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Pigmented Citrus Cultivars Can Differentiate Market for Consumers

Fruit Quality Evaluations of New Introduced Red-fleshed Citrus Cultivars

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Boukhobza blood orange fruit longitudinal and cross section, Riverside, California, on January 27, 2014.

Project Summary

Citrus with red internal coloration and rind blush due to the presence of anthocyanin[1] pigments can be a significant way to differentiate cultivars in the market. This progress report describes fruit quality evaluations of three introduced red-fleshed cultivars (Shahani Red navel orange, Amoa 8 tangor and Boukhobza blood orange) compared with two industry standards (Moro and Sanguinelli) from 2014-18. Fruit from all five cultivars were evaluated from trees grown on C35 citrange and/or Carrizo rootstocks in Riverside, California. Boukhobza was compared alone with the two standards on both rootstocks at the University of California (UC) Lindcove Research and Extension Center (LREC) in Exeter, California. At UC Riverside (UCR), Shahani Red and Boukhobza fruit had higher Brix levels and lower titratable acidity relative to other cultivars, indicating earlier maturity. At Exeter, Boukhobza fruit had higher Brix, lower acidity and higher Brix-to-acid ratio than standards, also indicating earlier maturity than standard. These and additional fruit characteristic differences provide growers with information to select future cultivars.

Boukhobza blood orange fruit on young tree, Exeter, California, on December 13, 2007.

Orange, yellow, green – we tend to associate the type of citrus with the internal and external color of oranges, lemons and limes. Yet we often identify citrus with pink or red internal flesh as "pigmented" for the pink-colored lycopene[2] pigments in Cara Cara navel oranges and red grapefruit, and red-colored anthocyanin pigments in blood oranges. Citrus with pink and red internal color can be a significant way to visually differentiate sweet oranges and other citrus in the market for consumers. Cara Cara is a good example of a navel orange cultivar that has transcended from a rare, specialty item to a more mainstream variety in recent years due to both its flavor and distinctive pink color that visually differentiates Cara Cara from Washington navel and other navel orange cultivars. In Italy, three cultivars of blood or pigmented oranges with distinctive red flesh, Tarocco, Moro and Sanguinello, account for 70 percent of all sweet oranges produced there (Rapisarda et al. 2003). These pigmented oranges are economically important cultivars for the citrus industry in Italy and are differentiated from other sweet oranges.

In addition to their role in red pigmentation of the flesh and blush on the rind of some blood orange cultivars, anthocyanin pigments contain health-promoting features associated with the antioxidant properties of these compounds, since their chemical structure appears ideal for free radical scavenging in humans (Amorini et al. 2003). The association of anthocyanin pigments with higher biological properties relative to other orange-pigmented citrus is another value added attribute that could differentiate pigmented cultivars in the market for consumers and possibly increase their economic value for the California citrus industry.

This progress report describes fruit quality evaluations of three new red-fleshed cultivars (Shahani Red navel orange, Amoa 8 tangor and Boukhobza blood orange) compared with two industry standards (Moro and Sanguinelli) to help growers and the industry make informed decisions when selecting future cultivars. This research is part of our Citrus Research Board-funded project entitled "Integrated Citrus Breeding and Evaluation for California."

Shahani Red navel orange likely originated as a bud sport from a Washington navel orange tree on the property of Frank Shahani in southern California, and was then selected by Toni Siebert-Wooldridge, David Karp and Tracy Kahn in 2008 (Kahn et al. 2018). Shahani Red is currently undergoing citrus pathogen clean-up at the Citrus Clonal Protection Program (CCPP) as Variety Index (VI) 969. Budwood is not yet available from the CCPP, but it is slated for release as part of the CCPP "Early Release" program in the fall of 2020 with its distribution restricted to California nurseries and growers.

Amoa 8 is an intensely red-fleshed tangor that resulted from a cross of Moro blood orange with Avana mandarin sometime around 1990 by Francesco Russo of the Research Centre for Olive, Citrus and Tree Fruit (CREA-OFA), Acireale, Italy. Seeds were received in 2002, and seedling selections were made by Siebert-Wooldridge in 2005. This variety was released from Federal and California quarantine from the CCPP as VI 925. Amoa 8 is now available as part of the "Early Release" program from the CCPP and is restricted to California nurseries and growers.

