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Compositional changes during guava fruit ripening

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Abstract

Compositional changes of fruit pulp and peel during ripening of white- and pink-fleshed guava fruits were studied. The white and pink guava fruits exhibited a typical climacteric pattern of respiration. Fruit tissue firmness decreased progressively, in a similar manner, in both guava fruit types. Total soluble solids (TSS) and total sugars increased in pulp and peel of both guava types with decrease in flesh firmness. More increase in total sugars was observed after the climacteric peak of respiration. Reducing sugars and titratable acidity increased up to the full-ripe stage and then decreased. Ascorbic acid and phenolic compounds decreased continuously during ripening of the two types. The peel showed higher values of ascorbic acid, total protein and phenolic compounds than the plup. The white-fleshed guavas had higher levels of TSS, total sugars, reducing sugars. titratable acidity, phenolic compounds and ascorbic acid content then the pink-fleshed fruits.

Keywords: Guava; Compositional changes; Fruit ripening

1. Introduction

Guava (*Psidium guajava* L.) is a popular fruit crop in Sudan. It is grown in almost every State. Although Sudan has great potential to produce high quality guavas and to export them to other countries, its marketability is still limited to local markets. This is due to the delicate nature of the fruit, poor handling practices, and inadequate transportation and storage facilities. Therefore, proper handling techniques and control of the ripening process are crucial for the development of a sound guava industry in Sudan. Compositional changes of the fruit is of concern for understanding metabolic processes such as fruit ripening, softening and general senescence. Moreover, they are of importance in determining commercial practices and postharvest requirements. This study was conducted to investigate the compositional changes during guava fruit ripening and to provide a base-line information regarding these biochemical changes, to assist in development of sound programmes for controlling guava fruit ripening and/or loss of flesh firmness during transport and storage.

2. Materials and methods

2.1. Experimental material

Mature green fruits of white- and pink-fleshed guava types were obtained from the University of Khartoum orchard at Shambat (Lat. 15° 40′ N. long. 32° 22′ E). Fruits were selected for uniformity of size, colour and freedom from blemishes. About 400 fruits of each guava fruit type were washed, dried, placed in carton boxes, and stored in the ripening room at 22±1 °C and 90–95% RH. Random samples of 16 fruits from each type, were removed daily for respiration and flesh firmness determination. Respiration rate was determined for each fruit of the sample, separately, using the total absorption method of Charlimers (1956). Flesh firmness was measured by the Magness and Taylor firmness tester (D. Ballauf Meg Co.) equipped with an 8 mm-diameter plunger tip. Two readings were taken from opposite sides of each fruit after the peel was removed. The fruits were labelled and stored at −12 °C and later

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sorted into seven groups (2.13, 1.82, 1.52, 1.21, 0.91, 0.61 and 0.30 kg/cm^2) according to their flesh firmness. Each group consisted of 10 fruits, replicated 4 times.

2.2. Compositional changes

The frozen fruits of the different groups were thawed separately for 90 min. Total soluble solids (TSS) were measured directly in the fruit juice, using a Kruss hand refractometer (model HRN-32). Thirty grammes of pulp or peel from each group were homogenized in 100 ml of distilled water for one min in a Sanyo Solid State blender (model SM 228 P) and centrifuged at 10,000 rpm for 10 min in a Gailenkamp portable centrifuge (CF 400). The volume of the supernatant, which constitutes the pulp or peel extracts, was determined. Total sugars were determined, in pulp or peel extract, using the Anthrone method of Yemm and Willis (1954). Reducing sugars were determined according to the technique described by Nelson (1944), as modified by Somogyi (1952). Titratable acidity was measured according to the method described by Ranganna (1979). The protein-dye binding procedure of Bradford (1976) was used for total protein determination. Total phenolic compounds were measured by the Folin–Ciocalteu method (Singleton & Rossi, 1965). Ascorbic acid was determined by the 2,6-dichiorophenol-indophenol titration method of Ruck (1963).

2.3. Statistical analysis

Analysis of variance (ANOVA), followed by Fisher's protected LSD test with a significance level of $P<0.05$, were performed on all data.

