



Physico-chemical Changes during Growth and Development of Guava (*Psidium guajava* L.) fruits

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INFORMATION:

Submission: 30/12/2020

Accepted: 29/11/2021

Publication: 30/03/2023

ABSTRACT

The aim of this study was to evaluate the physico-chemical changes during growth and development of ‘Shendi’ (pink-flesh) and ‘Pakistani’ (white-flesh) guava fruits, to provide base-line information regarding the biochemistry of the developing fruit to assist in determining harvest maturity of guava fruits. Twenty trees were selected from each cultivar in the horticultural field, University of Khartoum farm at Shambat, Khartoum State, Sudan. At time of flowering, the newly open flowers were tagged and fruit samples were harvested at different stages of growth and development. The first sample was picked four weeks after anthesis, and sampling continued every two weeks up to the over-ripe stage (6 samples). Forty fruits (10 fruits per replication) of uniform size and free from blemishes were picked at the designated stage, washed, air dried and arranged in a completely randomized design with four replicates. Physical and chemical changes were determined using standard methods. The fruits of both cultivars followed a typical sigmoid curve. Fruit fresh weight, volume, length and diameter progressively increased from 4 up to 10 weeks after anthesis (WAA), at physiological maturity, and then remained constant. Fresh weight increased from 12.1 g and 14.5 g at 4 WAA to 95.2 g and 107.1 g at physiological maturity (10 WAA) in ‘Shendi’ and ‘Pakistani’ cultivars, respectively. The white and pink guavas exhibited a typical climacteric pattern of respiration. Respiration rate was decreased from 85.6 and 69.9 mg CO₂ kg⁻¹ hr⁻¹ (4 WAA) to 39.7 and 29.6 mg CO₂ kg⁻¹ hr⁻¹ at physiological maturity (10 WAA), increased to 48.5 and 37.1 mg CO₂ kg⁻¹ hr⁻¹ at the ripe stage (12 WAA), and dropped afterwards to 29.6 and 20.1 mg CO₂ kg⁻¹ hr⁻¹ at the over-ripe stage (14 WAA) in ‘Shendi’ and ‘Pakistani’ fruits, respectively. Total sugars steadily increased on average, from 4.1 g/100 g (4 WAA) to 12.4 g/100 g (14 WAA). Ascorbic acid increased from 19.9 mg/100 g (4 WAA), reaching a peak of 87.5 mg/100 g at physiological maturity and then decreased to 71.4 mg/100 g at the over-ripe stage. Phenolic compounds steadily decreased during growth and development from an average of 0.81 g/100 g at 4 WAA to 0.15 g/100 g at 14 WAA. The white-fleshed guavas had higher levels of total sugars, phenolic compounds, and ascorbic acid content, compared to the pink-fleshed fruits. It was recommended that guava fruits should be picked at physiological maturity (10 WAA), where the fruit size, fresh weight and volume are at their maximum values, respiration rate at the minimum level, total and reducing sugars are high, ascorbic acid content at maximum level and phenolic compounds are reasonably low.

KEYWORDS:

Guava; Pakistani; Physico-chemical; Shendi

INTRODUCTION

Guava (*Psidium guajava* L) is one of the important fruit crops cultivated in several tropical and subtropical countries of the world, with total world production of 6,752 thousand metric tons (FAO, 2017). In Sudan, guava is still a minor fruit crop, but it is commercially grown in every state and its production continues all the year round, with total production of 145 thousand tons (HSA, 2017).

The fruit has a characteristic odor and is eaten fresh, as well as for making jam, jelly, nectar, *etc.* (Patra *et al.*, 2004). The ripe fruit is an excellent source of ascorbic acid (vitamin C) and dietary fiber. It has about five times more vitamin C than orange. It is also a good source of vitamin A, phosphorous, calcium and iron, as well as thiamin and niacin (Watt and Merrill, 1975).

The fruit is delicate and cannot withstand long-distance transportation and may reach the market in a meshy and over-ripe state. It can store well only for few days at ambient conditions. Due to the delicate nature of the fruit and poor transportation and storage facilities, marketability is limited to local markets (Mohamed-Nour and Abu-Goukh 2013).

Evaluation of physical characters and chemical composition of commercially important guava cultivars are needed. Compositional changes of the fruit are of concern for understanding metabolic processes such as fruit maturity, ripening, softening and general quality. Moreover, they are of importance in determining commercial practices and post-harvest requirements (Bashir and Abu-Goukh, 2003). Also, the quality and storage life of the fruit depend on various physiological and biological changes, which occur during fruit growth, development and maturity (Harding and Hatton, 1967). Many physical and chemical changes undergone by the developing fruits have been used or suggested as means of assessing the optimal picking date for immediate consumption or storage. Sufficient data are not available on many commercial cultivars to fix maturity standards for harvesting on the basis of fruit growth and physical and chemical parameters (Abu-Goukhet *et al.*, 2005). None of the parameters are reliable individually for determining harvest maturity. It usually requires a combination of chemical and physical parameters, coupled with considerable experience (Salunkhe and Daseai, 1984).

