Culetu et al. 2014). Sucrose, pH and pectin are critical components of jams to ensure gelling for spreadability and are routinely manipulated in jam recipes to ensure adequate gel structure (Culetu, et al., 2014). Sugar binds water molecules, removing water away from pectin molecules which allows them to chemically link with each other and form polymeric network.

Although apricots are cultivated and enjoyed throughout the world, damage due to spring frosts and the lack of winter-hardy cultivars with good fruit quality limit the production of apricots in northern climates such as USDA Zones 3 and 4 (Mehlenbacher et al., 1991). Early breeding programs, including the University of Minnesota, developed winter-hardy apricot hybrids by crossing commercial cultivars with hardy wild species (Anderson and Weir, 1967; Hoover et al. 2015). A number of hardy apricot hybrids, most notably 'Moongold' and 'Sungold', were developed using the Manchurian apricot (*P. mandshurica* [Maxim.] Koehne) as a male parent (Anderson and Weir, 1967). The apricots 'Brookcot', 'Debbie's Gold', and 'Westcot' are also considered winter-hardy cultivars (Ames, 2013). Although a number of hardy apricot selections and cultivars were introduced decades ago (Hoover and Zins, 1998), little is known about the quality of jam made from the fruits of these genotypes.

The objective of this paper was to quantify attributes of jams made from select USDA Zone 4 winter-hardy apricot genotypes from the University of Minnesota breeding program along with named comparisons. Specifically, physicochemical properties and sensory profiles were examined to determine quantitative genotypic differences. Qualitative data, including the desire to purchase jams, were also evaluated.

Materials and Methods

Genotypes and fruit harvest. During weeks 31-32 (2013) mature fruits from apricots *P. armeniaca* 'Brookcot', 'Debbie's Gold', 'Sungold', 'Westcot' and unnamed selections MN604, MN206, MN203, MN202 were harvested from trees at the University of Minnesota research plots in Excelsior, MN (44°52'06.5" N lat., -93°38'03.9" W long.). Week number is defined as the number of weeks from January 1st, 2013. All trees in the research plots were managed for fruit production. Fruits were stored at 3-5°C no more than one week prior to pitting and jam preparation. All apricot fruits were cut along the suture line with a pairing knife to remove the pit prior to jam preparation.

Jam preparation. Sugar and pectin were added to increase the concentrations in the harvested fruit mixture (Culetu, et al., 2014). Jams were made in sterilized dishes using sterilized wooden, glass or non-reactive metal utensils in a semi-commercial, private kitchen (Kurz et al. 2008). All jams were made according to a standard recipe of 1.5 L (6.33 US cups) pitted fruit, 74 ml (5 US tablespoons) fresh-squeezed lemon juice, 14.2 g (1 US tablespoon) unsalted butter, 56.8 g (4 US tablespoons) Ball® RealFruit® Classic Pectin (Hearthmark, LLC dba Jarden Home Brands) and 1350 g (6 US cups) sugar. Pitted fruit were macerated using a hand-held puree machine (KitchenAid® 2-Speed Immersion Hand Blender, #KHB1231) until fruit and skins were thoroughly pureed. Fruit, lemon juice, butter, and pectin were combined in an uncovered, non-reactive Revere® copper-clad base stainless steel pot (4.26 L or 4.5 US quart), stirring constantly with a flat wooden spoon. The mixture was allowed to vigorously boil for 1 minute. Sugar was then added, again stirring constantly until the jam began sheeting off from the flat, wide spoon. Each mixture was then removed from the heat source. The jam surface was skimmed to remove any impurities and immediately poured into sterilized 0.24 L (0.5 US pint) glass jars and lids/rings were attached to the jars. Jars were inverted for 5 minutes and then reverted to upright position and cooled under a towel for 24 hours until sealed. Jars were labeled with the cultivar name and fruit type and stored at 12.8°C (55°F) in darkness for up to 6 months to maximize color retention and stability (García-Viguera, et al., 1999; Touati et al. 2014). Minimums of three jars of each cultivar were made for sensory evaluations.

Chemical analyses. Sugar content of the jams was measured in °Brix using an Atago Digital Hand-held "Pocket" Refractometer PAL-2 (Cole-Parmer, Court Vernon Hills, IL). All measurements were made in triplicate (n=3 replications) with new samples placed on the refractometer each time. The refractometer was washed in between measurements with deionized water and dried with a Kimwipe (KIMWIPES™ Delicate Task Wipers, 11.2 cm x 21.3 cm or 4.4" x 8.4"). Between cultivars, the refractometer was washed with mild detergent and dried with a Kimwipe.

Titratable acidity (g/L) citric acid equivalent, a measure of the total amount of protons available, was determined by titrating a solution containing 5 mL of jam and 50 mL of deionized water with 0.1 M NaOH (sodium hydroxide) to the endpoint of pH=8.20 using an Thermo Scientific Orion 950 ROSS® FAST QC™ Titrator with a Thermo Scientific Orion ROSS Sure-Flow pH electrode. Titrations were done in duplicate with all materials rinsed in between with deionized water. The pH of each sample was measured in triplicate using a Thermo Scientific Orion 950 ROSS® FAST QC™ Titrator with a Thermo Scientific Orion ROSS Sure-Flow pH electrode. The electrode was rinsed with deionized water between measurements of the same sample, between samples the junction was flushed and the electrode rinsed with deionized water.

