ORIGINAL RESEARCH

Morphological Characterization and Consumer Acceptance of Sweet Orange Cultivars *vis-à-vis* Sour Orange in Sri Lanka

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Abstract

Sweet orange, *Citrus sinensis*, is an important fruit crop. In Sri Lanka, sweet orange industry is not well developed. The present study was conducted to characterize the fruit traits of sweet orange cultivars in Sri Lanka in comparison to the sour orange to make informed decisions in cultivar release and to characterize the parents for future breeding.

Six sweet orange cultivars, *Arogya, Bibila-sweet, MKD, Sisila, BAN* and *MT*, and sour orange were collected from Regional Agricultural Research and Development Centers at Bandarawela and Monaragala, Sri Lanka. Five trees from each orange type was randomly selected and from each tree five fruits were taken for measurements. Fruit weight, height, width, peel thickness, juice volume, number of seeds, pH and colour of juice were measured. A sensory evaluation test was conducted to find the preferred cultivar for sweetness and colour of juice.

For larger fruits with higher juice volume, the cultivars *MKD* and *MT* can be recommended. The cultivar *MKD* can be recommended for the minimum peel thickness, which enhances consumer preference. The cultivars *BAN* and *MT* had the lowest acidity. The best appealing juice colour was observed in the fruits of *Arogya, Bibila-sweet* and *Sisila*. The cultivars *MT* and *MKD* have moderate colour intensity and the cultivar *BAN* has relatively a colourless juice, making it significantly distracted to the consumer. Cultivars *MT* and *Arogya* were the most preferred for sweetness. These results are useful in ranking sweet orange cultivars and selecting parents for future breeding programmes.

Key words: Sweet orange, sour orange, sensory evaluations

Introduction

Sweet orange, *Citrus sinensis* (L.) Osbeck, is one of the most important fruit crops in the world and is the most prominent fruit species among all other *Citrus* fruits. European Union, Russia and Saudi Arabia were the major importers of sweet orange in year 2013. These countries imported 880,000; 450,000 and 350,000 metric tons (mt) of sweet orange, respectively. The top most sweet orange producers in the world are Brazil (17,355,000 mt), China (7,650,000 mt) and USA (6,451,000 mt)[1]

In Sri Lanka sweet orange industry is not well developed. Only 3,393 hectares are under sweet orange cultivation and is grown mainly as a component in mixed cropping systems or as home garden trees [2]. In Sri Lanka, sweet orange production is seasonal, and peak production can be seen from February to April [3]. Therefore, to fulfill the local sweet orange demand, Sri Lanka depends heavily on imports. Sweet orange cultivation is often hampered by many factors, such as lack of quality planting material and segregation of important traits due to sexual reproduction, pests and diseases. Because of the long generation cycle, farmers have to wait many years to decide the fruit quality. There are complaints that sweetness and the overall consumer acceptance would be reduced in fruits obtained from daughter trees, which were sexually propagated from sweet orange mother trees. In certain instances, the daughter trees may have deteriorated their fruit quality as low as that of sour orange, *Citrus aurantium*. This sort of segregation could be attributed to polygenic inheritance, hybridity and variable heritability of fruit quality traits in sweet orange[4] Therefore, the objective of the present study was to characterize the fruit morphology and consumer acceptance of sweet orange cultivars in comparison to sour orange, for the identification of better sweet orange cultivars.

Materials and Methods

Plant material

Sample fruits were collected from Regional Agricultural Research and Development Centers (RARDCs) at Bandarawela and Monaragala, Sri Lanka. Six sweet orange cultivars; *Arogya*, *Bibila-sweet*, *MKD*, *Sisila*, *BAN* and *MT* (*BAN* and *MT* are not yet released as cultivars) and sour orange (*Citrus aurantium*) grown at RARDCs were considered for the study. Five completely matured unripe fruits were collected from five randomly selected trees per cultivar.

Fruit parameters

Seven morphological parameters of the fruit; weight, height, width and peel thickness; were measured (Figure 1). Juice volume per gram of fruit was recorded for each fruit after extracting the juice of two cross sectionally cut halves, using a standard orange squeezer. Precautions were taken to apply a uniform pressure to each half of the fruit. Number of seeds was also counted for each fruit. pH of the juice of each fruit was recorded and the colour of the juice was recorded using a colour chart (Figure2).