This study was carried-out to evaluate the physico-chemical changes during growth and development of white- and pink-fleshed guava fruits, to provide base-line information regarding the biochemistry of the developing fruits to assist in determining harvest maturity of guava fruits.

MATERIALS AND METHODS

Experimental material

Two cultivars of guava fruits; 'Shendi' (pink-flesh) and 'Pakistani' (white-flesh) were selected for this study. Twenty trees were selected from each cultivar grown in the horticultural field located at the University of Khartoum farm in Shambat, Khartoum State (15°40' N, 32°22' E). At the time of flowering, the newly-opened flowers were tagged and fruit samples were harvested at different stages of growth and development. The first sample of fruits was picked four weeks after anthesis (WAA), and then sampling continued every two weeks up to the over-ripe stage (6 samples). Forty fruits from each cultivar (10 fruits per replication) of uniform size, color, and free of blemishes were picked at the designated stage, washed, air dried and arranged in a completely randomized design with four replicates.

Physical changes

Physical changes were determined on 10 fruits per replicate of each cultivar, picked at the designated stage. The physical changes studied were fresh weight, volume, length, diameter and density of the fruits. Average fruit fresh weight was determined by using an electrical balance and was expressed in grams. The fruit volume was estimated by water displacement and expressed in cubic centimeters. Fruit length and diameter were determined using a Vernier caliber (White-Grew Model) and were expressed in centimeters. Fruit density was determined by dividing the fruit fresh weight by fruit volume at the different stages of development and was expressed as ratio.

Chemical changes

Chemical changes were determined on 10 fruits per replication of each cultivar, picked at the designated stage. The chemical changes studied were respiration rate, total and reducing sugars, phenolic compounds and ascorbic acid content. Respiration rate was determined on the fruit samples using the total absorption method of Charlimers (1956), as modified by Mohamed-Nour and Abu-Goukh (2010). Respiration rate was expressed in $\text{mg CO}_2 \text{ kg}^{-1} \text{ hr}^{-1}$.

Thirty grams of pulp from each fruit sample were homogenized in 100 ml of distilled water for one minute in an electric mixer (Molinox model No. 241) and centrifuged at 6,000 rpm for 10 minutes in a Gallenkamp portable centrifuge (CF-400). The volume of the supernatant, which constituted the pulp extracts, was recorded. Total sugars were determined in the pulp extracts using the anthrone method of Yemm and Willis (1954). Reducing sugars were determined in the pulp extracts according to the Nelson-Somogyi technique (Somogyi, 1952). Total and reducing sugars were expressed in grams per 100 grams fresh weight. Phenolic compounds were determined in the pulp extracts according to the Folin-Ciocalteu method of Singleton and Rossi (1965) and were expressed in grams per 100 grams fresh weight.

Ascorbic acid content was determined using the 2, 6-dichlorophenol-indophenol titration method described by Ruck (1963). Thirty grams of pulp from each fruit sample was homogenized in 100 ml of oxalic acid for one minute in an electric mixer (Molinox model No. 241) and then centrifuged at 6,000 rpm for 10 minutes in a Gallenkamp portable centrifuge (CF-400). The volume of the supernatant was topped to 250 ml oxalic acid. Ascorbic acid content was expressed in milligrams per 100 grams fresh weight.

Statistical analysis

Analysis of variance (ANOVA) and Fisher's protected LSD test with a significance level of $P \leq 0.05$ were performed on the data using Genstat software (version 18, 2016).

RESULTS AND DISCUSSION

Physical changes during growth and development

Fruit fresh weight and volume

A significant variation in fruit weight of guava was observed among the various stages of fruit growth and development and between cultivars. The fruit growth of guava fruits followed a typical sigmoid curve. The fresh weight was progressively increased with advancement in growth and development in both cultivars. It increased from 12.1 g at 4 weeks after anthesis (WAA) to 95.2 g at physiological maturity (10 WAA) in 'Shendi' and from 14.5 g to 107.1 g in 'Pakistani' and then remained constant (Fig. 1).

