PHYSICOCHEMICAL CHANGES DURING FRUIT DEVELOPMENT AND MATURATION IN GRAPEFRUIT (CITRUS PARADISI MACF.) CV. STAR RUBY

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INTRODUCTION

The grapefruit (Citrus paradisi Macf.) is a sub-tropical plant and an important citrus fruit known for its sour fruit. Its flesh is juicy, soft in texture and provides vitamin C, minerals and antioxidants. Grapefruit juice is consumed widely in today’s health conscious world as a protector against cardiovascular diseases and cancers. It has however, been found to be an inhibitor of the intestinal cytochrome P - 450 3A4 system, which is responsible for the first pass metabolism of many drugs (Kiani and Imam, 2007) and also reduces atherosclerotic plaque formation (Cerda et al., 1994).

In citrus, the harvesting period of fruits vary depending upon the species, variety and purpose of consumption. Information on biochemical changes and correlation among different fruit characters at various stages of fruit development is important in determining the optimum harvest period to meet the demand of fruit for a specific purpose. Till date, however, very limited work on analysis physico-chemical properties of the grapefruit has been carried out under sub-tropics of India. Earlier studies have shown concurrent changes in physico-chemical properties (soluble solids content, titratable acidity, vitamin C etc.) during fruit development and ripening in Kinnow mandarin (Singh et al., 1998b), guava (Bisen et al., 2014) and peach (Patel et al., 2014). Many of the changes have been primarily characterized in climacteric fruits, but are poorly understood in non-climacteric fruits (Palma et al., 2011). However, the citrus fruits cannot be picked immature for after-ripening because it contains little starch and is non-climacteric (Baldwin, 1993). The knowledge of quality changes during fruit development and maturity is a pre-requisite to harvesting intended for fresh fruit market, storage and processing. Hence, present investigations were conducted to study physico-chemical changes during the fruit development of Star Ruby grapefruit, the intention of this work was to identify the optimum period of harvesting of this cultivar under sub-tropical conditions of India.

MATERIALS AND METHODS

Fresh fruits of grapefruit cv. Star Ruby were collected from uniformly managed plants growing at Regional Station of Punjab Agricultural University at Abohar, Punjab, India during the year 2012. The experiment site was situated at 30°12’ N and 74°21’ E with an altitude of 190 meters above mean sea level. The grapefruit cv. Star Ruby plants, budded on Rough lemon were spaced at 6m x 6m in a square system of planting and eight year old plants were selected from the citrus orchard of the experiment farm. Fruits were picked manually at monthly intervals from July to December at 90, 120, 150, 180, 210 and 240 DAFS for various physico-chemical parameters viz; fruit weight, peel thickness, specific gravity, etc.

ABSTRACT

Physico-chemical changes in fruits of grapefruit cv. Star Ruby was studied during growth and development under arid irrigated conditions of north-western India. Fruit samples taken from 90 to 240 days after fruit set (DAFS) at monthly interval for quality analysis. Studies revealed that the mature fruits of Star Ruby were rich in the total sugars, reducing sugars, non-reducing sugars and TSS contents than the developing fruits, while titratable acidity declined with advancement of fruit maturity. The fruit weight increased from 94.95 gm to 355.29 gm and peel thickness decreased from 9.78 mm to 6.37 mm during the study period. Maximum TSS/acid ratio (6.42%), reducing sugars (4.06%), non-reducing sugars (2.65%) and total sugars (7.26%) and the lowest juice acid content (1.39%) were recorded at 210 DAFS. Vitamin C content of fruit juice was decreased with the advancement of the season. TSS/acid ratio was correlated with the weight of the fruit during fruit development, which accounted 91% variability in the data. From present studies, it can be concluded that optimum time for harvesting the grapefruit cv. Star Ruby is 210 DAFS when fruit attained best internal quality characteristics.

KEY WORDS
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TSS, acidity, TSS/acid ratio, vitamin C and sugars. These parameters were determined on twenty fruits picked randomly at designated stage. Fruit weight was recorded with the help of electronic pan balance and expressed as mean weight in gram. The peel thickness was measured with digital vernier’s caliper (Mitutoyo, Japan) and expressed in millimeter. The specific gravity was measured by water displacement method. Total soluble solids were recorded by digital hand refractometer (Atago, Japan) and expressed in °Brix. The fruit acid content was determined by titrating juice against 0.1 N sodium hydroxide, using phenolphthalein as an indicator and sugars content by the methods of AOAC (2000). Ascorbic acid (vitamin C) content was determined by the using 2,6-Dichlorophenol-indophenol dye method of Freed (1966).