3. Results and discussion

3.1. Changes in fruit flesh firmness

Fruit flesh firmness values of the two guava types studied showed a progressive decline during ripening (Fig. 1). The decline in firmness observed was about eight-fold from the hard mature green stage to the final soft ripe stage. Most of this decline occurred during the first 10 days. Similar drops in guava fruit firmness have been reported (Rodriguez, Agarwal, & Saha, 1971). Abu-Goukh and Abu-Sarra (1993) observed a rapid decrease in flesh firmness during ripening of three mango cultivars. Similar patterns of changes were

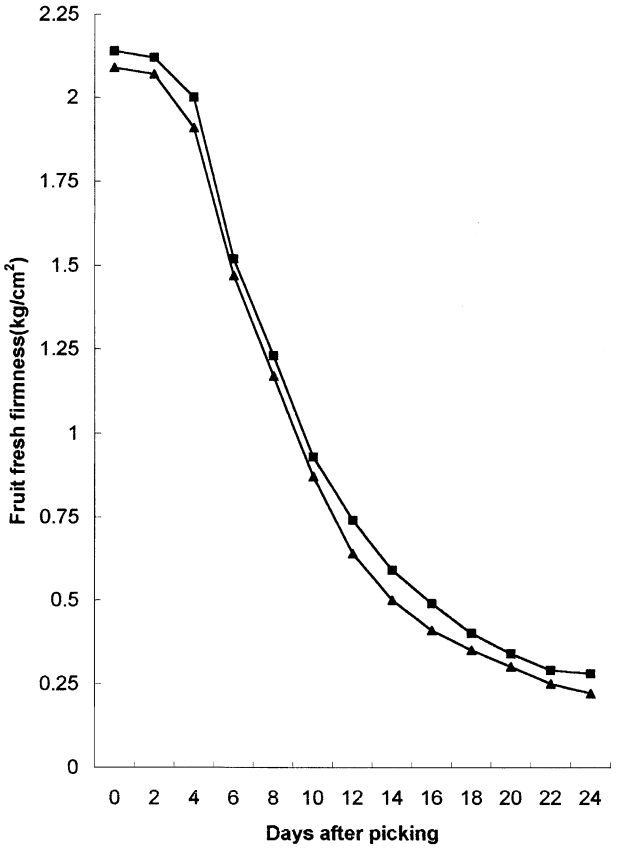

Fig. 1. Changes in fruit flesh firmness during ripening of white (■) and pink (▲) guava fruits.

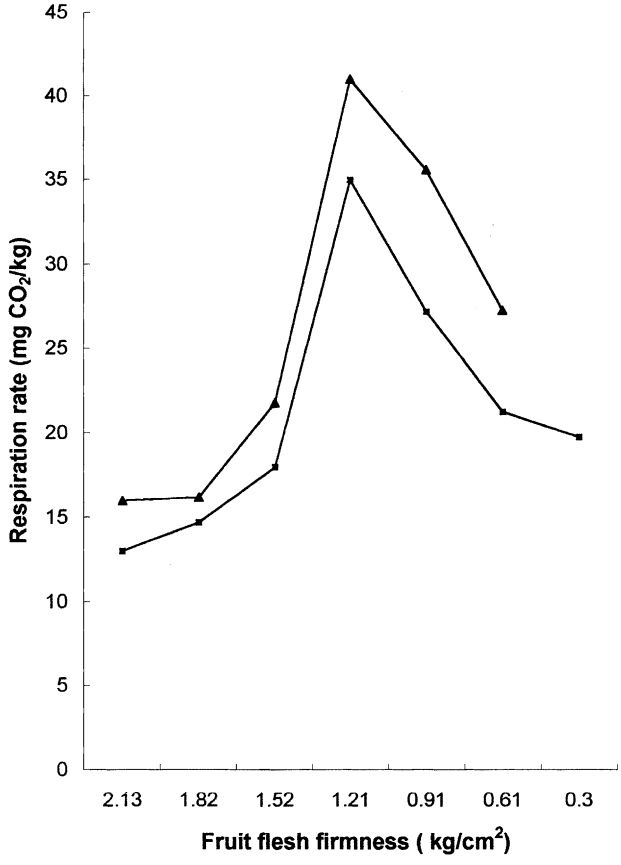

Fig. 2. Relationship between CO_2 production and fruit flesh firmness during ripening of White (■) and pink (▲) guava fruits.

reported for banana (Abu Goukh, Ibraham, & Yusuf, 1995), pear (Luton & Holand, 1986), apple, peach and apricot (Salunkhe & Wu, 1973) and date (Barrevelled, 1993).

3.2. Changes in respiration rate

The rate of CO_2 production, during ripening of both guava types exhibited a typical climacteric pattern of respiration, with a climacteric peak at 1.21 kg/cm^2 flesh firmness (Fig. 2). Respiration rate was significantly higher in the pink guavas than the white ones. A similar climacteric pattern was reported by Akamine and Goo (1979).