Reports indicate Boukhobza originated in Jardin Boukhobza, La Soukra, Tunisia, as a seedling selection of Maltaise Sanguine. The CCPP received Boukhozba budwood from L'Ariana, Tunisia in 2006. Budwood of Boukhobza currently is available from the CCPP as VI 719.

Fruit quality evaluations of these three cultivars were conducted from 2014-18 and compared to Moro, an early-maturing pigmented orange, and Sanguinelli, a late-maturing pigmented orange. Amoa 8 and Boukhobza fruit were from trees grown on Carrizo and C35 citrange rootstocks, while Shahani Red fruit were evaluated from trees grown only on Carrizo citrange rootstock at the UCR Citrus Variety Collection (CVC). Boukhobza trees were grown on Carrizo citrange rootstock at LREC. Moro and Sanguinelli trees with fruit for comparison were grown at Riverside on both Carrizo and C35 citrange rootstock. Standards of comparison at Exeter were collected from Moro trees grown on Carrizo citrange and Sanguinelli trees grown on Troyer citrange rootstocks.

As shown in **Table 1**, in Riverside, Shahani Red, Amoa 8 and Boukhobza had higher Brix than both Moro and Sanguinelli fruit at all three sample periods from early January to mid-February. Sanguinelli had significantly higher titratable acidity in early and late January than the other four, but not significantly higher than Amoa 8 in mid-February. By

Table 1: Means and standard errors (in parentheses) of select fruit quality characteristics for Shahani Red navel orange, Amoa 8 tangor and Boukhobza blood orange cultivars conducted from 2014-18 compared to the standards Moro and Sanguinelli blood orange for three sample date ranges from trees in Riverside, California. CZO=Carrizo citrange and C-35=C35 citrange.

Date	Cultivar	Rootstock	Brix	Titratable acidity	Brix acid ratio	Fruit weight (g)	Texture rating	Rind thickness (mm)	Seed number per fruit	% Juice
Early Jan 2014-18	Moro	CZO/C-35	12.7 (0.4)	1.1 (0.0)	11.5 (0.4)	139.2 (13.8)	2.6 (0.3)	5.1 (0.2)	2.0 (0.3)	49.3 (7.2)
	Sanguinelli	CZO/C-35	12.6 (0.2)	1.5 (0.1)	8.5 (0.3)	110.8 (3.8)	2.3 (0.3)	4.1 (0.2)	2.6 (0.3)	44.2 (0.7)
	Shahani	CZO	13.4 (0.2)	1.0 (0.0)	14.1 (0.6)	177.1 (7.5)	2.2 (0.2)	3.9 (0.2)	0.7 (0.1)	44.8 (0.9)
	Amoa 8	CZO/C-35	14.3 (0.4)	1.2 (0.0)	11.8 (0.3)	80.0 (4.6)	6.5 (0.3)	4.7 (0.4)	12.3 (0.9)	24.2 (1.2)
	Boukhobza	CZO/C-35	14.4 (0.3)	1.1 (0.1)	14.1 (1.2)	150.0 (10.2)	2.8 (0.3)	4.3 (0.3)	2.1 (0.2)	50.3 (0.6)
Late Jan 2014-18	Moro	CZO/C-35	13.7 (0.5)	1.1 (0.0)	13.1 (0.4)	140.9 (15.2)	2.6 (0.3)	4.9 (0.3)	1.4 (0.2)	44.7 (1.3)
	Sanguinelli	CZO/C-35	12.8 (0.2)	1.4 (0.1)	9.7 (0.4)	101.4 (4.6)	2.4 (0.3)	4.3 (0.3)	2.5 (0.2)	40.0 (1.7)
	Shahani	CZO	14.6 (0.2)	0.9 (0.0)	16.3 (0.5)	169.7 (7.9)	2.1 (0.2)	4.3 (0.2)	0.7 (0.1)	41.7 (0.9)
	Amoa 8	CZO/C-35	15.1 (0.3)	1.2 (0.1)	12.7 (0.5)	76.1 (4.6)	5.5 (0.5)	4.6 (0.2)	10.5 (1.7)	24.0 (1.5)
	Boukhobza	CZO/C-35	15.1 (0.2)	1.0 (0.1)	15.8 (0.8)	143.2 (8.5)	2.7 (0.3)	4.6 (2.3)	2.0 (0.2)	51.1 (1.5)
Mid Feb 2014-18	Moro	CZO/C-35	13.4 (0.6)	0.9 (0.0)	14.4 (0.4)	137.9 (17.1)	3.5 (0.3)	5.4 (0.3)	2.7 (0.8)	45.0 (1.9)
	Sanguinelli	CZO/C-35	12.8 (0.4)	1.1 (0.1)	12.1 (0.6)	100.3 (4.3)	3.0 (0.3)	4.4 (0.2)	3.1 (0.5)	41.9 (0.9)
	Shahani	CZO	15.0 (0.2)	0.8 (0.0)	20.0 (0.4)	157.2 (7.2)	2.3 (0.1)	4.6 (0.1)	1.7 (0.4)	45.5 (0.9)
	Amoa 8	CZO/C-35	15.0 (0.7)	1.1 (0.1)	14.2 (0.7)	70.1 (3.6)	5.9 (0.5)	4.7 (2.2)	9.6 (1.1)	27.0 (1.5)
	Boukhobza	CZO/C-35	15.4 (0.3)	0.9 (0.1)	18.0 (0.9)	147.8 (9.1)	3.8 (0.3)	5.0 (2.4)	2.7 (0.4)	51.4 (0.6)

