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Changes in chemical composition of guava fruits during development and ripening

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Changes in the chemical composition of four guava cultivars were studied during development and ripening of the fruits. Guava fruit was analysed at three developmental stages for chemical composition, total sugars (fructose, glucose and sucrose), ascorbic acid, total soluble solids, total pectin and polyphenols. Investigation showed that total sugar contents were significantly increased with fruit growth and development in all cultivars. The maximum level varied from 13·7 to 30·6 mg per 100 ml of juice. Individual sugar contents increased gradually with fruit growth and development. The maximum level varied from 5·64 to 7·67, 1·90 to 8·00 and 6·20 to 7·78 mg per 100 ml of juice for fructose, glucose and sucrose, respectively, in all cultivars. Ascorbic acid was significantly increased with fruit growth and development in all cultivars. The maximum level varied from 88·2 to 113·3 mg per 100 g. Total soluble solids gradually increased with fruit development in all cultivars, which differed in their final value (11·1–13·2°B). Polyphenols significantly decreased with fruit growth and development in all cultivars, which differed in their final value (0·20–0·30%). Total pectin for Shambati and Shendi cultivars significantly increased with fruit growth and development, while for Pakistani and Ganib it reached its maximum when the fruits were 106 days old, and thereafter it declined rapidly. The maximum level varied from 0·62 to 1·00%.

INTRODUCTION

Guava is one of the most important commercial fruit crops in Sudan consumed locally. It is a good source of ascorbic acid, pectin, sugars and certain minerals. Its skin and flesh colours vary from variety to variety depending on the amount and type of pigments. The fruit softens very rapidly during ripening (Wilson, 1980). In early stages of development the firmness of guava is due to the presence of pectic substances. The softening is the result of degradative changes in the pectic substance due to the activity of pectic enzymes (Huber, 1983). In papaya, as the fruit ripens the activity of pectin methylesterase increases and more pectin is solubilized (Jagtiani *et al.*, 1988); therefore, the pectin content of guava fruit is higher in the mature stage than in the ripe stage (Chyan *et al.*, 1992). Studies on ascorbic acid in guava (Rodriguez *et al.*, 1971) showed that the ascorbic acid content for developing guava increased slowly during the initial growing period, followed by rapid increase during maturation and ripening. Mowlah & Itoo (1982) reported that, in white and pink seedling varieties of guava, the main sugar components were fructose and sucrose. The soluble solids content of guava fruit gradually increased with maturation except during the end of the growth period (Rodriguez *et al.*, 1971).

Studies of the chemical composition of guava fruits in Sudan during development and ripening are not fully reported. It was decided, therefore, that, as the fruits of a number of cultivars of guava are widely consumed in the Sudan at all stages of ripening, it might be of interest (1) to select, on the basis of commercial importance, a number of cultivars popular in the Sudan, and (2) to analyse typical samples of guava at each developmental stage to determine the extent to which the levels of the major components, notably those of potential nutritional value for humans, change over the growing season.

MATERIALS AND METHODS

Four guava cultivars, Shambati, Pakistani, Shendi and Ganib, were obtained from the University of Khartoum Farm during the season 1991/1992. Fruits were picked manually at different stages of development: immature

(15–33 days), mature (51–88 days) and ripe (106–126 days after fruit set).

Ascorbic acid determination

Ascorbic acid was determined by the method described by Ruck (1963). A 30 g portion of homogenised sample was blended with about 100 ml of 0·4% oxalic acid for 2 min in a Waring blender. The blended mixture was made to 500 ml with 0·4% oxalic acid and was filtered; 20 ml of the filtrate were titrated with standard 2,6-dichlorophenol indophenol. Results were expressed as mg per 100 g wet basis.

Total soluble solids determination

Fruits were blended in a Waring blender. Total soluble solids expressed as °Brix (°B), were determined with a refractometer (Abbe No. 27137, UK) at 25°C.

Glucose, fructose and sucrose determination

Glucose, fructose and sucrose were determined colorimetrically using the method of Blakeny & Mutton (1980).