3.3. Compositional changes

3.3.1. General quality and composition

During ripening, a fruit passes through a series of overt changes in colour, texture and flavour, indicating that compositional changes are taking place.

Attainment of maximum eating quality of a fruit necessitates completion of such chemical changes. Unripe fruits, are usually hard in texture, starchy and acidic in taste and sometimes astringent. After ripening, they become soft, sweet, non acidic, less astringent and highly flavoured, so more acceptable as human food. These changes generally coincide with the peak of respiration. Compositional changes were determined during ripening in pulp and peel of both guava types.

3.3.2. Total soluble solids and total sugars

Total soluble solids (TSS) and total sugars increased in both guava types with decrease in flesh firmness (Fig. 3). TSS increased 1.2-fold in both types. Rodriguez et al. (1971) observed a gradual increase in TSS and total sugars during guava fruit ripening. Similar findings were reported for banana (Ibrahim, Abu-Goukh, & Yusuf, 1994), mango (Abu-Goukh & Abu-Sarra, 1993; Minessy, Saeed, & El-Rayeh, 1984) and date (Dowson & Aten, 1962). Biale (1960) attributed that increase in TSS and total sugars during fruit ripening to hydrolysis of starch to sugars. More increase in total sugars in pulp and peel was observed after fruit firmness reached 1.21 kg/cm^2, which coincided with the climacteric peak of respiration (Fig. 2). The remarkable increase in total sugars observed after the climacteric peak (Fig. 4) may be attributed to the increase in activity of enzymes responsible for starch hydrolysis and for decline in the rate of sugar breakdown by respiration. The peel, in

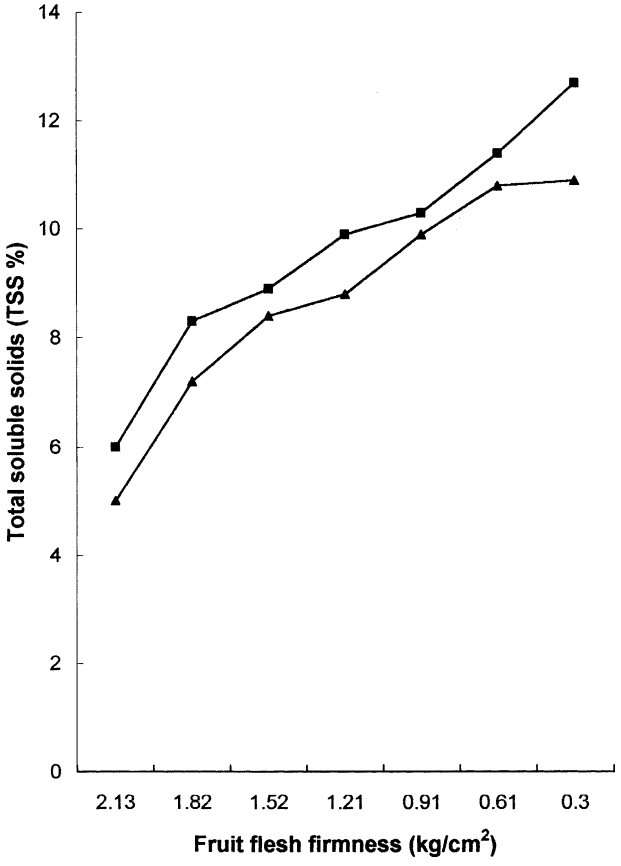

Fig. 3. Changes in total soluble solids (TSS) during ripening of white (■) and pink (▲) guava frults.