Hue, lightness and color saturation angles for each sample were measured in triplicate for each jam sample using a Konica Minolta CR-400 chroma meter; data were expressed as L* a* b* color space or CIELAB where L* indicates lightness, higher values are lighter in color, and a* and b* are the chromaticity coordinates (Konica Minolta Sensing, Inc., 2003). Chromaticity coordinates a* and b* indicate the directions of color: +a* (red), -a* (green), +b* (yellow) and -b* (blue) with the center being "achromatic" (Konica Minolta Sensing, Inc., 2003). Color saturation increases as a* and b* values increase in size. Chroma or saturation (C_{ab}*) values were calculated using $\sqrt{a^2 + b^2}$ and are expressed as distance between the center, the "achromatic point", and color (Gulrajani, 2010). Medium to high values of C_{ab}* indicate bright or saturated color whereas lower values indicate duller or less saturated colors (Gulrajani, 2010). Hue angle (H_{ab}) expresses the angle measured beginning at the +a* axis (Konica Minolta Sensing, Inc., 2003). H_{ab} was calculated using Arctan $\left(\frac{b^*}{a^*}\right)$ (Gulrajani, 2010).

Sensory evaluation. Jams were evaluated by a sensory panel made up of n=33 individuals of which 45% were female and 55% male, aged from their early 20s to 70s. Some of the panel members had sensory training and others had little to no sensory panel experience.

For the sensory session, all eight apricot jams along were randomized and assigned an alphanumeric code. While avoiding duplication, four codes were assigned to each evaluator's seat. Each seat was also assigned each of three commercial jam standards for comparisons: Bonne Maman® apricot preserves (apricot control; http://www.bonnemaman.us/preserves-jellies/apricot-preserves/), Bonne Maman® cherry preserves (tart cherry control; http://www.bonnemaman.us/preserves-jellies/cherry-preserves/) and Bonne Maman® plum preserves (plum control; http://www.bonnemaman.us/preserves-jellies/plum-preserves/) for a total of seven samples / evaluator. The tart cherry and plum controls were included to provide diversity of flavor and color. For statistical purposes, individual evaluators were considered incomplete blocks.

Jam jars were labeled with their corresponding code, and then approximately 15 g of each sample was placed in a neutral colored, 29.6 mL plastic, disposable, odor-free cup (Culetu, et al., 2014) labeled with the jam code, along with a 7.62 cm plastic taster spoon. These samples were placed at their corresponding seats along with one instruction (Fig. 1) and seven evaluation

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Name________________________________

***Taste the Difference!* Sensory Evaluation**
26 February 2014
Jams from the University of Minnesota *Prunus* Collection

You will be evaluating individual jam samples based on the ten criteria below. Please adhere to the following instructions as closely as possible and evaluate characteristics in the numbered order.

- Please taste the samples in order, from left to right
- Watch for pits!
- Write the code (on the side of sample cup) at the top of the evaluation sheet.

1. Color:
Align the spectrum card with the bar scale on the scoring sheet - blue on the left, red on the right. Using the blank sheet of paper supplied, examine closely the color of the jam, and to the best of your ability match that color on the spectrum card. Draw a vertical mark through the bar scale at the point corresponding to the color on the spectrum card.

2. Spreadability:
Using the spoon, move the jam back and forth in the cup, gauging its' resistance to your movement. Using water as the thin extreme and frozen ice cream as the thick extreme, draw a vertical mark through bar scale at the point most accurately reflecting your impression.

The following characteristics all require the jam to be placed in your mouth. You will not have enough of each sample to evaluate each characteristic with a separate mouthful. Therefore, please read through the instructions for criteria 3-10 before starting, so that you can evaluate numerous characteristics with each mouthful. You do not have to swallow the jam. The paper cup next to your water glass is a spit cup, if needed.

3. Texture:
Move a small amount of jam around in your mouth. With your tongue, push the jam against the inside of your mouth paying close attention to the texture of the jam. Using pudding as a smooth extreme and gritty as the opposite extreme, make a vertical mark on the bar scale corresponding to your impression of the texture of the jam.

4. Fruit Pieces (if present):
With a small amount of jam in your mouth, take note of the texture of any fruit pieces in the jam; bite down on one of the pieces. With melting as a soft extreme and citrus rind as a firm extreme, make a vertical mark on the bar scale corresponding to your impression of the texture of the fruit pieces.

5. Flavor:
While moving a small amount of jam around in your mouth, take note of the intensity of fruit flavor. Is the flavor extremely strong and pronounced (intense) or is it barely perceptible or absent (none)? Make a vertical mark on the bar scale corresponding to your impression of the fruit flavor.

6. Off-Flavor:
While moving a small amount of jam around in your mouth, take note of the intensity of any distracting or unpalatable flavor you would not normally associate with the corresponding fruit (cherry or plum). Is the flavor extremely strong and pronounced (intense), or is it barely perceptible or absent (none)? Make a vertical mark on the bar scale corresponding to your impression of the off-flavor.

7. Sweetness:
While moving a small amount of jam around in your mouth, take note of the intensity of sweetness. Is the sensation of sweetness strong and overpowering (intense) or is it barely perceptible or absent (dry)? Make a vertical mark on the bar scale corresponding to your impression of the sweetness.

8. Bitterness:
While moving a small amount of jam around in your mouth, take note of the intensity of bitterness. Is the sensation of bitterness strong and overpowering (intense) or is it barely perceptible or absent (none)? Make a vertical mark on the bar scale corresponding to your impression of the bitterness.

9. Overall Quality:
What is your overall impression of the jam? Is it an enjoyable, well-balanced product, or do you find it distasteful or unpalatable? Make a vertical mark on the bar scale corresponding to your impression of the quality of the jam.