Shahani Red navel orange fruit on tree, Riverside, California, on January 29, 2016.

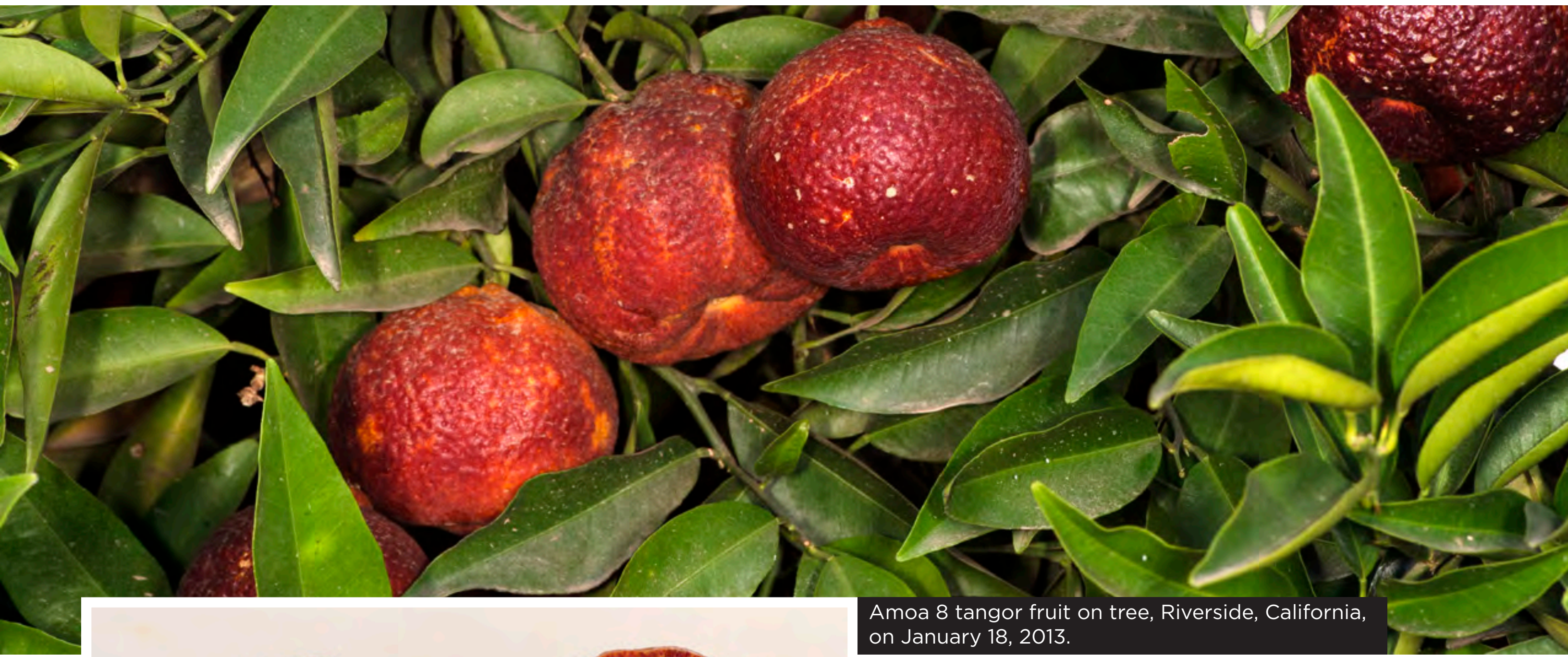
Shahani Red navel orange longitudinal and cross section, Riverside, California, on January 29, 2016.