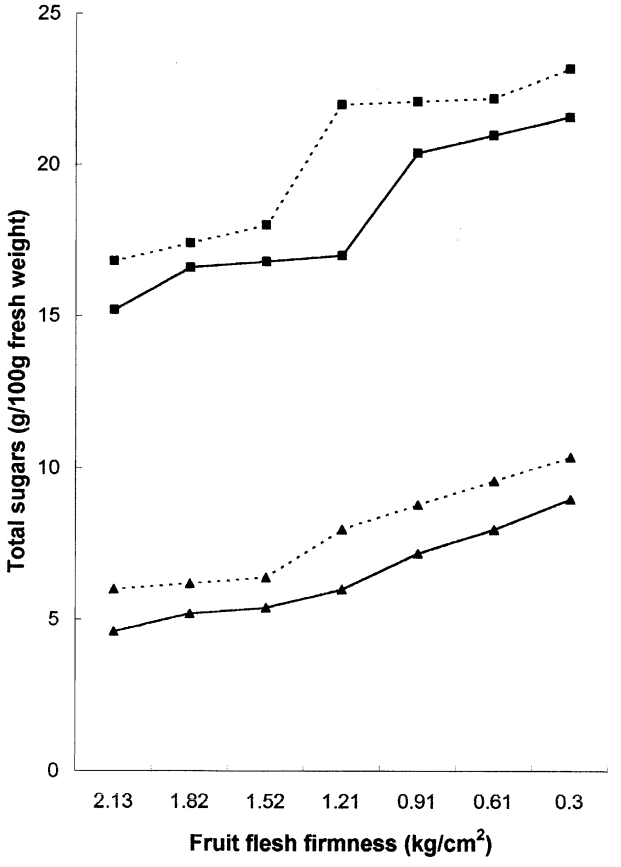

Fig. 4. Changes in total sugars in pulp (—) and peel (.....) during ripening of White (■) and pink (▲) guava fruits.

both guava types, contained more total sugars than the pulp. This may be due to the lower moisture content of the peel compared with the pulp, since sugars were expressed in g per 100 g fresh weight (Fig. 4).

3.3.3. Reducing sugars

The reducing sugars in the pulp and peel increased up to the climacteric peak and subsequently decreased. Maximum values reached were 5 and 8 in the pulp and 6 and 10 (g/l00 g fresh weight) in the peel of the pink and white guavas, respectively (Fig. 5). Climacteric fruits, in particular, may show considerable changes in sugar content during fruit ripening (Hulme, 1970). Starch and sucrose change into glucose during fruit ripening (Wills, Lee, Graham, McGlasson, & Hall, 1981). Mowlah and Itoo (1982) showed that glucose, fructose and sucrose were the main sugars in the white- and pink-fleshed guavas. The level of fructose increased during guava fruit ripening and then decreased in the over-ripe fruits (Le-Riche, 1951). Subramanyam and Acharya (1957) also found that reducing sugars increased during guava fruit ripening and then decreased. Similar results were also reported in mango fruits (Abu-Goukh & Abu-Sarra, 1993, Subramanyam, Gouri, & Krishnamarthy, 1976).

3.3.4. Titratable acidity

Titratable acidity in both guava types increased up to the climacteric peak and declined thereafter (Fig. 6). Similar results were reported during ripening of banana (Ahmed & Tingwa, 1975; Desai & Deshpande, 1975) and mango (Abu-Goukh & Abu-Sarra, 1993). The pulp in both guava types showed lower titratable acidity than the peel. Similar findings were reported in mango fruits (Abu-Goukh & Abu-Sarra, 1993).

3.3.5. Total protein

Total protein in pulp and peel of the white and pink guava types increased systematically up to the full-ripe stage (fruit firmness 0.61 kg/cm) and suddenly decreased (Fig. 7). Abu-Goukh and Abu-Sarra (1993) reported that total protein in pulp and peel of three mango cultivars increased up to the full-ripe stage and then decreased at the over-ripe stage. That decline was explained as breakdown of proteins during senescence, which supported the view that proteins in ripening fruits are enzymes required for the ripening process (Frenkel, Klein, & Dilley, 1968). Although the peels of both guava types studied had higher protein contents than the pulps, no higher metabolic activity can be ascribed to the protein at this stage, but it can be explained by