10. Would you buy this?
Exactly that - please circle either YES or NO.

Once you have finished evaluating this sample, cleanse your palate with water and eat one unsalted cracker and then proceed to the next jam. Rinse your mouth again, if necessary. Once you are finished please double check that you have written your name on the top of the packet and that the code for each jam is written on the top of each evaluation sheet.

Thank you for your participation.

Jam Code____________

1. Color

Blue						Red

2. Spreadability

Easy (water)			Moderate			Firm (ice cream)

Starting here, you will need to put the jam in your mouth.

3. Texture

Smooth (pudding)						Gritty

4. Fruit Pieces (if present)

Soft (melting)			Moderate			Firm (citrus rind)

5. Flavor

None			Moderate			Intense

6. Off-Flavor

None			Moderate			Intense

7. Sweetness

Dry			Moderate			Intense

8. Bitterness

None			Moderate			Intense

9. Overall Quality

Poor			Average			Excellent

10. Would you buy this jam?

Yes	No

Fig. 1. Sensory evaluation panel instructions used with the apricot jam taste tests.

sheets (Fig. 2), one color reference card, one neutral white and unlined 7.62 x 12.7 cm card, water cup, spit cup, and unsalted crackers (Fig. 3; Halat et al., 1997). All sensory evaluation panels were conducted at room temperature to match the predominant conditions for jam consumption and conditions for previous panels (Culetu, et al., 2014).

Each group was given a brief, oral introduction on how to taste jams, palette cleans-

Jam Code____________

1. Color

Blue | Red

2. Spreadability

Easy (water) | Moderate (Syrup) | Firm (ice cream)

3. Mouth Feel

Thin (water) | Thick (cream)

4. Fruit Pieces (if present)

Soft (descriptor) | Moderate | Firm (citrus rind)

5. Flavor

None | Moderate | Intense

6. Off-Flavor

None | Moderate | Intense

7. Sweetness

Dry | Moderate | Intense

8. Bitterness

None | Moderate | Intense

9. Overall Quality

Poor (unpalatable) | Average | Excellent

10. Would you buy this?

YES NO

Fig. 2. Example score sheet used by each evaluator during the sensory evaluations.

ing procedures, use of the color chart (*cf.* Fig. 3) and a review of the instruction (Fig. 1) and evaluation (Fig. 2) sheets. A modification of the standard Hedonic 9-point (Lawless and Heymann, 2010; Basu et al. 2011) to 7-point scale (Grujić, et al., 2007) was implemented with an unnumbered scalar range of seven boxes for recording scores (Fig. 2). All members of each group taste-tested the first sample (apricot control) together using the instructions (Fig. 1) and, once they had recorded their evaluative assessments of the

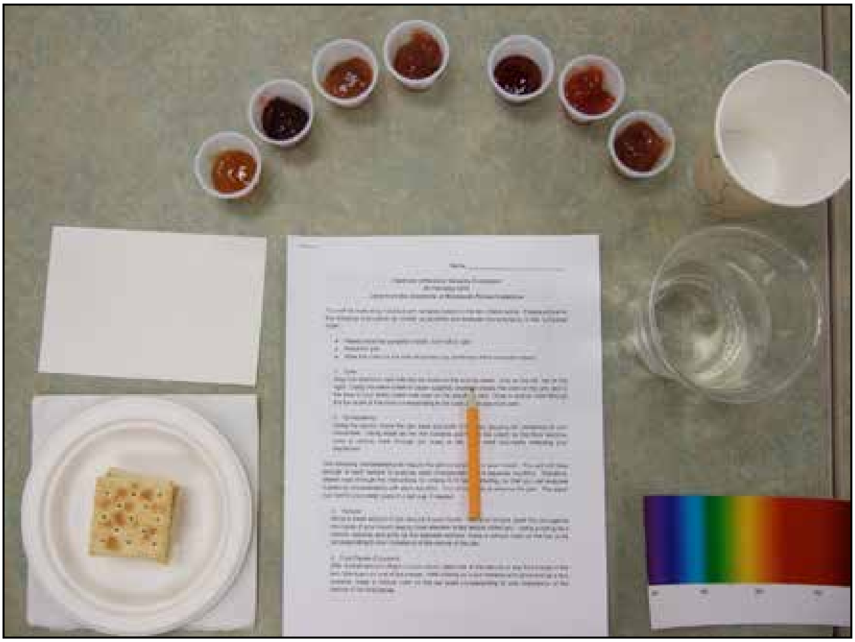

Fig. 3. Setup of all items used in the sensory evaluation panels (see text)

apricot control, discussed the potential data points for each of the ten factors for each jam (Fig. 2). Sensory sessions took place in classroom settings with overhead cool white florescent lighting (538 Lux) and room temperature conditions (21°C). Each panelist was provided adequate space to evaluate his or her samples. However, physical barriers did not separate panelists.

Since evaluators marked the first nine sensory characteristics in the linear box plots (Fig. 2), these were transformed into quantitative data points, based on measuring (mm) from the beginning (far left-hand side) of the scale to wherever the panelist made their mark. This value was then divided by the total length of the scale and then multiplied by ten to give data points on a ten-point scale.