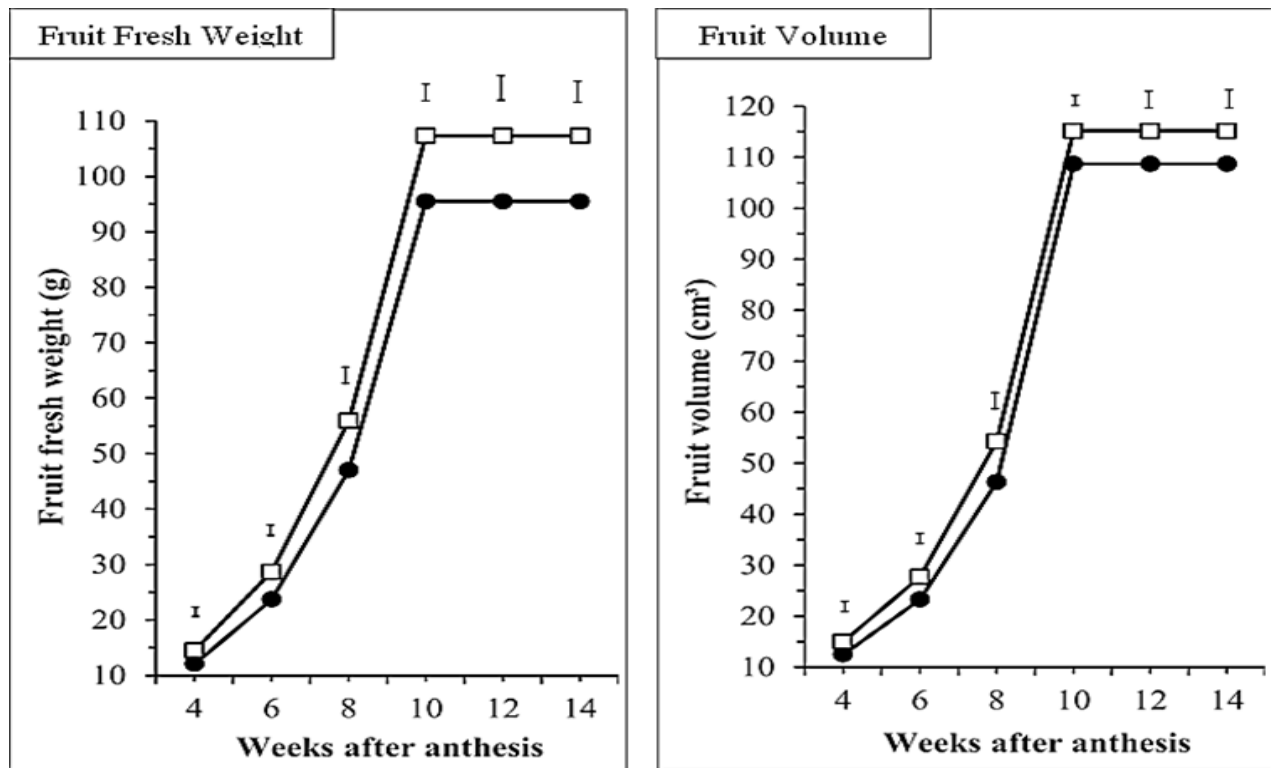


Fig. 1. Fruit fresh weight and volume of guava during development

Rodriguez *et al.* (1971) reported that guava exhibit an unusual sigmoid growth curve. Fruit of ‘Safeda’ guava increased rapidly in weight during the first 50 days of growth, more rapidly up to 100 days and very slow during the last stages of maturity. The slow growth during initial stage might be due to rapid development of seeds, resulting in slow growth of the pulp.

Changes in fruit volume during growth and development followed the same pattern of fruit fresh weight. Fruit volume increased simultaneously with advancement of growth period depending on fruit cultivar. It increased from 12.5 cm³ (4 WAA) to 108.5 cm³ (10 WAA) in ‘Shendi’ and from 15.0 cm³ to 115.7 cm³ in ‘Pakistani’ and then remained constant (Fig. 1). Hedge (2001) reported that guava fruit development can be divided into three distinct phases. The initial phase of about 70-75 days after fruit set was of rapid cell division with no deposition of stored materials. During this phase, fruit fresh weight increased moderately. The second phase, which lasted up to 135 days after fruit set, consisted of rapid accumulation of stored materials, which was accompanied by rapid increase in fresh weight, while during the third phase; fresh weight of the fruit remained almost constant with a slight or negligible decline after 155 days from fruit set because of dehydration or desiccation. Also Datta and Mukherjee (1980) observed that the weight and volume of guava fruit cultivars ‘Allahabad Safeda’ and ‘Red-fleshed Pyriform’ guava cultivars were increased during fruit development in three different phases.

Fruit length and diameter

The length and diameter of the developing fruits significantly increased with the advancement in age. The fruit length had increased from 36.1 mm (4 WAA) to 52.8 mm (10 WAA), while the fruit diameter increased from 27.1 mm (4 WAA) to 53.3 mm (10 WAA) in ‘Shendi’ cultivar and then remained constant (Fig. 2). The fruit length increased from 33.0 mm (4 WAA) to 49.4 mm (10 WAA), while the fruit

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diameter had increased from 29.4 mm (4 WAA) to 56.7 mm (10 WAA) in the ‘Pakistani’ cultivar and remained constant. ‘Shendi’ cultivar was longer and with less diameter, compared to ‘Pakistani’ cultivar (Fig. 2).