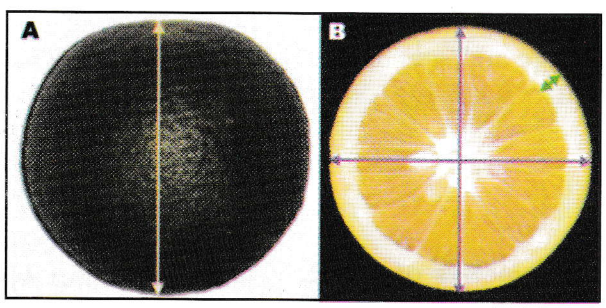

Figure 1. Morphometric measurements of sweet orange / sour orange fruit. A: Side view, B: Cross Section. Yellow arrow, - fruit height Purple lines, - fruit width (the mean was calculated from two perpendicular measurements). Green line, peel thickness (the mean was calculated from three measurements at three different places of the peel to overcome variability).

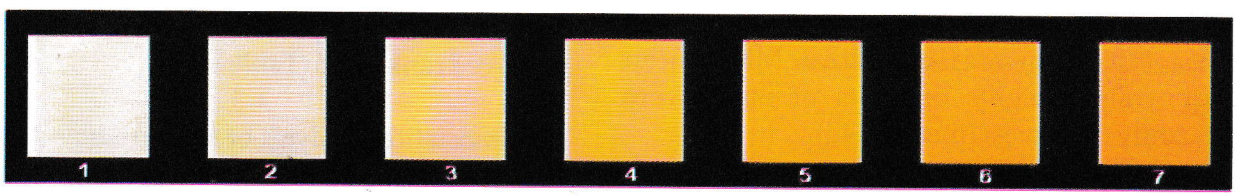

Figure 2. The standard colour chart used for the recording of juice colour. 1: Lightning White 2019-7, 2: Lemon Sorbet 2019-60, 3: Lemon Drops 2019-50, 4: American Cheese 2019-4, 5: Sunflower 2019-30, 6: Golden Nugget 2019-20, 7: Mardigras Gold 2019-10. The colour chart was modified from Benjamin Moore Paints Chip, Colour, Swatch, Sample and Palette (www.materials-world.com/paint-colors/benjamin_moore/Benjamin-Moore-Color-04.htm)

Organoleptic properties

A sensory evaluation test was conducted having a panel of 10 participants. Each participant was provided with juice samples from each sweet orange cultivar and sour orange, and were requested to rank each juice sample, according to the preference on sweetness and colour appearance of the juice. One to seven scale was used for the rating in which 'one' was considered as the least preferred and 'seven' as the most preferred.

Data analysis

Fruit parameters were analyzed using GLM procedure in SAS 9.1 (SAS Institute Cary, NC, USA). Pearson correlation coefficients among quantitative fruit parameters were calculated using Corr procedure in SAS. A dendrogram was constructed using the principle components calculated for fruit weight and pH of the juice (Average Linkage and Pearson Distance in Minitab 14, Minitab Inc. USA). The associations between the organoleptic properties; preferred sweetness, preferred juice colour, reading of colour chart and the type of cultivar (sweet orange and *sour orange* separately) were conducted using the Freq procedure in SAS.

Results

Fruit size and organoleptic parameters of sweet orange cultivars and sour orange are shown in Table 1. The top, bottom and cross sectional views of sweet orange and sour orange fruits are shown in Figure 3. The fruits of cultivar MT at maturity (unripe stage) were significantly heavier (mean 236.5g) than other cultivars and sour orange. The next heaviest fruits were from cultivar MKD (mean 207.2g) whilst weights of fruits of Sisila were significantly the lowest (mean 86.4g).

Fruit height was not significantly different among sweet orange cultivars and *sour orange* except *Sisila,* whose mean height was (5.7 cm),The cultivar *MT* had the highest mean fruit width of 7.9 cm while *Sisila* had the significantly lowest mean width of 5.7 cm. The mean widths of the rest of cultivars were between these two. The mean peel thickness was significantly higher in *Bibila-sweet (0.7 cm)* and *sour orange* (0.8 cm) as compared to other cultivars . The mean juice volume per gram was highest in *MT* (90.1 ml/g), followed by MKD (88.3ml). The juice volume of cultivar *sisila* (mean 24.1ml) and sour orange (mean 36.6ml) were significantly low as compared to others. *Bibila-sweet,* BAN *and* MT (0.38 ml/g) followed by *Arogya,* (0.31 ml/g) and *Sisila* (0.28 ml/g). The significantly lowest mean juice volume per gram was observed in the cultivar *sour orange* (0.26 ml/g). The mean pH of juice was significantly lower in *sour orange* (pH 2.5) and highest in *BAN* and *MT. Arogya* and *MKD* showed slightly less acidity (pH 3.1). while *Bibila-sweet* and *Sisila* showed relatively high acidity (pH 2.9). . The colour of the juice in comparison to the colour chart (*i.e.* juice colour intensity) showed that *Arogya, Bibila-sweet* and *Sisila* had more intense juice colour (3.6 of 7.0 indicating higher yellowness) whereas *MKD, MT* and *sour orange* showed moderate juice colour intensity of 2.4. The cultivar *BAN* showed the least juice colour intensity (least yellowness) of 1.6 (Table 1).

