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Comparative Study of Nutritional Quality of Orange (*Citrus sinensis)* at Different Maturity Stages in Relation to Significance for Human Health

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Abstract: Citrus fruit are important source of some essential dietary micronutrients. The quality of citrus can be evaluated on the basis of commonly used and accepted worldwide indicators of fruit quality i.e., TSS, acidity, TSS/acidity ratio, juice contents and total sugar contents. Besides many factors, ripeness and maturity are the key factors that influence the quality of a fruit. Therefore, the main purpose of the present study was to investigate the effect of maturation in a season on the quality of orange (*Citrus sinensis*). Fruit samples were taken randomly from the fresh fruits markets of Quetta city of Pakistan, three times during marketing seasons i.e., early stage when fruits were immature, mid stage when fruits were fully mature and end stage when fruits were over mature. Different physiochemical characters were evaluated i.e., juice contents, TSS, acidity, TSS/ acidity ratio, pH, ascorbic acid contents and total sugars. The obtained results indicated that stage of maturity had significant effect on the quality characters of all citrus fruits. Two different trends were observed in the present study. Sugars, total soluble solids and TSS/ acidity ratio, juice contents and pH were tend to be increasing toward maturity but at the end of the season, slight decrease in these contents were noted. On the other hand, acidity and ascorbic acid contents were high at the early stage when fruits were immature. So all fruits samples were rich in sugars, TSS and TSS/ acidity ratio and all these contents were seems to be high only at the stage of maturity, which was in agreement with previous publish literature. Hence, from the present study, it was concluded that over or under mature fruits did not possess absolute proportion of quality characteristics, thence not as beneficial for human health as mature fruits.

Key words: Nutritional Quality · Orange (*Citrus sinensis*) Maturitystages

INTRODUCTION

Nutrition is the cornerstone of healthy life. There are number of illnesses that could be prevented with proper nutrition. Antioxidant theory depicts that, the decline of dietary antioxidants through the westernization of diet has led to enhancement in susceptibility to oxidative damage and inflammation, resulting in prevalence of diseases [1, 2]. It is proven that intake of natural antioxidants in diet can reduce the risk of cancer and many other disorders related to oxidative stress [3]. Large numbers of plant species, including many fruits have been studied for their antioxidant, therapeutic and pharmaceutical behavior [3, 4]. Citrus fruits have received much attention because of its nutritional and pharmaceutical properties. Consumption of citrus can decrease the incidence of cardiovascular disease and risk of different types of cancer [5]. Citrus is one of the important nutritious fruit crop having a good vitamin profile especially vitamin C. Fruit weight, size, juiciness, taste and aroma are the selection traits for fresh citrus acceptance by the public and the fruit industry [6].Quality of citrus like other fresh fruits depends on its external (Colourand firmness) and internal characters viz; Total Soluble Solids (TSS) or Brix,

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total acid, total soluble solids / acid ratio and juice content, characters [7]. The factors influencing fruit quality characteristics include type of cultivar and stage of maturity [8]. Stage of maturity is considered more important, as it determines storage-life and final fruit quality. Immature fruits are extra subject to mechanical damage and of inferior flavor quality. Over mature fruits become mealy with insipid flavor. Fruits either picked too early or too late in their season are more susceptible to postharvest physiological disorders and less nutritive than the fruits picked at proper maturity. Therefore, harvesting of fruits at proper stage of maturity is of principal importance for attaining desirable quality and to attain its proper nutritive benefits [9, 10].

Keeping in view the importance of citrus fruit and effect of maturity on the quality index, present study was planned to ascertain the healthy contents in citrus fruit varieties viz., orange (*Citrus sinensis*) at different stages of maturity i.e., early stage when fruits were immature, mid stage when fruits were fully mature and end stage when fruits were over mature, during a marketing seasons in Quetta city of Pakistan in relation to their significance for human health.

MATERIALS AND METHODS

Sampling: Citrus fruit Orange (*Citrus sinensis*) samples (n=216) at three different stages of maturity (i.e., early stage when fruits were immature, mid stage when fruits were fully mature and end stage when fruits were over mature) were collected during marketing season (October 2011 to April 2012) from fresh fruit market of Quetta. Fruit samples were collected in polythene bags early in the morning with the start of fruit market and transported for analysis to laboratory of Sardar Bahadur Khan Women's University, Quetta. Samples were processed within five hours after receiving laboratory.