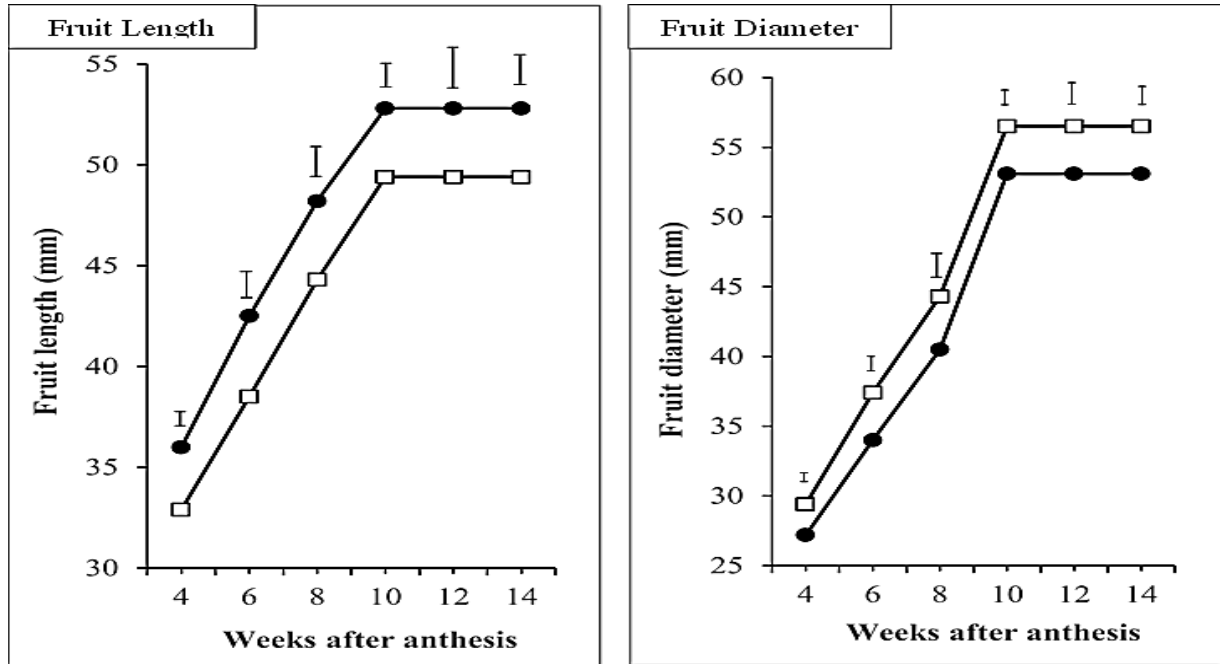


Fig. 2. Fruit length and diameter of guava during development

Fruit density

The fruit density increased from 0.98 at 4 WAA in ‘Shendi’ cultivar, reaching a maximum value of 1.01 at 8 WAA, decreased to 0.88 at physiological maturity (10 WAA) and remained constant afterwards (Fig. 3). Similarly, in ‘Pakistani’ cultivar, the fruit density increased from 0.95 at 4 WAA, reaching a value of 1.02 at 6 WAA, decreased steadily to 0.93 at physiological maturity (10 WAA) and remained constant after that (Fig. 3). Datta and Mukherjee (1980) reported that specific gravity decreased with maturity in ‘Allahabad Safeda’ and red- fleshed Pyriform’ guava cultivars. Agarwal *et al.* (2002) reported that weight of guava increased from 36.82 g/cm size at 100 % green to 50.24 g/cm size at 100 % yellow and the true density was decreased from 1.03 to 0.91 g/cc.