mid-February, Moro, Shahani Red and Boukhobza acidity had dropped and had the lowest acidity of the five. The high Brix-to-acid level present in Shahani Red and Boukhobza for the first two sample dates indicates these cultivars are earlier maturing by comparison to the standards.

Additionally, Shahani Red produced the heaviest and largest fruit at all three sample dates in Riverside, while Amoa 8 had the lightest and smallest fruit. The fruit shape of Shahani Red, Boukhobza, Moro and Sanguinelli is spheroid, which contrasts with the mandarin-like fruit shape of Amoa 8, thus reflecting the Avana parent of this tangor (*personal observation*). Naturally externally bumpy, Amoa 8 has the roughest rind texture of all five cultivars, and a similar rind thickness to Moro compared to the others. Shahani Red had the lowest seed number with an average of less than two seeds per fruit at all sample dates compared to all of the cultivars. Amoa 8 fruit were very seedy and had a low percentage of juice

Table 2: Means and standard errors (in parentheses) of select fruit quality characteristics of Boukhobza blood orange conducted from 2014-19 compared to the standards Moro and Sanguinelli blood orange for three sample date ranges from trees at the University of California Lindcove Research and Extension Center, Exeter, California. CZO=Carrizo citrange and TROY=Troyer citrange.

Date	Cultivar	Rootstock	Brix	Titratable acidity	Brix acid ratio	Fruit weight (g)	Texture rating	Rind thickness (mm)	Seed number per fruit	% Juice
Early Jan 2014-19	Moro	CZO	11.7 (0.3)	1.0 (0.1)	12.6 (0.8)	128.7 (18.1)	2.8 (0.4)	4.0 (0.3)	1.6 (0.2)	41.0 (2.9)
	Sanguinelli	TROY	10.3 (0.2)	1.3 (0.0)	8.1 (0.2)	123.7 (3.5)	2.5 (0.1)	5.3 (0.2)	3.1 (0.2)	39.1 (2.0)
	Boukhobza	CZO	13.4 (0.2)	0.7 (0.0)	21.3 (1.0)	160.6 (6.2)	3.2 (0.1)	4.7 (0.2)	2.0 (0.1)	45.9 (1.3)
Late Jan 2014-19	Moro	CZO	11.9 (0.4)	0.9 (0.1)	14.1 (0.9)	111.0 (6.1)	2.7 (0.2)	4.2 (0.1)	1.9 (0.2)	41.3 (1.0)
	Sanguinelli	TROY	10.7 (0.2)	1.1 (0.0)	10.2 (0.5)	128.1 (6.9)	2.3 (0.2)	4.8 (0.2)	3.5 (0.4)	40.0 (1.2)
	Boukhobza	CZO	13.8 (0.2)	0.6 (0.0)	23.3 (1.0)	158.8 (6.5)	3.2 (0.2)	4.7 (0.2)	1.9 (0.1)	45.8 (1.0)
Mid Feb 2014-19	Moro	CZO	12.1 (0.3)	0.7 (0.0)	17.9 (0.7)	103.9 (7.6)	2.7 (0.2)	3.8 (0.2)	2.1 (0.2)	38.7 (1.1)
	Sanguinelli	TROY	11.1 (0.3)	1.0 (0.1)	12.1 (1.3)	123.1 (3.7)	2.9 (0.3)	5.0 (0.2)	2.4 (0.3)	37.3 (1.5)
	Boukhobza	CZO	14.2 (0.1)	0.6 (0.0)	25.9 (1.3)	164.8 (6.9)	3.5 (0.2)	5.0 (0.2)	2.0 (0.2)	46.0 (1.1)