Data Analyses. One-way Analysis of Variance (ANOVA) as well as mean separations with Tukey's Honest Significant Difference (HSD) tests α=0.05 were carried out for all quantitative data. Quantitative chemical analysis and ratings data were also analyzed using principle components analysis. Qualitative data, specifically desire to purchase, was analyzed using a Chi-square test with equal distribution across the two classes (1:1 χ^2). Since there was only 1 degree of freedom for the Chi-square test, the Chi-square correction of $(\text{Observed-Expected-}0.5)^2$ was used. Pearson's Rank Correlations were carried out between variables.

Results

Chemical analyses. Mean soluble solid concentration of jams ranged from 48.87° Brix for the tart cherry control to 68.47° Brix for MN604 (Table 1). The tart cherry control and 'Westcot' differed significantly for soluble solid concentration from all other jams (Table 1). In addition, MN604 differed significantly from both 'Sungold' and the cherry control (Table 1).

The range in mean pH values was 3.00 for MN604 and 'Sungold' to 3.35 for the tart cherry control (Table 1). The tart cherry control pH differed significantly from all other

Table 1. Mean soluble solids (S.S.; °Brix), pH, titratable acidity (T.A.; g/L citric acid equivalent), L*a*b* color space or CIELAB (where L* indicates lightness; a* and b* are the chromaticity coordinates), hue angle (H_{ab}* = arctan(b*/a*) and chrome (C_{ab}*= sqrt [a^{*2}+b^{*2}]) for apricot, tart cherry and plum jams used in the sensory evaluation panel. Mean separations within traits (columns), based on Tukey's 5% HSD.

Jam	S.S. (°Brix)	pH	T.A.	Color L*	a*	b*	H_{ab}*	C_{ab}*
Tart cherry control	48.87 c	3.35 a	7.29 f	29.93 bc	13.18 abc	4.11 d	0.32 e	13.84 d
Plum control	65.87 ab	3.23 b	8.44 f	24.62 c	17.70 a	10.13 d	0.52 d	20.39 cd
Apricot control	67.30 ab	3.20 bc	12.37 de	41.24 a	16.44 ab	38.71 a	1.17 bc	42.06 a
MN604	68.47 a	3.00 f	16.23 ab	39.71 ab	13.22 abc	31.05 abc	1.17 bc	33.79 ab
MN206	65.50 ab	3.15 cd	11.74 e	38.44 ab	14.16 ab	27.65 bc	1.10 c	31.07 abc
MN203	61.57 ab	3.02 ef	15.41 abc	36.89 ab	14.83 ab	30.71 abc	1.10 c	34.55 ab
MN202	66.50 ab	3.12 d	14.17 cd	44.88 a	8.53 c	29.89 abc	1.29 a	31.10 abc
'Brookcot'	64.93 ab	3.01 f	14.54 bc	46.25 a	8.71 c	31.49 abc	1.30 ab	32.68 ab
'Debbie's Gold'	64.37 ab	3.11 d	15.17 bc	42.06 a	13.51 abc	38.78 a	1.24 ab	41.07 a
'Sungold'	59.77 b	3.00 f	14.41 c	41.45 a	12.27 bc	35.93 ab	1.24 a	38.00 a
'Westcot'	50.70 c	3.06 e	17.60 a	42.73 a	8.93 c	23.57 c	1.21 ab	25.09 bc

jam types whereas the plum control differed significantly from all jams except for the apricot control (Table 1). MN206 was significantly different from the majority of other jams' pH values except for the apricot control, MN202, and 'Debbie's Gold' (Table 1). 'Westcot' was significantly different than the majority of jams except for MN203. Apricot jams from MN604, MN203, 'Brookcot', and 'Sungold' were not significantly different from each other but differed from the remaining jams for pH (Table 1).

There was significant variation among the apricot jams for titratable acidity. The titratable acidity ranged widely, from 7.29 ml (tart cherry control) to 17.60 ml for 'Westcot' (Table 1). Both the plum and tart cherry controls were significantly different than all of the other jams in this study.

Color lightness (L*) ranged from the darkest L*=24.62 (plum control) to the lightest (L*=46.25 for 'Brookcot'; Table 1). As would be expected with lighter colored or yellower apricots, the darkest jams (plum and tart cherry controls) did not differ from each other in L* values or most other jams tested (Table 1). The only exceptions were MN604, MN206, and MN203 (Table 1), which were significantly lighter than the plum control but overlapped with the tart cherry control.

The chromaticity coordinates for green-red (a* values) ranged from a*=8.53 units for MN202 to a*=17.70 units for the plum control, which had the "reddest" color (Table 1). The plum control differed significantly from MN202, 'Brookcot', 'Sungold' and 'Westcot' for the green-red coloration; the apricot control, MN206, and MN203 were significantly different than MN202, 'Brookcot' and 'Westcot' for a* (Table 1). All other jams had intermediate a* values (Table 1). Chromaticity coordinates for blue-yellow (b*) varied from b*=4.11 (tart cherry control) to b*=38.78 ('Debbie's Gold; Table 1). The jam with the "yellowest" or least coloration saturation chromaticity coordinates was 'Debbie's Gold', which was significantly different than both the tart cherry and plum controls as well as MN206 and 'Westcot' (Table 1). The plum and tart cherry controls differed for b* from all apricot accessions, including the apricot control (Table 1).

Hue angles, H_{ab}*, were distributed from 0.32 (tart cherry control) to 1.30 ('Brookcot'; Table 1) with significant variation among genotypes. The plum and tart cherry controls were significantly different than all apricot jams for hue angles (Table 1). There was significant variation among the apricot jams for hue angle with MN202 and 'Sungold' differing significantly from the majority of other genotypes except for 'Brookcot', 'Debbie's Gold', and 'Westcot' (Table 1). In addition, 'Brookcot' and 'Debbie's Gold' were significantly different than about half of the other genotypes (Table 1).

