



Research Article

Comparison and Evaluation of Physico-Chemical Properties of Five Orange Varieties under Agro-Climatic Conditions of Sargodha, Pakistan

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Abstract | An elaborated study on evaluating quality characteristics of exotic fruits belonging to orange group of citrus was carried out at Citrus Research Institute Sargodha. The candidate varieties/cultivars were Rhode Red Valencia, Cara Cara, Amber Sweet, Sun Star and Salustiana. All of these different five citrus varieties evaluated objectively assessing their suitability both for direct consumption and value addition. The work spread over two years (2018 and 19) produced distinctive results for their commercial exploitation. The attributes in analytical work for fruit quality evaluation were fruit size, weight, peel thickness, peel percentage, juice percentage, rag percentage, total soluble solids (TSS), acidity, TSS/acid ratio, number of segments, and number of seeds, maturity period and degree of granularity. This was ever important study in Pakistan for evaluating the citrus exotic material of latest generation. This endeavour led to the sound recommendation of sweet oranges like Rhode Red Valencia and Sun Star in the two years of study. In case of taste imparting characteristics like TSS, acidity and their respective ratio in the Rhode Red Valencia TSS 11.4 %, Acidity 1.05, TSS/Acid Ratio 10.97, Cara Cara produced TSS 10.95, Acidity 0.74, TSS/Acid Ratio 14.81, Amber Sweet TSS 10.95, Acidity 1.03, TSS/Acid Ratio 11.11, Sun Star TSS 10.54, Acidity 0.95 and TSS/Acid Ratio 11.02 and in Salustiana TSS 10.5, Acidity 1.17, TSS/Acid Ratio 9.00. On the basis of cumulative and maximum presence of quality characteristics Rhode Red Valencia, Cara Cara, and Amber Sweet have been recommended as suitable varieties/cultivars of the future both for direct consumption and value addition.

Received | December 07, 2021; **Accepted** | January 24, 2022; **Published** | November 07, 2022

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Citation | Hayat, A., Haque, E.U., Nasir, M., Nawaz, R., Mahmood, T. and Afzaal, S., 2022. Comparison and evaluation of physico-chemical properties of five orange varieties under agro-climatic conditions of Sargodha, Pakistan. *Journal of Innovative Sciences*, 8(2): 236-242.

DOI | <https://dx.doi.org/10.17582/journal.jis/2022/8.2.236.242>

Keywords | Amber sweet, Adaptability of oranges, Cara cara, Granulation, Rhode red valencia, Value addition of citrus



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1. Introduction

Citrus fruits are produced in many tropical and subtropical countries of the world. Pakistan is also one of the largest producers of Citrus (Kinnow)

fruit along with leading countries like Brazil, USA, China, Japan and Mexico etc. (Amador, 2008). Moreover, citrus, in the entire scenario of Pakistan fruit culture constitutes to be the major fruit crop of the country both in area and production. These fruits

in the province of Punjab are grown on an area of 210.47 thousand hectares with the production level of 2.29 million tons ([Agriculture Statistics Pakistan, 2019-20](#)). In the entire citrus activity share of Kinnow mandarin is well above 70% which have rendered citrus a potential entreprenuring sector. Considering the need of broadening the varietal base, Citrus Research Institute, Sargodha remained in a continuous quest to import exotic material of a wide range of citrus cultivars to study their acclimation under local Agro-climatology. In this pursuit a number of superior varieties have already been released for commercial cultivation. It is an established reality that citrus fruits besides direct consumption has a tremendous scope in the industry of value addition and by-products ([Azhar et al., 2007](#)). Most fruit juices are preferred in the filtered and clarified form however citrus juices are preferred in a pulpy and opaque form. Most of opaque nature of citrus juices is attributed to the colloidal cloud material. The solid particles of fruit that eventually settle out, which are primarily juice sacs and membrane material imparting a mouth feel is called citrus pulp. Citrus pulp is divided into two main groups- sinking and floating pulp ([Braddock, 1999](#)). Citrus peel is valued for flavoring compound in beverages, cosmetics and chemical industries as cold pressed oil (CPO) or cold pressed peel oil (CPPO) ([Ladaniya, 2008](#)). In juice industry it can be added back to juice drinks to give natural appearance to the product. Besides possessing 70 % of carotenoids of the whole fruit to serve as a rich source of coloring agent; the pulp thrown out by processing units can be made useful for animal feed after dehydrating the same.