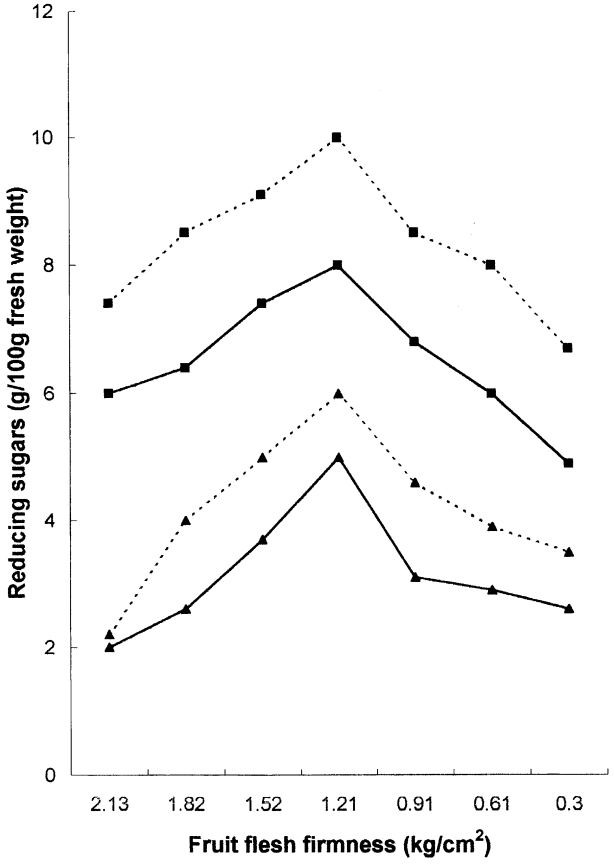

Fig. 5. Changes in reducing sugars in pulp (—) and peel (.....) during ripening of white (■) and pink (▲) guava fruits.

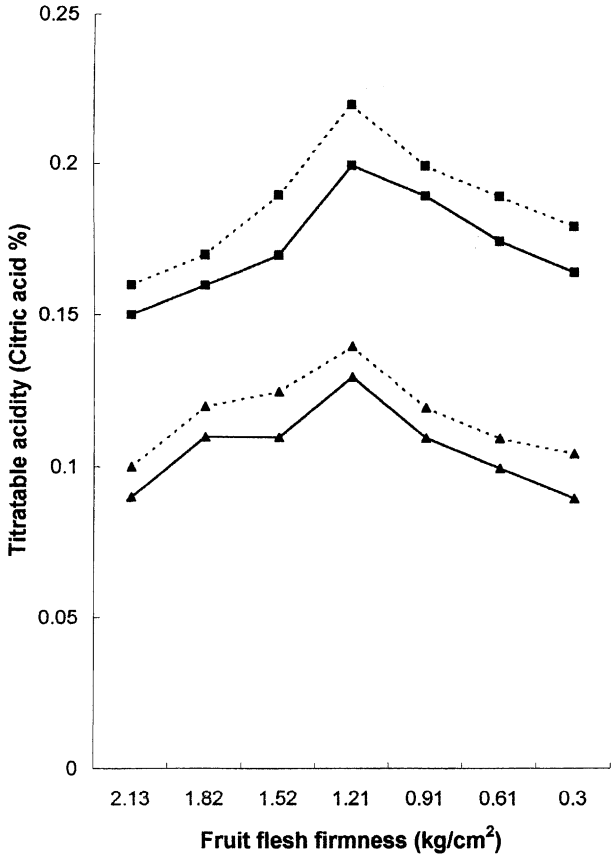

Fig. 6. Changes in titratable acidity in pulp (—) and peel (.....) during ripening of white (■) and pink (▲) guava fruits.

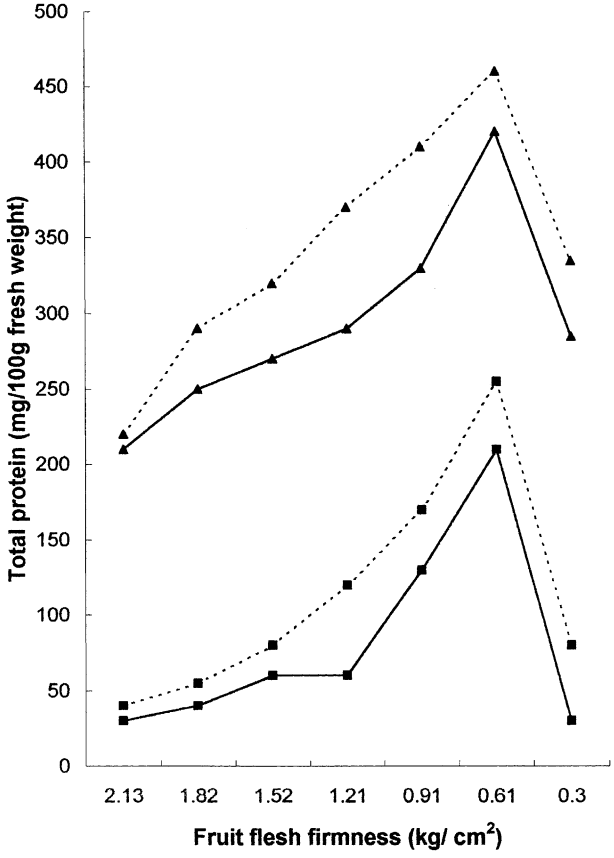

Fig.7. Changes in total protein content in pulp (—) and peel (.....) during ripening of white (■) and pink (▲) guava fruits.