The cultivars *MT* and *Arogya* had the highest preferred sweetness (rank 5.6 of 7.0) followed by *Bibila-sweet* and *MKD* Sour orange exhibited the least sweetness (rank of 1.5). The preferred juice colour was highest for *Arogya* (rank of 5.9 of 7.0) followed by *Sisila* and *Bibila-sweet. MKD, sour orange* and *MT* had preferred juice colour with prefered range of rank from 2.5 to 4.3. The cultivar *BAN* had the least preferred juice colour with the preferred rank of 1.6 (Table 1).

The association analysis of the variables regarding consumer preference revealed that the preferred sweetness, preferred juice colour and pH of juice were closely associated with the type of orange cultivar ($P<0.05$; Crammer's V Coefficient of 0.3 to 1.0). Preferred sweetness was significantly associated with the pH of juice (Crammer's V Coefficient of 0.4.). Juice colour intensity and pH of the juice were also very closely associated (Table 2).

The correlation analysis revealed that fruit weight, height, width and juice volume per gram of fruit were significantly correlated to each other (71% to 98% of Pearson Correlation Coefficient). The peel thickness, however, was only significantly negatively correlated with juice volume per gram of fruit (-71% of Pearson Correlation Coefficient). The pH of the juice was significantly correlated with fruit size parameters and the juice volume (67% of Pearson Correlation Coefficient) (Table 3).

Cluster analysis using principle components calculated for fruit weight and pH of the juice (all the correlated and non-significantly different variables were not used to calculate the principle components) revealed that *Arogya*, *MKD* and *Bibila-sweet* were in a single cluster at 71.1% similarity and *BAN* and *MT* got clustered at 53.4%, similarity. These two clusters joined as a single cluster at 49.7%, similarity. *Sour orange* was only 29.1% similar to the five cultivars in these two clusters, whereas *Sisila* was an out group only showing 20.1% similarity to other cultivars and sour orange (Figure 4).