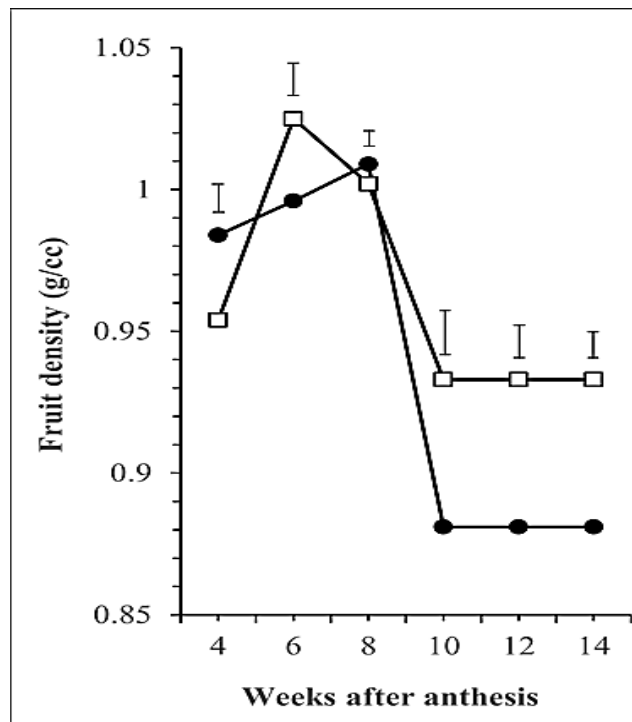


Fig. 3. Fruit density of guava during development

Chemical changes during growth and development

Respiration rate

The respiration curves of the two guava cultivars exhibit a typical climacteric pattern. It was decreased during growth and development from 85.6 and 69.9 mg CO₂ kg⁻¹ hr⁻¹ at 4 WAA to 39.7 and 29.6 mg CO₂ kg⁻¹ hr⁻¹ at physiological maturity (10 WAA), and then increased with a peak of 48.5 and 37.1 mg CO₂ kg⁻¹ hr⁻¹ at the ripe stage (12 WAA), and declined afterwards to a value of 29.6 and 20.1 mg CO₂ kg⁻¹ hr⁻¹ at the over-ripe stage (14 WAA) in ‘Shendi’ and ‘Pakistani’ cultivars, respectively (Fig. 4). The respiration rate was significantly higher in ‘Shendi’ than ‘Pakistani’ guavas during all stages of growth and development. Akamine and Goo (1979) studied the respiration and ethylene production in fruits of four guava cultivars. The fruits of all cultivars had a climacteric pattern of respiration with ethylene triggering the respiration rise. Similar climacteric pattern was reported during growth and development of three mango cultivars (Abu-Goukhet *al.*, 2005), and fruit ripening in guava (Bashir and Abu-Goukh, 2003; Mohamed-Nour and Abu-Goukh, 2013) and mango (Abu-Goukh and Abu-Sarra, 1993).

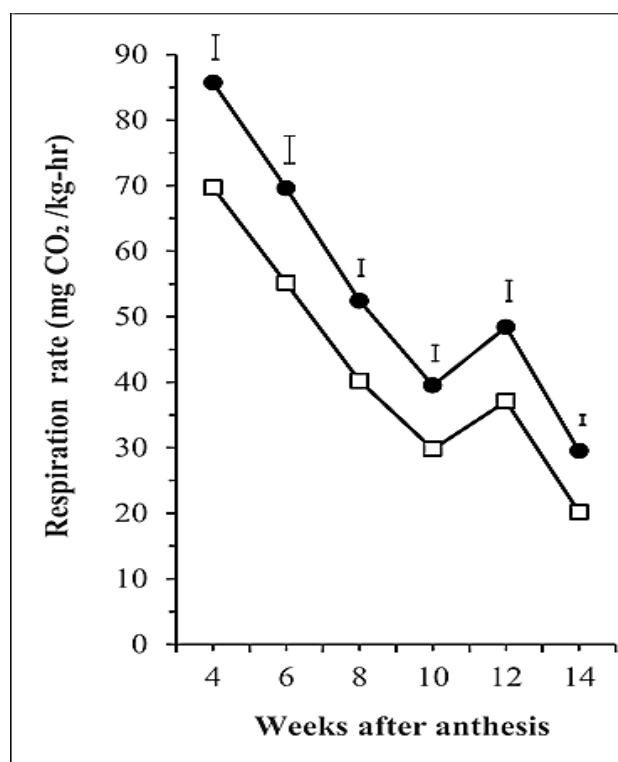


Fig. 4. Fruit respiration rate of guava during development

Total and reducing sugars

Total sugars progressively increased during growth and development of ‘Pakistani’ and ‘Shendi’ guava fruits. Total sugars were significantly higher in ‘Pakistani’ cultivar than in ‘Shendi’ cultivar at all stages. Total sugars had increased from 3.2 and 5.1 g/100 g at 4 WAA to 8.8 and 10.6 g/100 g at physiological maturity (10 WAA), and then to 11.6 and 12.9 g/100 g at the over-ripe stage (14 WAA) in ‘Shendi’ and ‘Pakistani’ cultivars, respectively (Fig. 5). El-Bulk *et al.* (1997) studied the changes in chemical composition of four guava cultivars (Shambati, Pakistani, Shendi, and Ganib) at three developmental stages; immature (15-33 days), mature (51-88 days) and ripe (106-126 days) after fruit set during development and ripening of fruits. They observed that sugars and ascorbic acid reached their maximum values 106 days from fruit set, and also emphasized that guava fruit at that stage had excellent nutrient resources. Abu-Goukh *et al.* (2005) studied compositional changes during growth and development in three mango cultivars, reported that total soluble solids (TSS) and total sugars remained unchanged or slightly decreased up to mature-green stage and sharply increased during the ripening phase. However, total and reducing sugars were reported to increase sharply during growth and development of dates (Barrevelled, 1993). Bashir and Abu-Goukh (2003) reported that TSS and total sugars increased in white and pink guava fruits with decrease in flesh firmness during fruit ripening. The increase in total sugars observed after physiological maturity (10 WAA) in the two cultivars was most probably due to activity of enzymes responsible for starch hydrolysis and /or decline in the rate of sugar break down by the respiration process.