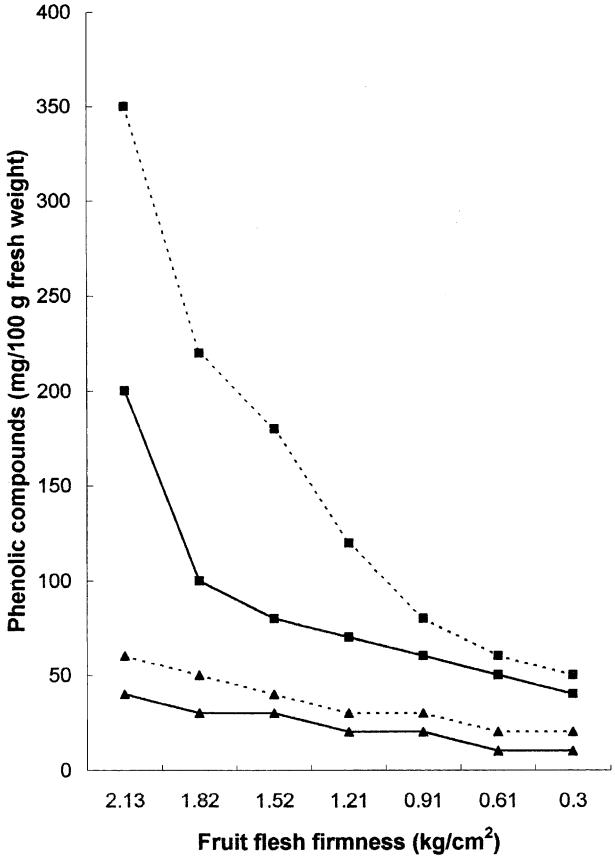

Fig. 8. Changes in phenolic compounds in pulp (—) and peel (.....) during ripening of white (■) and pink (▲) guava fruits.

the lower moisture content of the peel than the pulp, since the protein content was expressed in mg per 100 g fresh weight.

3.3.6. Phenolic compounds

Phenolic compounds in pulp and peel of both guava types progressively decreased with decrease in flesh firmness (Fig. 8). Mowlah and Itoo (1982) reported that the total polyphenol decreased in white and pink guavas throughout the immature stage to the full-ripe stage. The decrease in phenolic compounds with fruit ripening was also reported in banana (Ibrahim et al., 1994), mango (Abu-Goukh & Abu-Sarra, 1993) and date (Al-Ogaidi & Mutlak, 1986). The decrease in phenolic compounds in the white guava type was much more marked than that in the pink one. The decrease in total phenolics was 7- and 3-fold in the pulp in the white and pink types, respectively (Fig. 8). This may add to the better taste of the white-fleshed guava type which contains more total and reducing sugars than the pink-fleshed type (Figs. 4 and 5). The decrease in astringency in guava during ripening was associated with the increased polymerization of leucoanthocyanidins and hydrolysis of the astringent arabinose ester of hexahydrodiphenic acid (Goldstein & Swain, 1963; Misra & Swshadri, 1968). The peel of both types showed higher values of total phenolics than the pulp. This may have significance in plant disease resistance and thus protection of the fruit against diseases and insect pests.

3.3.7. Ascorbic acid

Ascorbic acid in pulp and peel of both guava types decreased steadily during fruit ripening. At the final stage (flesh firmness 0.3 kg/cm^2) the amount of ascorbic acid retained was 86.3% in the pulp and 85.6% in the peel of the white-fleshed guava fruits compared to 76.6% and 78.1% of the plup and peel of the pink-fleshed guavas, respectively (Fig. 9). The 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, Kapur, & Goel, 1962; El-Zorkani, 1968). The white guava fruits had 19.2% and 22.3% more ascorbic acid than the pink ones, in pulp and peel, respectively (Fig. 9). Variable reports are available regarding the amount of ascorbic acid in the white and pink guava types. El-Faki and Saeed (1975) reported higher values in the white guava, while other investigators reported the reverse (Agnihotri et al., 1962; El-Zorkani, 1968).