Processing: Fruit samples were washed with distilled water to remove dust particles. There after juice was extracted with citrus fruit extractor (Nowake N-999, Japan) for physiochemical analysis i.e.percent (%) juice contents, Total Soluble Solids (TSS), pH, percent (%) acidity, total sugar, vitamin C and TSS/acidity ratio of all collected citrus fruit samples.

Determination of Juice Contents: The juice contents were weighed and recorded in grams by using methods followed by Lacey *et al.* [11] and Grewal *et al.* [12]. The percent juice contents were calculated by using the following formula;

% juice contents = juice weight ÷ fruit weight x 100

Determination of pH: The juice pH for each sample was determined (In triplicate) using calibrated pH meter (Jenway- 350, England) following the method previously adopted by Anwar *et al*. [13].

Determination of Acidity: Acidity of the juices was determined (In triplicate) by acid base titration followed by Lacey *et al.* [11].

Percentage acid = Titer x acid factor x 10/10 (ml juice)
Factor for citric acid is 0.0064 (Citrus fruit)

Determination of Total Soluble Solids: Total soluble solids of the fruit juice were determined (In triplicate) as °Brix by using Abbe's refractometer (NAR- IT, Japan) under the protocol previously adopted by Lacey *et al.* [11].

Estimation of the TSS to Acid Ratio: Total soluble solid to acidity ratio (TSS: acidity) was calculated by dividing the total soluble solids by percent acid as followed by Lacey *et al.* [11] and Grewal *et al.* [12].

TSS: Acid = °Brix value / Percentage acid

Determination of Sugars: The sugars were estimated (In triplicate) by using chemical estimation method followed by Sethi [14].

Strength of unknown glucose solution= 4xWxV1/V gm. / litter

where
W = Weight of glucose in 250 ml standard solution.
V1 = Volume of standard glucose solution used for 25 ml Fehling's solution.
V = Volume of unknown glucose solution used for 25 ml Fehling's solution.

Determination of Vitamin C: Vitamin C contents in the fruit juices were determined (In triplicate) by iodine titration. Vitamin C in the juice sample was calculated as: X ml iodine solution used for standard solution of vitamin C / 0.250 g Vitamin C = x ml iodine solution for juice sample / X ml Vitamin C.☻

Statistical Analysis: The data was subjected to statistical analysis by using analysis of variance (ANOVA) technique with Completely Randomized Design (CRD).

The significance of difference (P<0.05) among means was compared using Duncan's Multiple Range test (DMR). Statistical package for Social Sciences (SPSS) 16 for windows was used for analysis.

RESULTS AND DISCUSSION

In the present study, the results concerning the juice contents of orange showed a significant difference (P<0.05) in the stage of maturity as shown in Table 1, respectively. In the present research, significant variations were observed in juice contents with different maturity stages.Late and mid stage with 46.8 and 48.8 % showed significantly high (P<0.05) juice percentage compared to early stage (40.30%). However, the difference between mid and late stage was non-significant (P>0.05). These contents remain variable for the entire period of fruit development. Decrease in juice contents reveals quality decline [15]. After mid stage, these contents started to decrease that might be due to the onset of new growth and new fruit development which sometimes suck back the moisture and nutrients from the old fruits. These findings of juice contents are in agreement with Anwar *et al*. [13].

Acidity in citrus fruits is one of the quality traits. In sweet citrus varieties, fruit quality will be better if acidity is on lower side. The main organic acid found in citrus fruits, with rare exceptions is citric acid. In most cases it is present in excess of the total testable acidity of fruit. In addition to citric acid, malic, succinic, fumaric and quinic acids can be found in appreciable quantities in the juice of the various fruits. Generally, acidity of the fruits decreased as fruits approach towards maturity and then increased as the fruit become over mature [12, 13]. Significantly higher (P<0.05) acidity percentage (1.17%) was noticed in early stage as compared to mid and late stage (Table 2). However, non-significant (P>0.05) acidity difference was observed between mid and late stage.

The pH of citrus juices provides the information about the state of acidity and basicity. In the present study it was observed that, pH increased up to mid stage of maturity after that it started Decreasing till the late stage. Orange collected during mid and late stages contained significantly higher (P<0.05) pH than early stage The increase in pH might be due to decrease in acidity with the maturity and decrease in pH indicates the increased acidity of the fruit and this might be due to the formation of acidic compounds due to degradation of reducing sugars [13]. The findings are in line with the findings of Anwar *et al*. [13].