Reducing sugars were increased from 6.7 and 5.1 g/100 g fresh weight at 4 WAA, reaching a peak of 11.3 and 10.6 g/100 g at the ripe stage (12 WAA), which coincided with the climacteric peak of respiration, and then declined to a value 10.7 and 10.1 g/100 g at the over-ripe stage (14 WAA) in ‘Shendi’ and ‘Pakistani’ guava

fruits, respectively (Fig. 5). Reducing sugars in the pulp of ‘Shendi’ cultivar were significantly higher than that of ‘Pakistani’ cultivar (Fig. 5). Mowlah and Itoo (1982) showed that glucose, fructose and sucrose were the main sugars in the white- and pink-fleshed guavas. Abu-Goukh *et al.* (2005) reported that reducing sugars slightly decreased during growth and development of three mango cultivars, and then increased to reach a peak, coincided with the peak of respiration and decreased afterwards. Bashir and Abu-Goukh (2003) found that the reducing sugars in the pulp and peel of white- and pink-fleshed guava fruits increased up to the climacteric peak and subsequently decreased during fruit ripening. Similar results, were reported during fruit ripening in mango (Abu-Goukh and Abu-Sarra, 1993).

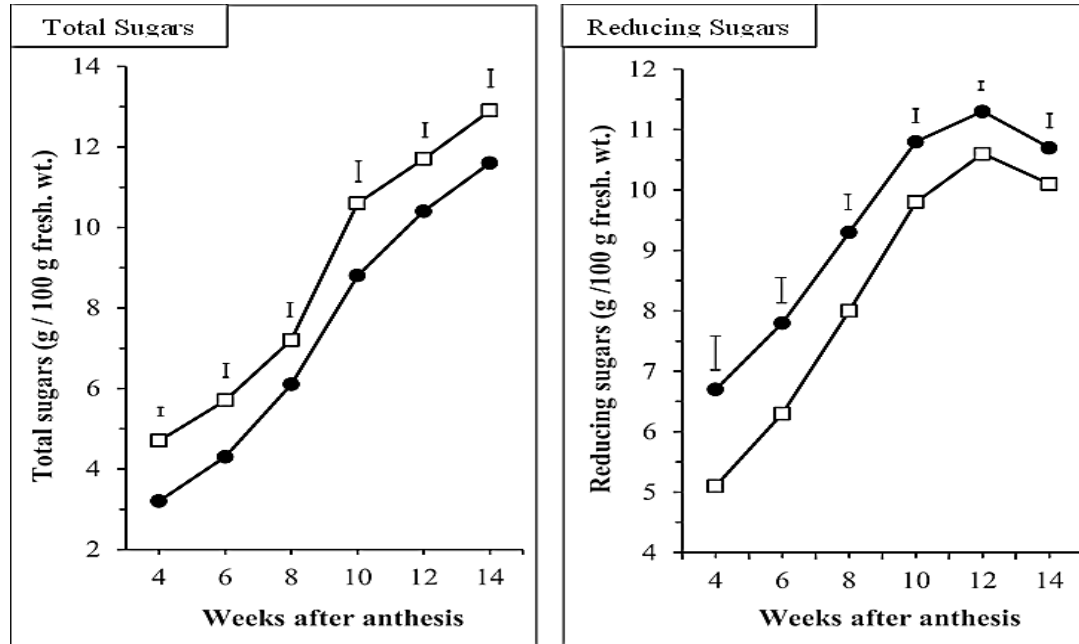


Fig. 5. Total and reducing sugars of guava fruit during development

Phenolic compounds

Phenolic compounds steadily decreased during growth and development of the two cultivars. It was decreased from 0.75 g/100 g at 4 WAA to 0.13 g/100 g at the ripe-stage (14 WAA) in ‘Shendi’ cultivar. While it decreased from 0.87 g/100 g at 4 WAA to 0.17 g/100 g at over-ripe stage (14 WAA) in ‘Pakistani’ cultivar (Fig. 6). The white guavas had significantly higher values of phenolic compounds in pulp, compared to the pink guava type. (Fig. 6). This is in agreement with earlier findings in guava fruits (Bashir and Abu-Goukh, 2003). Mowlah and Itoo (1982) reported that total polyphenols decreased in white and pink guavas throughout the immature stage to the full-ripe stage. Abu-Goukh *et al.* (2005) reported that total phenolic compounds decreased in pulp and peel during growth and development of three mango fruits. Bashir and Abu-Goukh (2003) found that the phenolic compounds in pulp and peel of white- and pink-fleshed guavas progressively decrease with decrease in flesh firmness during fruit ripening. Similar results were reported during fruit ripening in mango (Abu-Goukh and Abu-Sarra, 1993).