Data were analyzed statistically to an analysis of variance (ANOVA) and differences among the means were determined for significance at p<0.05 by LSD test using the statistical analysis system software version 9.3 (SAS Institute Inc., Cary, NC, USA) at 5% level of probability. Mean and standard errors of each sample were calculated for statistical comparison. Regression analysis was undertaken to find the relative correlation for seasonal variation between fruit TSS/acid ratio and weight by the statistical methods (Singh et al., 1998a).

RESULTS AND DISCUSSION

Weight of the fruit
A linear and significant (p<0.05) increase in fruit weight with the advancement of fruit development was observed up to 210 DAFS and subsequently a non-significant increase in fruit weight was recorded till harvesting of fruit at 240 DAFS (Fig. 1a). The mean maximum fruit weight (355.29 gm) was recorded on the last harvesting date i.e. 240 DAFS. The average percent increase in fruit weight was higher from 90 DAFS (94.95 gm) to 150 DAFS (260.97 gm) during the first stage. Thereafter, a slow increase in fruit growth was observed up to fruit harvest. Similarly, Randhawa et al. (1964) reported that the weight of grapefruit increased with season and the minimum percent increase in fruit weight was observed after seventh month of fruit set. The increase in fruit weight could be attributed to an increase in the size of the cells and accumulation of food substances in the intercellular spaces in fruit. Similar findings were also reported by Kishore et al. (2006) in passion fruit during the fruit development.

Peel thickness of the fruit
It is clear from the data in Fig. 1b that peel thickness of fruit was minimum during the peak harvesting time of grapefruit in the month of November-December at 210-240 DAFS. The peel thickness decreased significantly (p<0.05) from 90 DAFS (9.78 mm) to 210 DAFS (6.44 mm) afterwards a decrease was non-significant. Results indicate that there is increase in percent edible portion of fruit with maturity while non-edible portion decreased. Similarly, a decrease in peel thickness was recorded from 180-250 days after fruit set in Mosambi fruit by Ladaniya and Mohalle (2011).

Specific gravity of the fruit
No categorical trend was observed in specific gravity with season (Fig. 1c). However, a significant (p<0.05) increase in specific gravity was observed from the 90 DAFS (0.703 gm/mL) to 120 DAFS (0.923 gm/mL). Increase in specific gravity might be due to higher rate of accumulation or synthesis of food materials. Similar results were also reported by Sema and Sanyal (2003) in lemon. The specific gravity on 150 DAFS trailed behind its proceeding value on 120 DAFS. Thereafter, specific gravity showed significant increase from 150 DAFS (0.783 gm/mL) to 180 DAFS (0.873 gm/mL) and decreased significantly from 180 DAFS to 210 DAFS. The specific gravity during peak harvesting period i.e. from 210-240 DAFS remained at constant levels. Shyamali (2006) observed similar results in pear that specific gravity showed a decreasing trend.

TSS contents of the fruit
A gradual and significant (p<0.05) increase in TSS contents of the fruit were observed with the advancement of maturity (Fig. 1d). The TSS contents during the initial period of fruit sampling i.e. 90 DAFS were minimum (7.87 °Brix) and continuously increased till 210 DAFS reaching the maximum value of 8.87 °Brix. However, with the advancement of the season, TSS contents decreased slightly after 210 DAFS. The increase in TSS content might be the result of degradation of starch during later stage of harvest maturity. Similarly Singh et al. (1998b) in Kinnow and Candir et al. (2009) in persimmon reported that TSS increased with the advancement of fruit maturity.

Acidity of the fruit
Acid content of the fruit followed a decreasing trend as the fruit approached maturity stage (Fig. 1e). A non-significant increase in total acid content of fruit occurred from 90 DAFS (1.88%) to 120 DAFS (1.92%), subsequently, a significant decrease in total acid content was noted upto 180 DAFS. However, the lowest juice acid content (1.39%) was recorded when the fruits were picked at 210 DAFS. This decrease was may be attributed to conversion of organic acid into sugars. Similar results found by Sidahmed and Khalil (1997) in grapefruit and Deka et al. (2006) in Khasi mandarin, who observed decrease in juice acidity with maturity of fruit.

TSS/acid ratio of the fruit
In general, the TSS/acid ratio increased gradually until maturity (Fig. 1f). The TSS/acid ratio was increased non-significantly from 90 DAFS (4.19%) to 120 DAFS (4.28%). Thereafter, this ratio continued to increase significantly (p<0.05) upto 210 DAFS (6.42%), except, at the 240 DAFS (6.32%) where non-significant decrease was recorded. The lowest (4.19%) and highest (6.42%) TSS/acid ratio was recorded at the 90 DAFS and 210 DAFS, respectively.