Total sugar determination

Total sugar was determined by summation of individual values of fructose, glucose and sucrose.

Total pectin determination

Pectin was determined by the method of Ahmed and Labavitch (1977). To 1 g of guava fruit, 25 ml of 72% H_2SO_4 were added. The mixture was stirred for 30 min, diluted to 500 ml with distilled water and filtered through Whatman No. 1 filter paper. Pectin was assayed colorimetrically using the method of Blumenkrantz and Aboe-Hansen (1973). A standard curve was prepared expressing the results as glucuronic acid (mg ml^{-1}) which gives a colour intensity equivalent to that given by pectin after correcting for blank.

Polyphenols determination

Polyphenols were determined by the method described by Price and Butler (1977). A 60 mg portion of guava fruit was shaken manually for 60 s with 3 ml of methanol in a test tube. The mixture was filtered and the tube was quickly rinsed with 3 ml of methanol. The filtrate was mixed with 50 ml of water and analysed within an hour. To 1 ml of filtrate, 3 ml of 0·1 M $FeCl_3$ in 0·1 N HCl and 3 ml of 0·008 M $K_4Fe(CN)_6$ were added. The absorbance of the colour developed after 10 min at 30°C was read at 720 nm. A standard curve was prepared expressing the results as catechin equivalents, i.e. amount of catechin (mg ml^{-1}) which gives a colour intensity equivalent to that given by polyphenols after correcting for the blank.

Statistical analysis

Sample from each cultivar and at each harvest time was analysed in triplicate and the figures were then averaged. Data were assessed by analysis of variance (Snedecor & Cochran, 1987) and by Duncan's multiple-range test with a probability $P \leq 0{\cdot}05$ (Duncan, 1955)

RESULTS AND DISCUSSION

Tables 1 and 2 show changes in sugar and ascorbic acid contents in fruits of four guava cultivars during growth and development, respectively. For all cultivars both total and individual sugar contents (Table 1) increased gradually during the early stages of development and significantly ($P \leq 0{\cdot}05$) at the later stages of development (106–126 days after fruit set). When the fruits were 126 days old, fructose represented around 20%, 38%, 37% and 41% of the total sugar for Shambati, Pakistani, Shendi and Ganib cultivars, respectively. Glucose represented around 59%, 23%, 25% and 14% of the total sugar for the cultivars, respectively, while sucrose represented around 21%, 39%, 37% and 45% of the total sugar for the cultivars, respectively. The glucose/fructose ratio for all cultivars (except Shambati) is very low, indicating that fructose is rapidly built-up with fruit growth and development. This high level is of dietary significance, since fructose tends to lead to a lower level of post-prandial hyperglycaemia than would result from the same intake of glucose (Johnson, 1993). Results revealed that, when guava fruit attained the ripe stage (126 days), the main sugar components were fructose and sucrose (Table 1). However, there is a notable exception, i.e. for Shambati cultivar glucose content represents around 59% of the total sugar and the glucose/fructose ratio was about 2·98 when the fruits were 126 days old. The explanation for this difference may lie in physiological differences between the cultivars. These results are in agreement with those of Mowlah and Itoo (1982), who showed fructose and sucrose were the major sugars in guava fruits. For all cultivars, ascorbic acid content (Table 2) increased slowly during the initial growing period and significantly ($P \leq 0{\cdot}05$) during maturation and ripening. Few differences were found among the cultivars. These results are in agreement with those of Rodriguez *et al.* (1971), who reported that the ascorbic acid content for developing guava increased slowly during the initial growing period followed by a rapid increase during maturation and ripening.