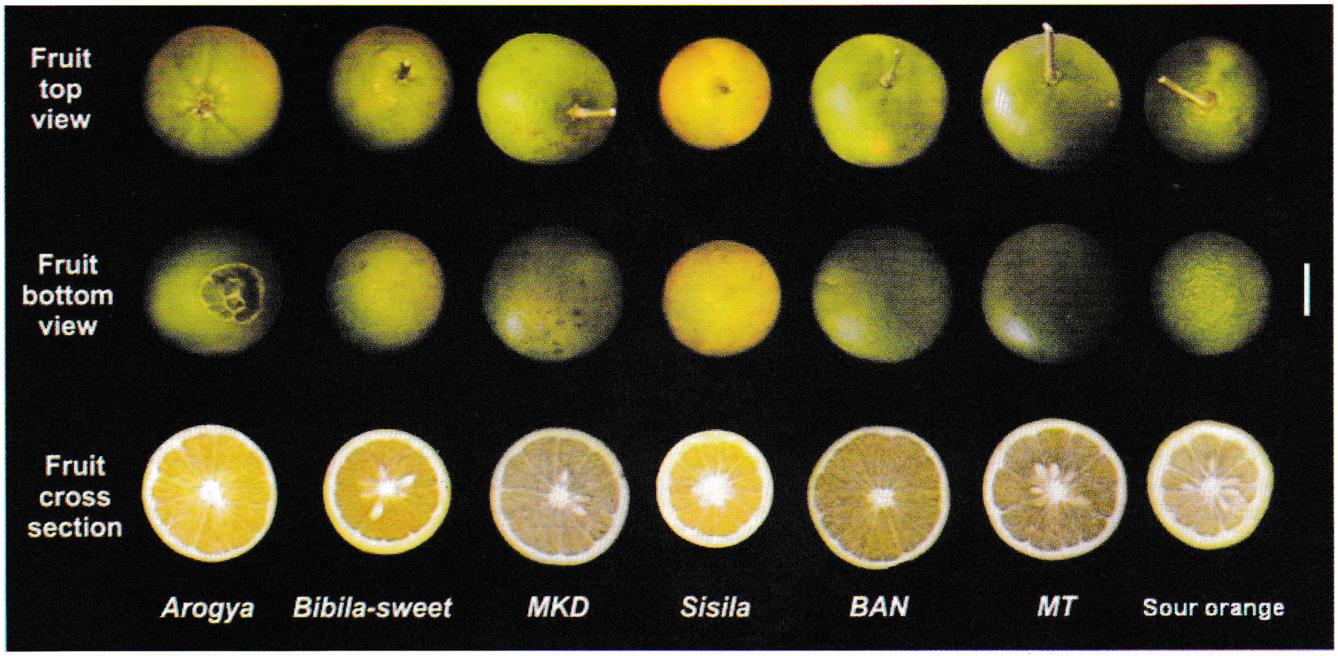

Figure 3. Fruit morphology of sweet orange cultivars and sour orange. Top, bottom andcross sections of the fruits are shown. Note that *Arogya* has a small secondary fruit likestructure at the bottom. Scale bar represents 3 cm.

Table 1. Fruit morphology and organoleptic parameters of sweet orange cultivars and sour orange

Fruit parameter	*Arogya*	*Bibila-sweet*	*MKD*	*Sisila*	*BAN*	*MT*	Sour orange
Weight (g)	185.0c	154.4c	207.2b	86.4d	176.1c	236.5a	137.9c
Height (cm)	7.3a	6.9a	7.5a	5.7b	7.1a	7.8a	6.8a
Width (cm)	7.3b	6.9b	7.5b	5.7c	7.1b	7.9a	6.8b
Peel thickness (cm)	0.6c	0.7b	0.4d	0.6c	0.5c	0.5c	0.8a
Juice volume (ml/g)	0.31c	0.38b	0.43a	0.28d	0.38b	0.38b	0.26d
pH of juice	3.1b	2.9c	3.1c	2.9c	3.4a	3.5a	2.5d
Juice colour intensity	3.6a	3.5a	2.4c	3.7a	1.6d	2.1c	2.7b
No. of seeds per fruit	36.9a	37.0a	37.4a	28.6a	35.3a	46.7a	40.8a
Organoleptic Parameters							
Preferred sweetness	5.2	4.7	4.5	3.4	2.6	5.9	1.5
Preferred juice colour	5.9	5.6	4.3	5.7	1.6	2.5	3.4

Means denoted by same letters within rows are not significantly different at *P<0.05*Shades of white, light grey, dark grey and black are used to mark significantly similar mean values for non-organoleptic parameters. Number of seeds includes both normal and empty seeds.

Table 2. Association analysis of sensory data

Variable in association	Chi square value	Cramer's V coefficient
Cultivar *vs.* preferred sweetness	51.7***	0.4
Cultivar *vs.* preferred juice colour	146.8****	0.6
Cultivar *vs.* juice colour intensity	76.5****	0.5
Cultivar *vs.* pH of juice	420.0****	1.0
Preferred sweetness *vs.* pH of juice	51.7**	0.4
Preferred sweetness *vs.* preferred juice colour	51.3	0.4
Preferred sweetness *vs.* juice color intensity	28.4	0.3
Juice colour intensity *vs.* pH of juice	145. 9****	0.6

****$P<0.0001$, ***$P<0.001$, **$P < 0.01$, *$P<0.05$

Table 3. Pearson correlation coefficient among fruit parameters of sweet orange cultivars and sour orange

	Height (cm)	Width (cm)	Peel thickness (cm)	Juice volume (ml/g)	pH of juice
Weight (g)	0.96***	0.97***	-0.32	0.71*	0.57**
height (cm)		0.98***	-0.19	0.66	0.49**
width (cm)			-0.21	0.67	0.49**
Peel thickness (cm)				-0.71*	-0.49
Juice volume (ml/g)					0.67*