The peel in both types showed much higher values of ascorbic acid than the pulp (Fig. 9). The peel of guava fruit was reported to contain most of the ascorbic acid

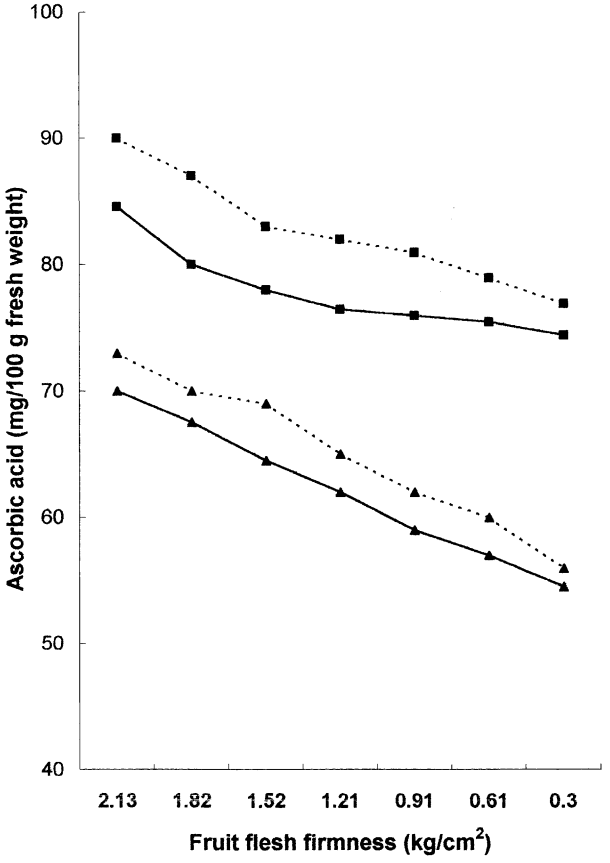

Fig. 9. Changes in ascorbicacid content in pulp (—) and peel (.....) during ripening of white (■) and pink (▲) guava fruits.

in the fruit (Wilson, 1980). Similar results were reported for mango (Lakshminarayana, Subhdra, & Subramamyam, 1970; Siddappa & Bhatia. 1954). The higher values of ascorbic acid in the peel were attributed to interference of phenolic compounds with the dye, 2.6 dichlorophenol indophenol, used in the assay (Lasksmiuarayana et al., 1970). In contrast, Abu-Goukh and Abu-Sarra (1993) reported lower values for ascorbic acid in the peel than the pulp in three mango cultivars.

References

Abu-Goukh, A. A., & Abu-Sarra, A. F. (1993). Compositional changes during mango fruit ripening. *University of Khartoum Journal of Agricultural Sciences*, *1*(1), 33–51.

Abu-Goukh, A. A., Ibrahim, K. E., & Yusuf, K. S. (1995). A comparative study of Banana fruit quality and acceptability under different ripening conditions. *Sudan University of Khartoum Journal of Agricultural Sciences*, *3*(2), 32–48.

Agnihortri, B. N., Kapur, K. L., & Goel, K. R. (1962). Ascrobic acid content of fruit during growth and maturity. *Science and Culture*, *28*, 435–438.

Ahmed, O. K., & Tingwa, P. O. (1995). Effect of gibberellic acid on several parameters of ripening banana fruit. *University of Khartoum Journal of Agricultual Sciences*, *3*(1), 47–59.

Akamine, E. K., & Goo, T. (1979). Respiration and ethylene production in fruits of species and cultivars of *Psidium* and *Eugenia* species. *Journal of the American Society for Horticultural Science*, *104*(5), 632–636.

Al-Ogaidi, H. K., & Mutlak, H. H. (1986). The phenolic compounds of four date cultivars during maturity stages. *The Date Palm Journal*, *4*(2), 191–196.

Barrevetled, W. H. (1993). *Date palm production (agricultural service bull. no. 101)*. Rome: Food and Agriculture Organization of the United Nations.

Biale, J. B. (1960). The post-harvest biochemistry of tropical and subtropical fruits. *Advances in Food Research*, *10*, 293–354.

Bradford, M. M. (1976). A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Analytical Biochemistry*, *72*, 248–254.

Charlimers, R. A. (1956). Respiration rate. In R. A. Charlimers (Ed.), *Quantitive chemical analysis* (pp. 101–102). Edinburgh and London: Oliver and Boyd Ltd.

Desai, B. B., & Deshpande, P. S. (1975). Chemical transformation in three varieties of banana fruits stored at 20 °C. *Mysore Journal for Agricultural Science*, *9*, 634–636.

Dowson, V. H., & Aten, A. (1962). *Dates handling, processing and packing (FAO plant production and protection series no. 13)*. Rome: Food and Agriculture Organization of the United Nations.