Mean chrome (C_{ab}*) values ranged widely from 13.84 for the tart cherry control to 42.06 for the apricot control (Table 1). The tart cherry and plum controls did not differ significantly from each other; the tart cherry control chrome values differed significantly from all jams with the exception of the plum control. The plum control C_{ab}* values differed significantly from the apricot control, MN604, MN203, 'Brookcot', 'Debbie's Gold', and 'Sungold' (Table 1). 'Westcot' jam differed significantly from the apricot control, 'Debbie's Gold', and 'Sungold' (Table 1).

Sensory evaluations. There was significant variation among jams for color, spreadability, texture, fruit pieces, flavor, off-flavor, and overall quality in this study ($p<0.05$). In contrast, for the sweetness and bitterness ratings there was no significant variation among genotypes ($p=0.09$ and $p=0.48$, respectively). The pooled mean rating for sweetness was 6.2 and 1.9 for bitterness (data not shown).

Mean ratings for color in the sensory evaluations (10 point scale) ranged from 5.3 for MN206 to 8.8 for the tart cherry control; all apricot jams differed significantly from the plum and cherry controls (Table 2). Spreadability mean ratings ranged from 4.2 (plum control) to 8.5 (MN206) with the tart cherry and plum controls differing significantly from only MN206 (Table 2).

Texture ratings ranged from 3.4 for the plum control to 8.7 for 'Brookcot' jams (Table 2). 'Brookcot' jam differed significantly from all other jams except for MN604; likewise, MN604 differed significantly from all other jams except for MN206 (Table 2). In addition to being significantly different from 'Brookcot', MN206 also differed from both the tart cherry and plum control jams (Table 2).

The mean ratings for fruit pieces in the jams ranged from 3.9 for the apricot control to 7.1 for MN604 (Table 2) with a higher presence of solids. MN604's mean fruit pieces rating was significantly different than the apricot and tart cherry controls as well as 'Westcot' (Table 2). 'Brookcot' differed significantly from the tart cherry and apricot controls (Table 2).

Table 2. Mean color, spreadability, texture, fruit pieces, flavor, off-flavor, and overall quality ratings (10 point scale) for apricot jams and tart cherry/plum controls as determined by sensory panelists (n=33). Mean separations within significant traits (columns), based on Tukey's 5% HSD.

Jam	Color	Spread-ability	Texture	Fruit Pieces	Flavor	Off Flavor	Overall Quality
Tart cherry Control	8.8 a	4.8 b	3.5 d	4.0 c	6.4 bc	0.9 c	7.0 a
Plum Control	8.2 a	4.2 b	3.4 d	5.2 abc	6.0 c	1.7 abc	5.6 b
Apricot Control	5.7 b	5.9 ab	3.9 cd	3.9 c	6.4 bc	1.7 abc	6.3 ab
MN604	6.0 b	6.0 ab	6.9 ab	7.1 a	7.4 bc	2.8 a	5.7 ab
MN206	5.3 b	8.5 a	5.3 bc	5.1 abc	6.3 abc	1.7 abc	5.8 ab
MN203	6.0 b	5.7 ab	4.9 cd	5.2 abc	7.3 abc	2.4 ab	6.7 ab
MN202	5.5 b	5.6 ab	4.7 cd	5.9 abc	7.1 abc	1.4 abc	6.1 ab
'Brookcot'	5.4 b	6.4 ab	8.7 a	6.4 ab	6.0 c	2.2 abc	3.6 c
'Debbie's Gold'	5.4 b	5.8 ab	4.8 cd	5.5 abc	7.6 ab	1.7 abc	6.4 ab
'Sungold'	5.6 b	5.2 ab	4.7 cd	5.5 abc	7.1 abc	1.0 bc	6.8 ab

Sensory evaluation ratings for flavor varied from 6.0 for 'Brookcot' and the plum control to 8.1 for 'Westcot', with the latter differing significantly from the cherry, plum, and apricot controls as well as MN604 and 'Brookcot' (Table 2). The mean rating for flavor of 'Debbie's Gold' jam differed significantly from the plum control and 'Brookcot'.

Off-flavor ratings for all jams were relatively low with mean ratings ranging from 0.9 for the cherry control to 2.7 for 'Westcot' (Table 2). Apricot jams from MN604 and 'Westcot' differed significantly from 'Sungold' and the tart cherry control (Table 2). MN203 apricot jam also was significantly different than the cherry control (Table 2).

The wide range in sensory evaluation values for overall quality was 3.6 for 'Brookcot' to 7.0 for the cherry control (Table 2). The tart cherry control differed significantly from the plum control, 'Westcot', and 'Brookcot' jams for overall quality (Table 2). 'Brookcot' had significantly lower overall quality ratings than all other jams, particularly the control comparisons (Table 2).

Correlations. The correlation matrix (Table 3) shows chemical and sensory evaluation trait combinations that were either positively or negatively correlated. Color ratings were positively and significantly correlated with overall quality, desire to purchase, pH, and negatively but significantly correlated with texture, fruit pieces, titratable acidity, L*, b*, H_{ab}*, and C_{ab}* (Table 3).

Texture ratings were positively and significantly correlated with fruit pieces, off-flavor, soluble solids, H_{ab}* but texture was negatively correlated with overall quality, desire to purchase, and pH (Table 3). Fruit pieces were positively and significantly correlated with flavor, off-flavor, bitterness, and soluble solids whereas fruit pieces were negatively, but significantly correlated, with overall quality (Table 3).