****P<0.001, **P < 0.01, *P<0.05*

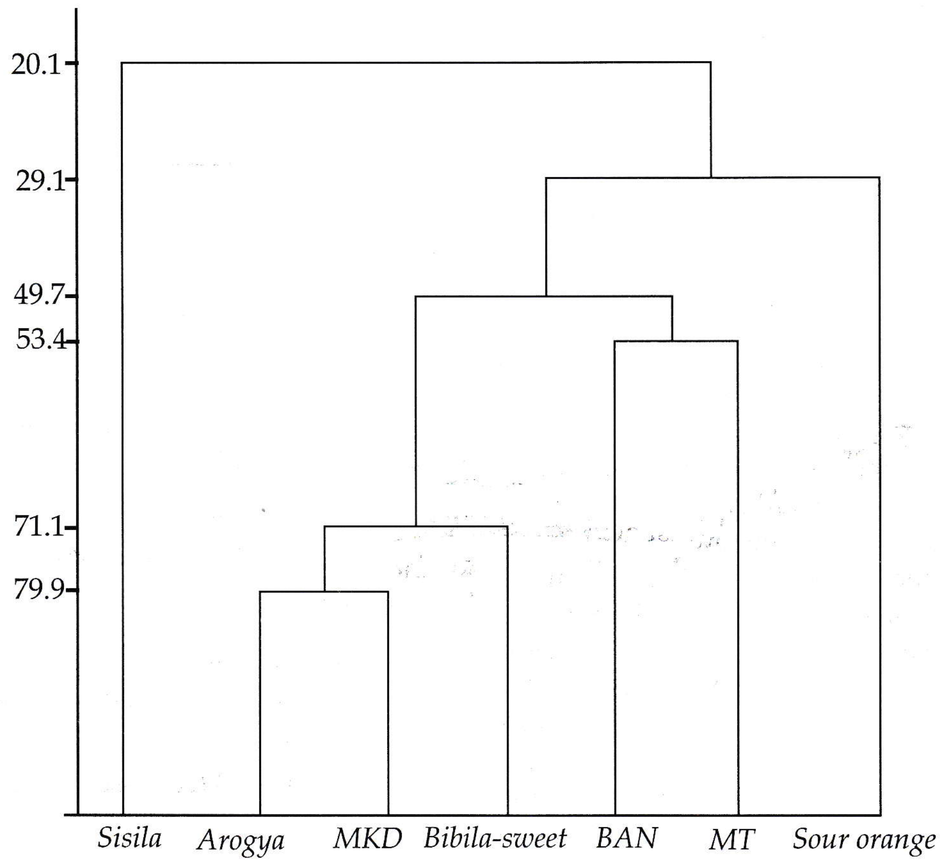

Figure 4. Dendrogram constructed based on the principle components computed using fruit weight and pH of the juice. Principle components were computed to remove the co-linearity among parameters. Cluster procedure of average Linkage and Pearson distance in MINITAB 14 was used. Y axis represents the morphological similarity coefficient.

Discussion

Genus *Citrus* contains mandarin, orange, lemon, grapefruit and lime[5] Morphological characterization studies[6,7] genetic characterization of inter and intra specific diversity[8] and genetic characterization using DNA markers[9-13] have been reported for citrus. Broad *et al*[14] conducted a varietal trial similar to present study to find suitable sweet orange cultivars for Western Australia. The cultivar trials are important to recommend the crops under various agronomic and industrial scenarios.

The fruit height and the number of seeds per fruit are governed by independent mechanisms, compared to the other fruit size related traits. The peel thickness seems to be a negative selection criterion as can be seen in sour orange, which has the thickest peel in the fruit because it was not subjected to any breeding. In the natural environments, thicker peels are important to prevent desiccation and to protect from herbivores. Less number of seeds in an orange fruit is important for its quality. However, this trait was not found in sweet orange in the present study.

On the fruit quality of sweet orange cultivars, larger fruits with higher juice volume such as *MKD* and *MT* can be recommended. The cultivar *MKD* can be recommended for the minimum peel thickness, which enhances the consumer preference. The cultivars *BAN* and *MT* had the lowest acidity. The best appealing juice colour was observed in the fruits of *Arogya*, *Bibila-sweet* and *Sisila*. The cultivars *MT* and *MKD* have moderate colour intensity. Although the other traits were promising, the cultivar *BAN* has relatively a colourless juice, making it significantly distracted from the consumers. *MT* and *Arogya* were the most preferred cultivars for sweetness (Table 1). This kind of sensory evaluation tests to evaluate the sweet orange cultivars were also reported by Apricio *et al.*[15] and Castro *et al*[16]. Unreleased cultivars have some promising characteristics along with some drawbacks. The Crammer's V Coefficient indicates the strength of association between ranked organoleptic parameters. The cultivars and sour orange used in qualitative measurements and in the taste panel revealed that the pH of juice is dependent on the type of cultivar/orange type by showing Crammer's V Coefficient of 1.0. However, the preferred sweetness, juice colour intensity were significantly associated with the pH of juice but the strength of the association is 0.4 to 0.6, indicating that preferred sweetness or the juice colour intensity are not entirely determined by the pH of the juice.

Conclusion

Assessment of fruit morphology and consumer acceptance of Sweet orange cultivars and *Sour orange* demonstrated that the cultivars *Sisila* and *sour orange* are different from the other sweet orange cultivars. The unreleased cultivar *MT* and the cultivar *MKD* possess higher consumer acceptance, whereas *MT* has the largest fruits. Based on these details, the decisions on release and utilization of these cultivars as parents in future breeding can be included to promote the sweet orange industry in Sri Lanka.

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