El-Faki, H. A., & Saeed, A. R. (1975). Physio-chemical studies on guava and their suitability for processing. *Sudan Journal of Food Science and Technology*, *7*, 9–17.

El-Zorkani, A. S. (1968). A preliminary report on vitamin C, sugars, pectin and acid contents of guava. *Agricultural Research Review*, *46*, 107–111.

Frenkel, C., Klein, I., & Dilley, D. R. (1968). Protein synthesis in relation to ripening of pome fruits. *Plant Physiology*, *43*, 1146–1153.

Goldstein, J. L., & Swain, T. (1963). Changes in tannins of ripening fruits. *Phytochemistry*, *2*, 371–373.

Hulme, A. C. (1970). *The biochenistry of fruits and their products (Vol. 1)*. New York: Academic Press.

Ibrahim, K. E., Abu-Goukh, A. A., & Yusuf, K. S. (1994). Use of ethylene, acetylene and ethrel on banana fruit ripening. *University of Khartoum Journal of Agricultural Sciences*, *2*(1), 73–92.

Lakshminarayana, S., Subhdra, N. V., & Subramanyani, H. (1970). Some aspects of developmental physiology of mango fruit. *Journal of Horticultural Science*, *45*(2), 133–142.

Le-Riche, F. (1951). *Chemical changes during the development of guava varieties*. Union of South African Department of Agriculture. Bulletin no. 21.

Luton, M. T., & Holland, F. A. (1986). The effect of preharvest factors on the quality of stored "Conference" pears. *Journal of Horticultural Science*, *61*(1), 23–32.

Minessy, F. A., Saeed, A. R., & El-Rayah, A. (1984). Respiration and chemical changes associated with ripening of mango fruit (*Mangifera Indica L.*). *Sudan Agricultural Journal*, *10*, 103–111.

Misra, K., & Swsbadri, T. R. (1968). Chemical components of the Fruit of *Psidium guajava*. *Phytochemistry*, *7*, 641–646.

Mowlah, G., & Itoo, S. (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.

Nelson, N. M. (1944). A photometric adaptation of the Somogyi method for the determination of glucose. *Journal of Biological Chemistry*, *153*, 375–380.

Ranganna, S. (1979). Titratable acidity. In S. Ranganna (Ed.), *Manual of analysis of fruit and vegetable products* (pp. 7–8). New Delhi: Tata Mc-Graw Hill.

Rodriguez, R., Agarwal, P. C., & Saha, N. K. (1971). Biochemical changes during development of "Safeda" guava fruit. *Indian Food Packer 25 (1)*, 5–20.

Ruck, J. A. (1963). *Ascorbic acid*. Canada Department of Agriculture. Publication no. 1154.

Salunkhe, D. K., & Wu, M. T. (1973). Effect of subatmospheric pressure storage on ripening and associated chemical changes of certain deciduous fruits. *Journal of the American Society for Horticultural Science*, *98*, 113–116.

Siddappa, G. S., & Bhatia, B. S. (1954). Tender green mangoes as source of vitamin C. *Indian Journal for Horticulture Science*, *11*, 104–106.

Singleton, V. L., & Rossi, J. A. Jr. (1965). Colorimetry of total phenolies with Phosphomolybodic- phosphotungestic acid reagents. *American Journal of Enology and Viticulture*, *16*(3), 144–157.

Somogyi, M. (1952). Notes on sugar determinations. *Journal of Biological Chemistry*, *195*, 19–23.

Subramanyam, V. V. R., & Acharya, K. T. (1957). Lesser-known Indian vegetable fat. 1. Oleic-rich fats. *Journal of Food Science and Agriculture*, *8*, 657–658.

Subramanyam, H., Gouri, S., & Krishnamarthy, S. (1976). Ripening behaviour of mango fruit graded on specific gravity basis. *Journal of Food Science and Technology*, *13*(2), 84–86.

Wills, R. H. H., Lee, T. H., Graham, D., McGlasson, W. B., & Hall, F. G. (1981). *Postharvest: an introduction to the physiology and handling of fruit and vegetables*. Westport, Connecticut: AVE Publ. Co.

Wilson, C. W. (1980). Guava. In S. Nagy, & P. F. Shaw (Eds.), *Tropical and subtropical fruits: compositional, properties and uses* (pp. 279). Westport, Connecticut: AVI. Publishing Co.

Yemm, E. W., & Willis, A. J. (1954). The estimation of carbohydrates in plant extracts by anthrone. *Biochemical Journal*, *57*, 508–513.