Citric acid in various citrus fruits is a weak organic acid and act as a natural preservative important to give taste to soft drinks and bakery items. It is valued for its property of cleansing agent. This important organic acid differ from cultivar to cultivar in citrus and circumstances in which certain cultivars are produced. Citric acid plays an effective role in regulating the size of calcium crystals in the bones ([Giovanni et al., 2002](#); [Sandra and Graeme, 2010](#)). Hence, evaluating acidity is very important in varietal characterization. The internal taste of citrus fruits is contributed by a favorable blend of (Total Soluble Solids) TSS and Acidity. Total soluble solids (Brix) are measured in juice which is primarily sucrose, fructose and glucose besides mineral substances.

All the said attributes of citrus are in varying degree in different citrus fruits. Hence, to evaluate latest citrus fruits on the basis of quality characters was direly needed to generate information in the best interest of growers, processors and other stake holders of the citrus industry. The candidate varieties included in this effort were Rhode red Valencia, Cara Cara, Amber sweet, Robinson and Sun Star fruit. Rhode-red Valencia is a mutated strain of Valencia late orange. It is better than Valencia late in juiciness and coloration. This important orange cultivar possesses cryptoxanthin to the extent of 152kg/100 ml of juice. Since cryptoxanthin is a vitamin- A precursor and remains fairly stable during processing so this makes it a highly desirable pigment in citrus juices. Its juice is lower in Acid contents but has darker color in both rind and flesh (juice) than other common Valencia Oranges. Cara Cara is a natural bud mutation Washington very sweet with low acid contents, this variety was discovered in 1994. It has deep pink flesh colour ([Hu et al., 2010](#)). Amber Sweet is a trigenic hybrid of Clementine x Orlando tangelo and mid sweet orange giving Amber Sweet a unique composition of 3/8 tangerine, 1/8 grape fruit and 1/2 orange. Amber Sweet consists of 10-12 segments which are easily separable; fruit is juicy with excellent flavour. Amber Sweet is nearly seedless ([Moshnas et al., 1991](#)). Studies provided basic scientific evidence used by the Florida department of citrus and FDA (US food and drug administration) to classify Amber sweet fruit as an orange which is a new orange hybrid produced by backcrossing which ripens in October with rich juice color ([Singh et al., 2002](#)). As regards Robinson, it is a hybrid of Clementine and Orlando released in 1994 at Orlando, Florida. Fruit of the variety is medium to large in size with 12-14 segments, juicy with rich flavor having 20 seeds ([Khan et al., 2005](#)).

Sun Star, came into existence in the form of open pollinated seedling of Berna orange and released in United States during 1987. Objective of current study was evaluation of excellent variety among all the tested varieties, so it may be recommended for cultivation to earn better foreign exchange.

2. Materials and Methods

The studies were carried out at the Experimental Fruit Farm Citrus Research Institute Sargodha. RCBD experimental design was carried out in current study, having six (06) replicates in each treatment. Exotic

Citrus varieties like Rhode Red Valencia (T₁), Cara Cara (T₂), Amber Sweet (T₃), and Sun Star (T₄) constituted to be the candidate material understudy. Salustiana (T₀) was used as control treatment, hence total thirty (30) plants were studied for under-given parameters. Good agricultural practices for cultivation and growth were carried out.

A representative sample of 20 fruits from the bulk sample was taken to measure the fruit's longitudinal length (major diameter) and width (minor diameter) to get its average size. Weighed total fruit in grams (g) by using a digital calibrated scale and divided by 20 to get average fruit weight. Fruits were picked at the optimum maturity for both years. The samples of fruits were collected from all sides of the tree i.e. from top and inside the canopy. Variation in plants and at the farm was also considered. The fruit was analysed against the physical parameters including fruit size, fruit weight, peel thickness, peel percentage, rag percentage, number of segments, number of seeds (seediness), and degree of granularity with optimum time of maturity (Ringblom, 2004).