Decrease in the concentration of juice acid with a gradual increase in TSS during fruit development resulted into an increase in the TSS/acid ratio. These findings are in conformity with those of Randhawa et al. (1964) that Solid/acid ratio increased throughout the season with Marsh Seedless and pink varieties of grapefruits and Singh et al. (2004) in banana.

Ascorbic acid content of the fruit
There was sudden and significant (p<0.05) decrease in ascorbic acid content from the 90 DAFS (55.72 mg/100 mL) to 150 DAFS (45.15 mg/100 mL) followed by a slight increase at 180 DAFS. However, it again decreased till the 240 DAFS i.e. 41.34 mg/100 mL (Fig. 1g). The ascorbic acid content was
The physicochemical changes during fruit development were studied. The weight of the fruit increased significantly from 90 DAFS to 210 DAFS, as indicated by the LSD (Least Significant Difference) test at p<0.05. The LSD for weight was 18.09, and the CV (Coefficient of Variation) was 36.68%.

The peel thickness also increased significantly from 90 DAFS to 210 DAFS, with an LSD of 0.64 and a CV of 16.02%.

The specific gravity (specific gravity) increased significantly from 90 DAFS to 240 DAFS, with an LSD of 0.058 and a CV of 9.34%.

The total soluble solids (TSS) content increased linearly up to 210 DAFS, with an LSD of 0.58 and a CV of 15.38%.

The acidity content decreased significantly from 90 DAFS to 120 DAFS, with an LSD of 0.12 and a CV of 14.23%.

The TSS/acid ratio increased significantly from 90 DAFS to 210 DAFS, with an LSD of 0.45 and a CV of 17.77%.

Ascorbic acid content noted 44.32 mg/100 mL during the harvesting stage of fruit in the month of November at 210 DAFS. The decline in ascorbic acid content might be attributed to an oxidation of ascorbic acid. Similar results were also reported by Dubey et al. (2003) in Khasi Mandarin and by Ladaniya and Mohalle (2011) in Mosambi. Singh et al. (1998b) also reported that ascorbic acid content increased initially and decreased with the advancement of fruit maturity in the Kinnow mandarin.

Sugar content of the fruit:
Both reducing and total sugars were found to increase linearly up to 210 DAFS. The increase in sugars was due to an increase in TSS and accumulation of glucose, fructose, and sucrose in fruit. Similar trend was also reported by Ladaniya and Mohalle (2011) that reducing and total sugars in the juice of Mosambi fruit increased.

Reducing sugars in the pulp showed a continuous increase till the fruits were ripe (Fig. 2). There was significant increase in reducing sugars from 90 DAFS to 120 DAFS. Later on, a gradual
increase was recorded with little variation throughout the period of fruit development. The values regarding reducing sugars increased from 2.49% during 90 DAFS to 4.06% on the fruit ripening stage at 210 DAFS in the fruit. But, it was decreased non-significantly at 240 DAFS (3.89%).

The data revealed that the total sugars continued to increase throughout the course of studies, except at 240 DAFS (Fig. 2). The level of total sugars content was lowest on the first sampling at 90 DAFS (4.73%) and thereafter an increase was observed during the harvesting period to the highest level (7.26%) at 210 DAFS. It was further decreased non-significantly at 240 DAFS (6.92%). Similarly, the level of non-reducing sugars was increased significantly from 90 to 120 DAFS and 150 to 210 DAFS. These findings are in conformity with those of Nivas et al. (2009) who reported that the mature fruits of Morinda citrifolia are rich in the total sugars and reducing sugars. However, two periods of significant decrease in the non-reducing sugars were noticed. The first decrease was from 120-150 DAFS and second was from 210-240 DAFS during the last month of sampling like reducing sugars and total sugars.

Relationship between fruit weight and TSS/acid ratio
Fruit TSS/acid ratio was highly significant (p<0.05) and positively correlated with fruit weight and described by the linear regression curve. The determination ratio (R²) is 0.91, which accounted 91% variability in data (Fig. 3). The correlation between fruit TSS/acid ratio and weight was relatively linear and the ratio was essentially 1:1. Similar results found by Sirisomboon and Theamprateep (2012) who stated that TSS/acid ratio was correlated with the fruit weight of Pomelo fruit.

The dynamics of intensity was recorded higher in fruit non-reducing sugars (CV = 47.22%) and lower in fruit TSS (CV = 4.62%). The correlation was relatively linear between reducing sugars (CV=47.22%) and lower in fruit TSS and acid. The correlation was relatively linear and the ratio was essentially 1:1. Similar results found by Sirisomboon and Theamprateep (2012) who stated that TSS/acid ratio was correlated with the fruit weight of Pomelo fruit.

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