Table 1: Juice content (%) and pH of orange at different maturity stages

Stage of maturity	Juice content		pH	
	Range	Mean±SEM	Range	Mean±SEM
Early Stage	38.30-42.15	40.30^{b}±1.11	2.90-3.60	3.20^{b}±0.20
Mid Stage	47.85-50.10	48.8^{a}±0.68	4.20-5.20	4.7^{a}±0.28
Late Stage	45.95-48.00	46.8^{a}±0.65	3.90-4.80	4.3^{a}±0.26

^{ab}Means in column with different superscripts differ significantly (P<0.05)

Table 2: Acidity and total soluble solids of orange at different maturity stages

Stage of maturity	Acidity (%)		TSS (%)	
	Range	Mean±SEM	Range	Mean±SEM
Early Stage	0.90-1.40	1.17^{a}±0.14	8.00-8.50	8.17^{a}±0.17
Mid Stage	0.55-0.80	0.65^{b}±0.08	9.90-10.50	10.13^{b}±0.19
Late Stage	0.60-0.80	0.70^{b}±0.06	8.80-10.20	9.60^{b}±0.41

^{ab}Means in column with different superscripts differ significantly (P<0.05)

Table 3: Total soluble solids / acidity ratio and total sugars content (g/100g FW) of orange at different maturity stages.

Stage of maturity	TSS / Acidity Ratio		Total sugars content	
	Range	Mean±SEM	Range	Mean±SEM
Early Stage	5.71-8.80	7.19^{b}±0.89	6.35-7.00	6.61^{c}±0.19
Mid Stage	13.12-18.18	15.93^{a}±1.49	8.80-9.60	9.18^{a}±0.23
Late Stage	12.25-14.66	13.82^{a}±0.79	7.70-8.25	8.01^{b}±0.16

^{abc}Means in column with different superscripts differ significantly (P<0.05)
*TSS: Total soluble solids

The observations pertaining to total soluble solids (TSS) of orange indicated consistent rise till maturity (Table 2) significantly higher (P<0.05) amount of TSS (10.13 and 9.60%) was detected during mid and late stage respectively, when compared with early stage. Non-significant (P>0.05) difference was noted between mid and late stage.

Increase in total soluble solids, decrease in acid contents and increase in ratio of solid to acid are main variations during the season [16-23].

Its levels normally increases as the fruit mature; conversely levels can decrease when fruit become over-mature.TheTSS/Acidity ratio differ significantly (P<0.05) among samples collected during different stages of maturity (Table 3). Maximum value (15.93) was noted in mature fruit, whereas immature oranges revealed minimum ratio (7.19). The concentration of the total soluble solids (TSS or Brix), total acidity and their ratios (TSS/acidity) are not static, but vary significantly during fruit development.

There are several kinds of sugars present in fruits, there of which prominent in citrus juices namely sucrose, glucose and fructose [24]. The total sugar contents were significantly higher both during mid (9.18 g/100g FW) and

Table 4: Vitamin C content (mg/100g FW) of orange at different maturity stages

	Vitamin C content	
Stage of maturity	Range	Mean±SEM
Early Stage	56.35-58.21	57.22[a]±0.54
Mid Stage	46.50-48.00	47.35[c]±0.44
Late Stage	49.55-52.00	50.63[b]±0.72

[abc]Means in column with different superscripts differ significantly (P<0.05)

late (8.01 g/100g FW) maturity stages compared to early stage (6.61 g/100g FW). Significant difference (P<0.05) was noted between early, mid and late stage (Table 3). It is observed that sugar level increased with fruit maturity [25]. Such increase has been attributed to a concurrent increase in the sucrose contents which is then hydrolyzed to simple sugars that affects both the taste and the texture of the fruit and the rise in sugars makes the fruit much sweeter [13].

Results observed in the present study revealed the decrease in ascorbic acid contents toward maturity and slightly increase at the end of the season. In sweet cultivars,Sinha *et al*. [16] and Cepeda*et al*. [26] also reported decrease in ascorbic acid content with maturity and then increased as fruit become over mature. Maximum vitamin C concentration (57.22 mg/100g FW) was observed in the samples collected during early stage of maturity, whereas lowest concentration (47.35 mg/100g FW) was observed in mid stage samples (Table 4). Significant difference (P<0.05) was noted between early, mid and late stage fruits.Thesevariations in ascorbic acid contents were due to change in acid and sugar contents of fruit juices with level of maturity. This loss of ascorbic acid can be attributed to the effect of processing, storage time, variety, exposure to light and other factors [9].

Recommendation: It is recommended that these mature fruits should be used widely to meet the nutritional demand of the local communities as well as exported to generate revenue only because an under and over mature fruits does not contain absolute proportion of nutrients hence usually not acceptable in international markets and also not beneficial for the human health.

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