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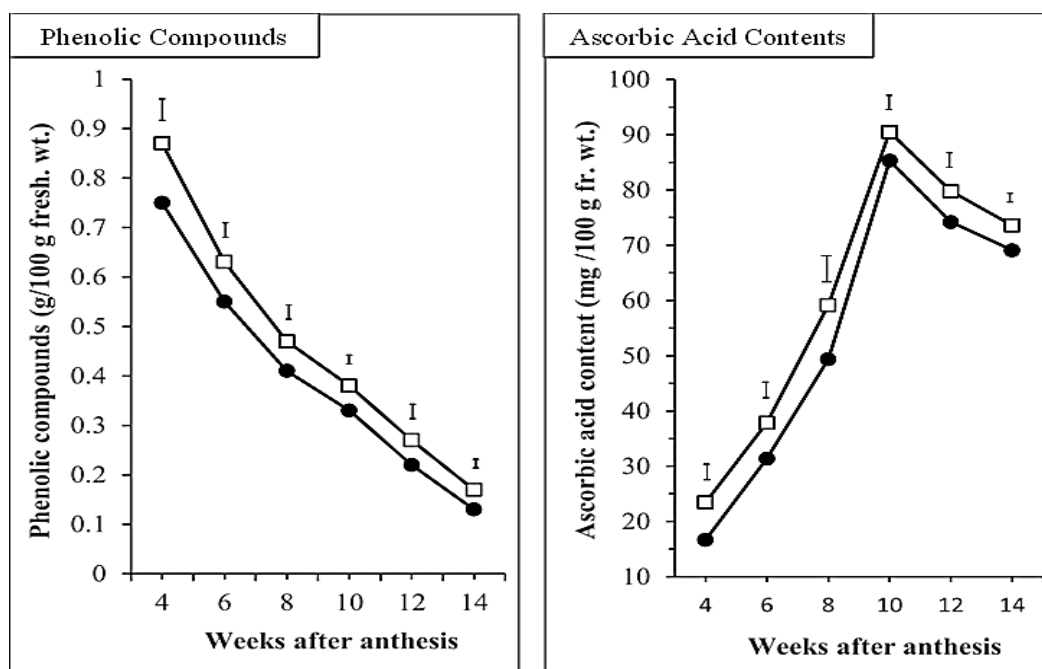


Fig. 6. Phenolic compounds and ascorbic acid content of guava fruit during development

Phenolic constituents are responsible for the astringent taste in unripe fruits. The decrease in astringency in fruit during ripening was associated with the increased polymerization of leucoanthocyanidins and hydrolysis of the stringent arabinose ester of hexahydrodiphenic acid (Misra and Swshadri, 1968). Phenolic compounds have been repeatedly demonstrated to play a vital role in plant disease resistance and protect fruits and vegetables against pests and diseases. Abu-Goukh *et al.* (2003) found a negative correlation between phenolic compounds and insect infestation during storage of dry dates. A key role was proposed for phenolics in resistance of dates to insect infestation during storage (Abu-Goukh *et al.*, 2003). Phenolics were reported to be higher in peel than pulp of guava (Bashir and Abu-Goukh, 2003) and mango fruits (Abu-Goukh and Abu-Sarra, 1993; Abu-Goukh *et al.*, 2005), and that was proposed to have significance in plant disease resistance in the fruits.

Ascorbic acid content

Ascorbic acid content increased from 16.4 and 23.4 g/100 g at 4 WAA, reaching a peak of 84.8 and 90.2 g/100 g at physiological maturity (10 WAA) and then gradually decreased reaching a minimum value of 68.9 and 73.8 g/100 g at the over-ripening stage (14 WAA) in 'Shendi' and 'Pakistani' cultivars, respectively (Fig. 6). This agrees with previous reports that ascorbic acid content in guava fruit reaches a maximum level at the mature-green stage, and starts to decline rapidly as the fruit ripens (Agnihotri *et al.*, 1962;). Bashir and Abu-Goukh (2003) reported that ascorbic acid in pulp and peel of white- and pink-fleshed guava types decreased steadily during fruit ripening. The post-harvest storage period resulted in great losses in ascorbic acid content in guava fruits. The amount of ascorbic acid content retained at the over-ripe stage, compared to the physiological mature stage was 81.3 % in 'Shendi' and 81.8 % in 'Pakistani' cultivars (Fig. 6). Bashir and Abu-Goukh (2003) found that at the final ripening stage (flesh firmness 0.3 kg/cm²) the amount of ascorbic acid content retained was 86.3 % in the pulp and 86.3 % in the peel of the white-fleshed guava fruits, and 76.6 % and 78.1 % of the pulp and peel of the pink-fleshed guavas.

CONCLUSION

Guava fruits should be picked at physiological maturity (10 WAA), where the fruit size, fresh weight and volume at their maximum values, respiration rate at the minimum level, total and reducing sugars are high, ascorbic acid content at maximum level and phenolic compounds are reasonably low.