Degree of granulation, time of maturity and four internal maturity parameters i.e., juice percentage, total soluble solids, acidity and their respective ratio (TSS: Acid) were measured using methods described by (Sharma *et al.*, 2006).

Juice from each fruit was extracted by using a rotary citrus squeezer and filtered through a 0.8 mm pore size sieve. Digital calibrated scale was used to measure the filtered juice weight and Juice percentage was expressed by the following expression (Khan *et al.*, 2005).

$$\text{Juice \%} = \text{Juice weight (g)} / \text{Fruit weight (g)} \times 100$$

The Brix or Total soluble solids (TSS) of the juice was determined by using a calibrated Atago Analog Refractometer and expressed as a percentage of sucrose in an equivalent solution. The total Titratable acidity is expressed as anhydrous citric acid on a weight basis. Titratable acidity was determined by titration with standardized 0.1N NaOH up to pH 8.2 (for double check Phenolphthalein as indicator was also used to check the persistent pink color) using known volumes of representative sample of juice. The results were expressed as grams of Citric Acid per 100 ml of juice (Kimball, 1991).

$$\text{Acidity \% (as Citric Acid)} = \text{Titer value (ml)} \times 0.0064 / 10 \times 100$$

TSS-Acid ratio is an arithmetical proportion of soluble solids to citric acid. It denotes the balance between the two. It may also indicate the ripeness (also called Maturity Index) of fruit used. The ratio was determined by dividing TSS value by the acidity percentage (Lacey *et al.*, 2009).

$$\text{TSS: Acid Ratio} = \text{TSS (Brix)} / \text{Acidity\%}$$

Results were analysed using two-way analyses of variance (ANOVA) by Statistix 10.1, and mean values were calculated using MS Excell 2016.

3. Results and Discussion

Studies on varietal assessment produced distinctive information particularly on different aspects like juice contents, peel and rag potential, Brix or TSS (Qureshi *et al.*, 2021). The other considerable features involve in the study were determination of extent of time found in the individual fruit varieties in respect of granularity a strong attribute to determine the worth of a certain cultivar/ variety about sustenance of juiciness for a considerable period of time. Seediness (number of seeds in a fruit) was also assigned significance to all the candidate varieties of different groups in view of direct consumption and prospects of individual varieties for value addition.

Among Citrus hybrids that are Rhode Red Valencia, Cara Cara and Amber Sweet the results brought into lime light their possibility in value addition. All fruits were good sized producing average weight, size, peel thickness, peel, rag and juice percentage. These values in Rhode Red Valencia remained 198.9g, 62mm, 4.1mm, 25.8%, 29.53% and 44.71% respectively. As regards TSS and acidity it stood 11.40 and 1.05 to produce TSS: Acid Ratio 10.97 (Figure 1). The prominent features of this variety of low seed counts (4-6) qualify it for the value addition (Table 1). The commercial maturity was 10 of January-February with no granularity till end of March. Followed Cara Cara 197.66g, 60mm, 5.33mm, 27.3%, 41.35% respectively. Amber Sweet produced almost same results without any considerable difference, whereas Amber sweet is the first hybrid classified as an orange by FDA (US food and drug administration) which made it possible for citrus processors to take full advantage of its

potential to improve the quality of orange juice due to its rich color (Singh *et al.*, 2002).

Sun Star did not emerge as a promising Citrus variety in terms of seediness (3-7 seeds) and occurrence of granulation in a short range of time after commercial maturity. Studies led to confirm the worth of Rhode Red Valencia and Cara Cara varieties with fair amount of TSS, acidity and their respective ratio as given in Figures 1 and 2.