Table 3. Correlations between parameters color, texture (Text.), fruit pieces (Pieces), falvor (Flav.), off-flavor (Off-Flav.), sweetness (Sweet.), bitterness (Bitter.), and over quality (Quality) ratings, desire to purchase (Purch.) and soluble solids (S.S.), pH, titratable acidity (TA), hue directions L*, a*, b*, H_{ab}*, and C_{ab}* for all jams tested. An asterisk (*) indicates a signficant correlation coefficient (<0.05).

					Off									Hue directions			
	Color	Text.	Pieces	Flav.	Flav.	Sweet.	Bitter.	Quality	Purch.	S. S.	pH	TA	L*	a*	b*	H_{ab}*	C_{ab}*
Color	1.00																
Text.	-0.25*	1.00															
Pieces	-0.15*	0.47*	1.00														
Flav.	-0.06	0.04	0.14*	1.00													
Off-Flav.	-0.06	0.26*	0.16*	0.18*	1.00												
Sweet.	0.10	0.02	0.00	0.11	-0.03	1.00											
Bitter.	0.00	0.26*	0.32*	0.20*	0.37*	-0.25*	1.00										
Quality	0.18*	-0.29*	-0.15*	0.29*	-0.26*	0.12	-0.23*	1.00									
Purch.	0.17*	-0.20*	-0.11	0.28*	-0.19*	0.13	-0.15*	0.73*	1.00								
S.S.	-0.33	0.44*	0.64*	-0.24	0.34	-0.10	0.27	-0.33	-0.16	1.00							
pH	0.70*	-0.39*	-0.30	-0.10	-0.23	-0.07	-0.16	0.02	0.09	-0.30	1.00						
TA	-0.82*	0.40	0.22	0.09	0.27	0.10	0.11	-0.07	-0.04	0.34	-0.86*	1.00					
L*	-0.76*	0.28	-0.07	0.13	0.18	0.09	0.21	-0.02	0.04	0.15	-0.59*	0.66*	1.00				
a*	0.34	-0.29	0.26	-0.14	-0.09	-0.20	-0.08	0.02	0.08	0.25	0.35*	-0.32	-0.73*	1.00			
b*	-0.82*	0.27	0.29	0.05	0.22	-0.11	0.21	-0.02	0.10	0.50*	-0.65*	0.75*	0.67*	-0.06	1.00		
H_{ab}*	-0.90*	0.37*	0.15	0.11	0.22	0.04	0.15	-0.05	-0.01	0.39*	-0.79*	0.86*	0.86*	-0.45*	0.88*	1.00	
C_{ab}*	-0.71*	0.23	0.34	0.00	0.20	-0.17	0.20	-0.01	0.11	0.54*	-0.54*	0.67*	0.48	0.15*	0.90*	0.75*	1.00

Flavor ratings were positively correlated with off-flavor, bitterness, overall quality, and desire to purchase. Off-flavor rating was positively correlated with bitterness and negatively correlated with overall quality and the desire to purchase (Table 3). As would be expected, sweetness ratings were negatively correlated with bitterness. The bitterness ratings were negatively correlated with overall quality and desire to purchase (Table 3). Overall quality was also positively correlated with desire to purchase.

Unexpectedly, soluble solid concentration was positively correlated with hue directions b*, H_{ab}*, and C_{ab}*. pH was positively correlated with a* but negatively correlated with titratable acidity, L*, b*, H_{ab}*, and C_{ab}* (Table 3). In addition, titratable acidity was positively correlated with L*, b*, H_{ab}*, and C_{ab}* (Table 3). Hue L* was positively correlated with b*, H_{ab}*, and negatively correlated with a* (Table 3). In addition, a* was positively correlated with C_{ab}*. Hue direction b* was positively correlated with H_{ab}* and Cab. Finally, H_{ab}* and C_{ab}* were positively correlated with each other (Table 3).

Chi-square. The expected χ^2 ratio of willingness to purchase or not (yes:no) was 1:1. For the majority of jams, the ratio did not differ significantly from the expected. Only the tart cherry control differed significantly from the expected ratio with 81.8% individuals stating they would purchase and 18.2% stating they would not (χ^2 value=6.1; Table 4).

Chemical Analysis PCA. The first two principal components for the chemical analysis data, PC1 and PC2, had eigenvalues ≥ 1.0 and, together, accounted for 80.9% of the variation. PC1 accounted for 59.1% of the variation and was positively associated with a*, soluble solid content, C_{ab}*, b*, and pH (Fig. 4A). PC1 was negatively associated with L*; PC2 accounted for 21.8% of the variation and was positively associated with soluble solids, C_{ab}*, b*, titratable acid, H_{ab}*, and L* (Fig. 4A). PC2 was negatively associated with a* and pH. The majority of apricot jams were positively associated with PC1 and PC2; 'Westcot' was negatively associated with PC1 (Fig. 4A). The plum control was positively associated with PC1 and negatively associated with PC2; the tart cherry control was negatively associated with both principle components (Fig. 4A).

Sensory Evaluation Ratings PCA. The first four principal components (PC1, PC2, PC3, and PC4) had eigenvalues ≥ 1.0 and accounted for 64.9% of the variation. PC1 accounted for 25.2% of the variation and was positively associated with all ratings except for texture and spreadability (Fig. 4B). The fruit pieces, bitterness, and off-flavor variable vectors were closely clustered on the PCA biplot (Fig. 4B). Flavor, off-flavor, fruit pieces,

Table 4. Chi-square tests of the desire to purchase (sensory evalution) for each jam type tested (1:1χ^2). Chi-square (χ^2) was corrected by (Observed-Expected-0.5)^2 due to the fact there was only 1 degree of freedom (df=1).