Amoa 8 tangor fruit on tree, Riverside, California, on January 18, 2013.

Amoa 8 tangor fruit longitudinal and cross section, Riverside, California, on February 12, 2016.

compared to the others, which had much higher juice percentages.

Based on fruit evaluations from Exeter (**Table 2**) in the same five-year period and sampling periods, Boukhobza fruit had higher Brix, lower acidity and higher Brix-to-acid ratio than Moro and Sanguinelli at all sample dates. Boukhobza fruit also were heavier, had rougher rind texture and a higher percentage of juice than Moro or Sanguinelli. Of the three, Moro had the thinnest rind. Boukhobza and Moro fruit were low seeded (2.1 seeds or less per fruit) and slightly less seedy than Sanguinelli fruit.

Table 3: Combined flavor descriptions contributed by Kim Juelg, Senior Flavorist II, and Megan Scholle, Flavorist I, from Givaudan based on multiple visits to taste cultivars at the Citrus Variety Collection in Riverside, California.

Cultivar	Flavor Profile Descriptors
Shahani Red	Cinnamon, slight candy-lime, cola aroma with fleshy pithy impact.
Moro	Floral, sangria notes with hint of apple cider and berry.
Amoa 8	Floral, dark berry impact, mulled wine and hint of allspice.
Boukhobza	Floral berry notes and slightly jammy, dry red wine.
Sanguinelli	Tart morello cherry, wild grape, floral lemon, deep red berry.

Standard Moro blood orange whole fruit, longitudinal and cross section, Riverside, California, on March 17, 2010.

The amount and composition of anthocyanins present in pigmented citrus can vary greatly since they are determined by variety, maturity of fruit, region of cultivation and other environmental conditions (Lo Piero 2015). One such condition is the requirement for a wide day-night thermal range to maximize color formation. This limits ideal growing regions to locations with large diurnal temperature changes present in inland parts of California. This requirement for wide day-night thermal ranges also accounts for year-to-year variation in the intensity of red pigmentation in both the flesh and rind (Lo Piero 2015). Among the five cultivars, Amoa 8 and Moro have the most intense overall anthocyanin pigmentation externally and internally across the cut surface, followed by Sanguinelli and, finally, Boukhobza and Shahani. The peel aroma and taste among the five cultivars also differ from each other, yet vary over and between seasons.

We have had a collaboration with Givaudan, one of the world's leading fragrance and flavor companies, since 2006 that brings rigorously trained flavorists or flavor chemists to the CVC to taste, smell and evaluate citrus diversity to create pleasing flavors for consumers. Further, the aroma and taste can be dependent on the person experiencing these aromas. Givaudan described the flavor difference of each cultivar based upon their experiences in Riverside (**Table 3**).

Standard Sanguinelli blood orange whole fruit, longitudinal and cross section, Riverside, California, on March 17, 2010.

For more information and data relating to these and other new cultivars, visit the UCR CVC web site and access the cultivars either by name in alphabetical order, by type or by those with evaluation data at *https://citrusvariety.ucr.edu/cultivars.html*. To obtain budwood of any of these new cultivars or standards in California, please visit the Citrus Clonal Protection Program web site at *http://www.ccpp.ucr.edu*.

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Glossary

[1]**Anthocyanin:** Water soluble, flavonoid pigments that impart red, blue, or purple colors to plant parts and are also found in berries, fruits, and vegetables.

[2]**Lycopene:** A red carotenoid pigment with antioxidant properties, most commonly found in plants such as tomatoes.

References

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