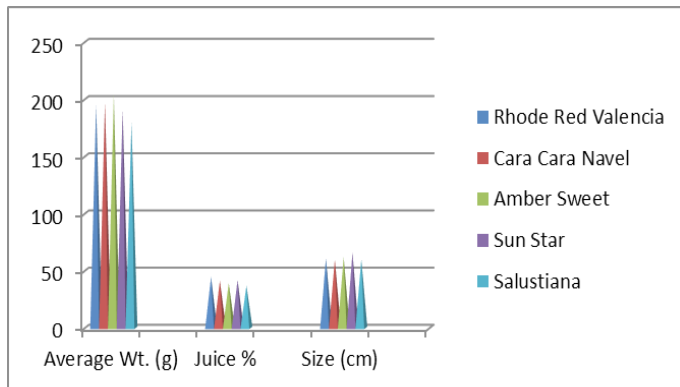


Figure 1: Representing the data for Physico-Chemical Analysis.

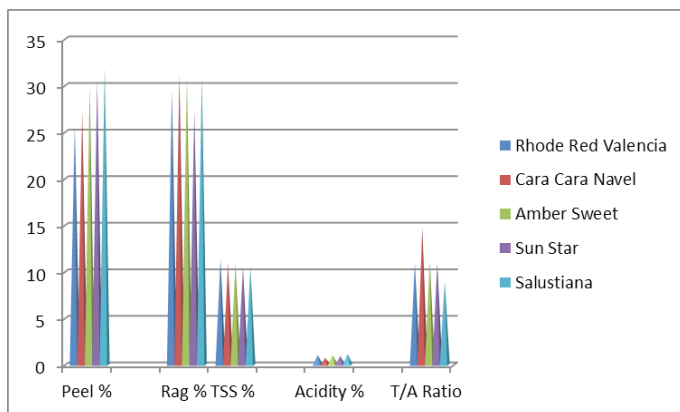


Figure 2: Representing the data for Physico-Chemical Analysis.

Juice percentage is considered as a valuable attribute towards internal quality of citrus fruit. It may be considered as a maturity testing criteria for oranges as under-ripened or over-ripened fruits contains low juice percentage as compared to optimally mature fruits ultimately directly imparting effects on eating quality (Khan *et al.*, 2005). Consumer prefers the fruits having more juice percentage. Current study revealed significant difference in regard of juice percentages among tested varieties. Rhode Red Valencia was found to be the superior and produced maximum juice percentage (44.71%). Juice percentage was followed by Cara Cara (Orange) (41.35%), Amber

sweet (41.0%), Sun star (41%), Salustiana (37%). Juice recovery is a qualitative parameter and Rhode Red Valencia proved itself as a commercially important variety. Juice recovery is directly related with the fruit size and weight. Rhode Red Valencia stood first among other varieties being an average sized fruit with fair weight and size. While Sun Star, Salustiana, Cara Cara and Amber Sweet *all* were closely at par with each other in terms of weight and size.

Maximum peel percentage (31.24%) was found in Salustiana (32%) closely followed by Sun star having (30%) peel. Rhode Red Valencia had minimum peel (25.8%) which was the lowest in thickness 4.12 mm among the all contestant varieties. Other four varieties containing 27-29% peel did not differ significantly with each other. Sun star having 27.39% rag was laid at bottom while Cara Cara, Salustiana and Amber Sweet remained at par in rag percentage but followed by other three varieties in ascending order. According to the UCR 2013 (Stewart *et al.*, 1975). Cara Cara is reported to be a pink-flushed navel with no blush to the skin which is of average thickness. Here it is imperative to note that the rag percentage was more in Salustiana fruit while its weight and size is very less as compared to other cultivars which clearly depict that the fruit of Salustiana have more fiber contents; having tremendous health benefits.

The percentage sugar, measured in degree Brix indicates the sweetness of the fruit by measuring the number of soluble solids in the juice. These are mainly sugars, with smaller amounts of organic acids, vitamins, proteins, free amino acids, essential oils and glycosides. Approximately 85% of the Total soluble solids of Citrus fruit are sugars- so TSS is an excellent guide to the sugar content of fruit. Brix is not only the measure of sugars but it indicates all the soluble solids which include acids and vitamins etc. The taste of citrus fruit is principally governed by the levels of sugars and acids in the juice and the relative ratio among them; the latter is also termed fruit Maturation Index calculated as the ratio of Total Soluble Solids (TSS) to Titratable Acidity (TA). TSS provides a reliable indication for total sugar levels, since sugars consist approximately 80 -85% TSS (Moshonas *et al.*, 1991).