Jam tested	% Yes	% No	χ^2
Tart cherry Control	81.8	18.2	6.1*
Plum Control	45.5	54.5	0.2
Apricot Control	60.6	39.4	0.5
MN604	37.5	62.5	0.8
MN206	66.7	33.3	0.5
MN203	83.3	16.7	3.4
'Brookcot'	25.0	75.0	2.5
'Debbie's Gold'	50.0	50.0	0.0
'Sungold'	73.3	26.7	1.2
'Westcot'	50.0	50.0	0.0

bitterness, texture, and spreadability ratings were positively associated with PC2 whereas overall quality, sweetness, and color were negatively associated with PC2 (Fig. 4B). Most jams, except for the apricot control, 'Brookcot', MN206, and the plum control, were positively associated with PC1 (Fig. 4B). Most jams were positively associated with PC2 except for the three controls (Fig. 4B).

Discussion

The pH values for the apricot jams and comparisons in the present study (Table 1) were similar to those reported by Aslanova et al. (2010). Apricot jams tested by Touati et al., (2014) had higher values (pH=3.54) prior to storage of the jams. Titratable acidity levels in the jams tested herein were similar to previous reports as well (Touati et al., 2014; Aslanova et al., 2010). The significantly lowest pH values found in MN 604, MN203, 'Brookcot' and 'Sungold' apricot jams could mean increased protection against the development of microorganisms over time (Touati et al. 2014), although this was not tested. Lightness (L*) is also an important factor in non-enzymatic browning (Touati et al., 2014), although L* and pH were negatively and significantly correlated for the 11 tested jam samples (Table 3).

'Sungold', 'Westcot' and the tart cherry jam control all had <60% soluble solids (°Brix; Table 1), which is the minimal level required by the Codex Alimentarious Standard (CODEXSTAN, 2009). All other apricot jams tested met the CODEXSTAN minimum soluble solid level and were similar to previous findings for other apricot (Touati et al., 2014) and quince jams (Ferreira et al., 2014).

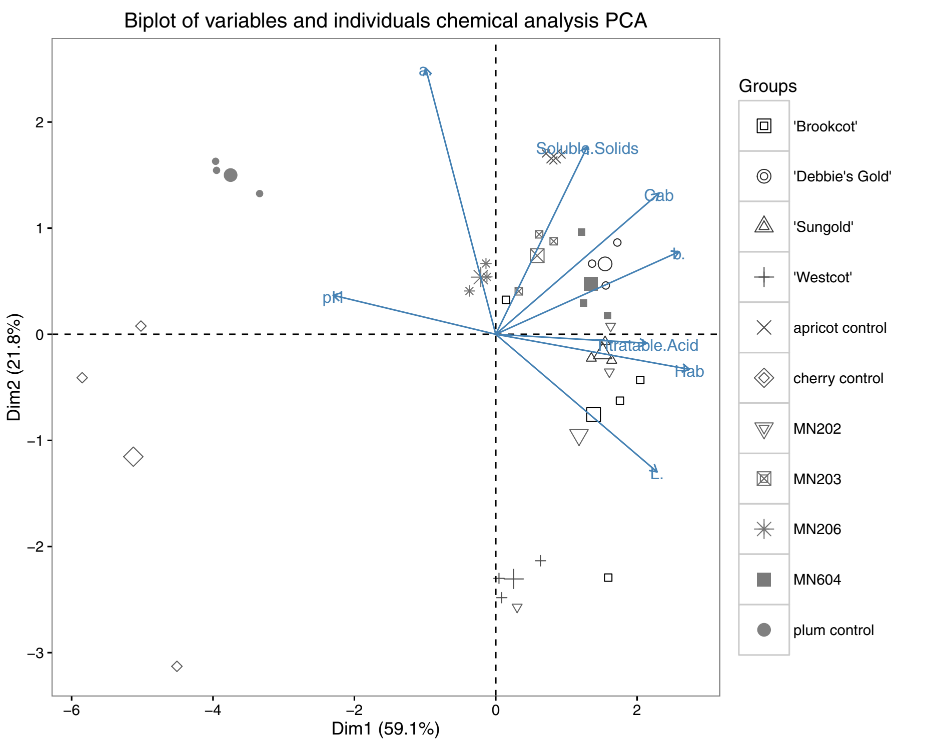

Fig. 4A.