REFERENCES:

- Abu-Goukh, A.A. and A.F. Abu-Sarra. 1993. Compositional changes during mango fruit ripening. University of Khartoum Journal of Agricultural Sciences 1(1): 33-51.
- Abu-Goukh, A.A., H.E. Mohamed and H.B. Garray. 2005. Physio-chemical changes during growth and development of mango fruits. University of Khartoum Journal of Agricultural Sciences 13(2): 179-191.
- Abu-Goukh, A.A., A.E. Shattir and M.M.A. El-Balla. 2003. Effect of harvesting method on quality and storability of dry dates in Sudan. Journal of Tropical Science 43(1): 53-56.
- Agnihotri, B. N., K. L. Kapur and K. R. Goel. 1962. Ascorbic acid content of fruits during growth and maturity. Journal of Science and Culture 28: 435-438.
- Agrawal, R., P. Parihar, B. L. Mandhyan and D. K. Jain. 2002. Physico-chemical changes during ripening of guava fruit (*Psidium guajava* L.). Journal of Food Science and Technology 39(1): 94-95.
- Akamine, E.K. and T. Goo. 1979. Respiration and ethylene production in fruits of species and cultivars of *Psidium* and species of *Eugenia*. Journal of American Society of Horticultural Science 104(5): 632-635.
- Barvelled, W.H. 1993. Dates Palm Products. Food and Agriculture Organization of the United Nation (FAO). Agricultural Service, Bulletin No. 101. Rome, Italy. 216 p.
- Bashir, H.A. and A.A. Abu-Goukh. 2003. Compositional changes during guava fruit ripening. Journal of Food Chemistry 80(4): 557-563.
- Charlimer, R.A. 1956. Respiration rate. pp. 101-102. In: R.A. Charlimer (ed.). Quantitative Chemical Analysis. Oliver and Boyd Ltd., Edinburgh, and London. UK.
- Datta, M. N. and S. K. Mukherjee. 1980. Studies on the changes during growth and development of guava (*Psidium guajava* L.) fruits. Indian Journal of Horticultural Sciences 37(3): 211-219.
- El-Bulk, R.E., E.F.E. Babiker and A.H.E. Tinay. 1997. Changes in chemical composition of guava fruits during development and ripening. Journal of Food Chemistry 59(3): 395-399.
- FAO. 2017. Crop Production Data. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. Available online at <http://faostat.fao.org>.
- Harding, P.L. and T.T. Hatoon. 1967. Mangoes at their best. pp. 137-145. Proceeding of International Symposium on Subtropical and Tropical Horticulture, Horticultural Society of India, Bangalore. India.
- Hegde, M.V. 2001. Studies on Fruit Growth, Development and Ripening and Effect of Radiation on Storage of Guava (*Psidium guajava* L.) Fruits. Ph.D. Thesis. C.C.S. Haryana Agricultural University, Hisar, India.
- HSA. 2017. Annual Reports. Horticultural Sector Administration (HSA), Ministry of Agriculture and Forestry, Khartoum, Sudan.
- Misra, K. and T.R. Swshadri. 1968. Chemical component of the fruit of *Pisidium guajava*. Journal of Phytochemistry 7: 641-645.

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- Mohamed-Nour, I.A. and A.A. Abu-Goukh. 2010. Effect of Ethrel in aqueous solution and ethylene released from Ethrel on guava fruit ripening. *Agriculture and Biology Journal of North America* 1(3): 232-237.
- Mohamed-Nour, I.A. and A.A. Abu-Goukh. 2013. Effect of maleic hydrazide and waxing on ripening and quality of guava (*Psidium guajava* L.) fruit. *Gezira Journal of Agricultural Science* 11(1): 91-101.
- Mowlah, G. and S. Ito. 1982. Guava (*Psidium guajava* L.) sugar component and relation to enzymes at stages of fruit development and ripening. *Journal of Japanese Society for Food Science and Technology* 29(8): 472-476.
- Patra, R., S. Debnath, B.C. Das and M.A. Hasan. 2004. Effect of mulching on growth and fruit yield of guava cv. 'Sardar'. *Orissa Journal of Horticulture* 32: 38-42.
- Rodriguez, R.P. C. Agarwal and N.K. Saha. 1971. Biochemical changes during development of 'Safeda' guava fruit, *Indian Food Packer* 25(1): 5-20.
- Ruck, J.A. 1963. *Chemical Methods for Analysis of Fruit and Vegetable Products*. Publication No. 1154. Department of Agriculture, Canada.
- Salunkhe, D.K. and B.B. Desai. 1984. Guava. pp. 39-46. In: *Postharvest Biotechnology of Fruits*. Vol. 2. CRC Press, Inc. Boca Raton, Florida, USA.
- Singleton, V.L. and J.R. Jr. Rossi. 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Viticulture* 16(3): 144-157.
- Somogyi, M. 1952. Notes on sugar determination. *Journal of Biological Chemistry* 195: 19-23.
- Watt, B.K. and A.L. Merrill. 1975. *Composition of Foods*. Agriculture Handbook No. 8. United States Department of Agriculture, Washington D.C., USA.
- Yemm, E.W. and A.J. Willis. 1954. The estimation of carbohydrates in plant extracts by anthrone. *Biochemical Journal* 57: 508-513.