Significant difference in TSS, Acidity and TSS: Acid Ratio were found among the varieties as depicted in Figure 1. Maximum TSS were observed in Rhode Red Valencia (11.40%) followed by Cara Cara

Table 1: Physical parameter of tested Varieties.

Variety	Rhode red valencia	Cara cara navel	Amber sweet	Sun star	Salustiana
Segments No.	13-14	10	10-12	13	13-14
Seediness	4-6	2-4	0-3	3-7	2-5
Time of maturity	Jan-Feb	Dec	End Oct-Nov	Mid Dec	10 Nov
Granulation	Nil	End Dec	10 th Dec	End Dec	End Dec

(10.95%) and Amber Sweet (10.95%) respectively. While Sun Star (10.54%) and Salustiana (10.5%) in the descending order don't differ significantly.

The data pertaining to acidity clearly showed the Salustiana (1.2%) followed by Rhode Red Valencia (1.1%) and Amber sweet (1.03%). All other varieties had a mild acid content that is less than 1 %.

A good tasty fruit requires high levels of sugars and moderate levels of acidity rather than any other combination resulting in a similar ripening ratio. In this context although Cara Cara had a good TSS value (10.95%) with mild acid contents (0.7%) resulted in comparatively good Brix: Acid Ratio i.e. 14.81, imparting good fruit flavour, taste and sensory acceptability to the said cultivars. While Rhode Red Valencia having better TSS value 11.4% with high Acidity 1.1% was placed at the bottom of the list in the report to Brix: Acid ratio (10.9).

Number of seeds per fruit was significantly higher in Rhode Red Valencia (4-6) and Sun Star (3-7) as compared to other varieties. Salustiana and Amber Sweet remained very less seedy or virtually seedless.

In terms of granulation Rhode Red Valencia remained on the top of all cultivars which showed no granulation providing larger band of time and opportunity for marketing of the fruit. While Cara Cara, Salustiana and Sun Star showed granulation in a short period of time (Table 1); ultimately providing very short window for marketing to grower after maturity of the crop. The evaluated varieties with promising results in internal quality characteristics have created a strong base to bring reasonable area under their cultivation. It is necessary for the commercial exploitation of their promising quality characteristics for juicing and other value addition/ by-products. The institute has started its efforts for the propagation of these high merit citrus varieties for large scale cultivation. This endeavour is reflection of the significance of exotic germplasm acclimatized and tested by the scientists of Citrus Research Institute for further breakthrough.

Conclusions and Recommendations

Research in the field of citrus is being diversified now days, due to continuous increment in global consumption and utilization of citrus especially oranges. Major attributes for developing new varieties include quality fruit in regard of taste, size and texture. In current study, efforts have been made to harmonize research and development in field of citrus science, possessing the objective to explore the new emerging varieties of oranges and their adaptation in indigenous environment of Pakistan. It can be concluded that new emerging orange varieties can perform better in Pakistan ultimately can earn huge foreign exchange. Rod red Valencia and Cara Cara performed excellent in all the aspects, hence it is strongly recommended for farmers to start cultivation of these two varieties. Sun star was least good only due to presence of seeds (up to 7), while other varieties were promising in all the attributes studied. While minimum possibility of seeds was found in amber sweet.

Acknowledgements

Punjab Agriculture Research Board (PARB), Lahore is acknowledged for providing financial assistance, and Post-Harvest Research Institute, Faisalabad for facilitation the analytical work.

Novelty Statement

Adaptability study of exotic orange varieties was done for the first in Pakistan to choose most appropriate one ultimately to earn huge foreign exchange.

Author's Contribution

Akbar Hayat, Ehsan Ul Haque and Marayam Nasir designed the study and conducted experimental trials and wrote the basic draft of manuscript. Rab Nawaz and Tariq Mahmood conducted the statistical trials. Sohaib Afzaal reviewed and finalized the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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