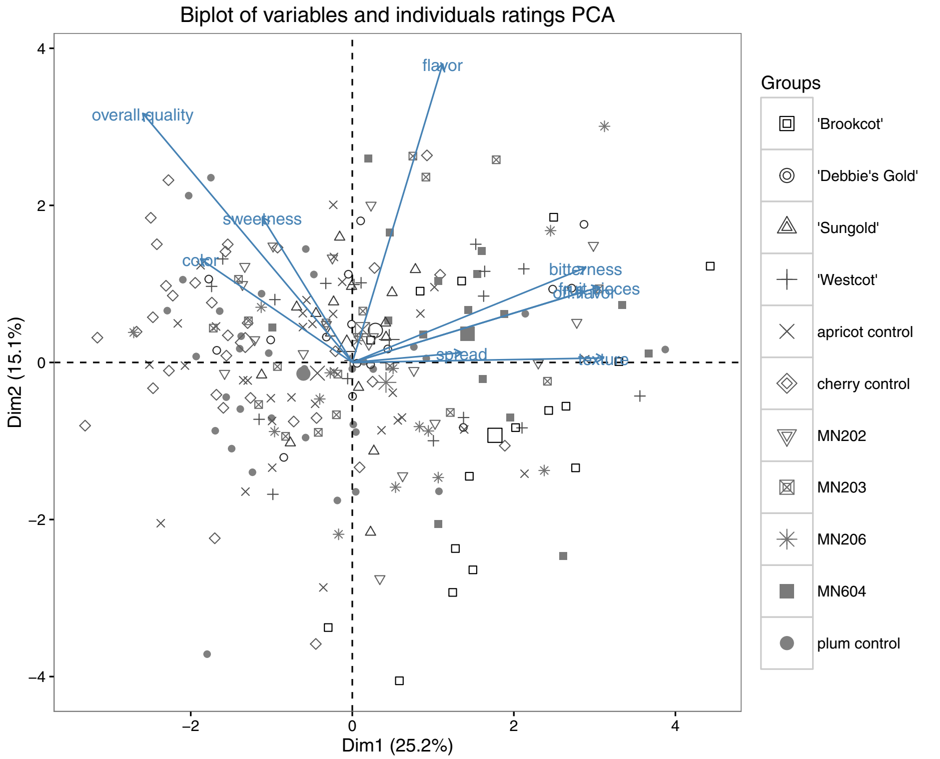

Fig. 4. Biplots from principal components analyses measured variables for the apricot jams and comparisons used in the (A) chemical analysis for mean soluble solids, pH, titratable acidity (g/L citric acid equivalent) L*a*b* color space or CIELAB (where L* indicateslightness; a* and b* are the chromaticity coordinates), hue angle ($H_{ab}* = \arctan(b*/a*)$) and chrome ($C_{ab}* = \text{sqt}\ [a*^2+b*^2]$) and (B) sensory evaluation panels for fruit pieces, flavor, off-flavor, sweetness, color and overall quality (10-point scale); spreadability, texture and bitterness ratings on a 0 to 10 scale.

Apricot jam color, as gauged by color lightness (L*), is one of the most important consumer selection criteria (Touati et al., 2014). L* was the lightest for ‘Brookcot’ jam (Table 1). The panelists in the sensory evaluation were also able to discern differences among the apricot jams and their comparisons for color (Table 2). Since apricot fruits range in colors of yellow to orange and red when ripe, chromaticity coordinates of blue-yellow (b*) indicate that ‘Debbie’s Gold’ was the yellowest apricot jam and significantly yellower than MN206, ‘Westcott’, the tart cherry and plum controls (Table 1). In contrast to ‘Brookcot’, apricot jams made from MN604, MN206 and MN203 were significantly darker in color and were statistically similar to the tart cherry control. Such darker-colored apricot jams, changing from yellower to more reddish tones may be due to the Maillard reaction whereby brown pigmentation is formed or enzymatic browning occurs. The browning of jams has been observed in previous studies of apricot (Touati et al., 2014) and strawberry jams (Wicklund et al., 2005; Patras et al., 2011).

The panelists in the sensory evaluation were able to discern differences among the apricot jams and comparisons for spreadability, texture, fruit pieces, flavor, off-flavor and overall quality (Table 1). For the spreadability scores, MN206 had the most similar value (8.5) reported in other studies (range of 7.0-8.11; Touati et al. 2014). Panelists could not distinguish differences for sweetness and bitterness ratings for any of the jams (data not shown). Thus, even if fructose or glucose levels in the fresh fruit differed, the addition of comparative sucrose levels during the jam making process may have masked such differences, if they existed. Future chemical research could identify whether or not fructose and/or glucose levels differ in the apricot cultivar jams tested herein. Likewise, future studies could include testing storage effects on all parameters to determine whether jam quality changes over time.

Oftentimes panelists in sensory evaluations are unable to discriminate for specific traits among jam samples. For example, some apricot jams are admixtures with undeclared additives such as apples (Drugovic-Uzelac et al., 2005b), pumpkin (Drugovic-Uzelac et al., 2005a) or sugar and water (Fuchs and Koswig, 1997; Hammond, 1997). Such additions occur due to the high cost of fresh apricot fruit, limited production or crop failures. Sensory evaluation panelists could not detect these adulterations in apricot jams (Drugovic-Uzelac et al., 2005b).

One unnamed apricot selection, MN 206, had the highest number of traits (5 in total) that differed significantly from other tested apricot jams. MN 206 had low T.A. and high scores for spreadability, texture, fruit pieces, flavor and overall quality. However, since MN 206 is not on the market and unavailable to consumers, the second tier of high quality apricot jams were made from 'Sungold' and 'Brookcot'. Both of these cultivars had significantly lower pH, which ensures long-term storage and has a lower likelihood of browning from the Maillard reaction, while 'Sungold' had <60% soluble solids as required by the Codex Alimentarious Standard. 'Sungold' also rated high in overall quality, T.A., and 73.3% of the sensory evaluation panelists said they would purchase this apricot jam. This is in contrast to 'Brookcot' where 75% of the panelists would not purchase it (Table 4). Thus, we recommend 'Sungold' as the best apricot for making jam with the currently available winter hardy trees for purchase.

Acknowledgements

Funding in support of this publication was a grant from the Minnesota Landscape Arboretum Land Grant Chair and the Minnesota Agricultural Experiment Station.

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