Figures 1–3 show changes in total soluble solids, polyphenols and total pectin in fruits of four guava cultivars during growth and development, respectively. Total soluble solids (°B) gradually increased with fruit development in all cultivars (Fig. 1). When fruits were 15 days old, total soluble solids contents were 7·70, 6·20, 6·60 and 9·70°B for Shambati, Pakistani, Shendi and Ganib cultivars, respectively. When the fruits were 126 days old, total soluble solids were 13·2, 11·1, 12·2, and 12·5°B, respectively. It was observed that a significant ($P \leq 0.05$) increase in total soluble solids content starts after day 106 from fruit set (Fig. 1). These results are in agreement with those of Rodriguez *et al.* (1971), who reported that soluble solids content of guava fruits gradually increased with maturation except during the end of the growth period. Polyphenols were significantly ($P \leq 0.05$) decreased with fruit growth and development in all cultivars (Fig. 2). When fruits were 15 days old, polyphenol contents were 0·15%, 0·21%, 0·27% and 0·27% for Shambati, Pakistani, Shendi and Ganib cultivars, respectively. When the fruits were 126 days old, polyphenol contents were 0·03%, 0·07%, 0·03% and 0·05%, respectively. It is observed that a significant ($P \leq 0.05$) decrease in polyphenol content starts after day 51 from fruit set (Fig. 2). The results revealed that phenolic compounds were present in relatively high quantities in the immature green fruits, and that when fruits attained the consumable stage only traces of polyphenols were observed. Similar results were obtained by Spayd and Morris (1981) in strawberry fruits. Total pectin markedly increased with fruit growth and development in all cultivars (Fig. 3). However, for

Table 1. Changes in sugar content (mg per 100 ml of juice, mean ± SD) of guava cultivars during growth and development

Cultivar	Days after fruit set	Total sugar	Fructose (F)	Glucose (G)	Sucrose	G/F ratio
Shambati	15	0·00 (±0·00)^{e}	0·00 (±0·00)^{e}	0·00 (±0·00)^{d}	0·00 (±0·00)^{d}	0·00
	33	2·20 (±0·23)^{d}	0·68 (±0·21)^{bcde}	0·53 (±0·01)^{de}	0·98 (±0·01)^{bcd}	0·78
	51	3·05 (±0·27)^{d}	0·72 (±0·56)^{bcde}	0·60 (±0·01)^{de}	1·73 (±0·64)^{bc}	0·83
	70	4·20 (±0·56)^{c}	2·02 (±0·40)^{bcd}	0·76 (±0·27)^{d}	1·42 (±0·89)^{bc}	0·38
	88	9·00 (±1·26)^{c}	2·62 (±0·28)^{bc}	5·10 (±0·01)^{bc}	1·32 (±0·97)^{bc}	1·94
	106	12·9 (±2·91)^{b}	3·14 (±0·22)^{b}	6·30 (±1·72)^{b}	3·43 (±0·08)^{ab}	2·03
	126	30·6 (±2·49)^{a}	6·08 (±1·95)^{a}	18·0 (±0·71)^{a}	6·53 (±0·33)^{a}	2·98
Pakistani	15	0·00 (±0·00)^{d}	0·00 (±0·00)^{c}	0·00 (±0·00)^{c}	0·00 (±0·00)^{c}	0·00
	33	1·70 (±0·05)^{cd}	0·83 (±0·01)^{c}	0·00 (±0·00)^{c}	0·89 (±0·02)^{bc}	0·00
	51	3·40 (±0·12)^{c}	1·28 (±0·05)^{b}	0·29 (±0·09)^{c}	1·83 (±0·08)^{b}	0·22
	70	3·60 (±0·08)^{c}	1·44 (±0·14)^{b}	0·32 (±0·08)^{c}	1·90 (±0·07)^{b}	0·24
	88	11·3 (±0·24)^{b}	2·68 (±0·86)^{b}	3·80 (±0·56)^{ab}	4·87 (±0·65)^{a}	1·40
	106	17·3 (±0·18)^{a}	6·15 (±0·01)^{a}	4·50 (±0·65)^{ab}	6·70 (±1·21)^{a}	0·73
	126	20·2 (±0·29)^{a}	7·67 (±0·38)^{a}	4·70 (±0·04)^{a}	7·78 (±0·13)^{a}	0·61
Shendi	15	2·10 (±0·01)^{d}	0·83 (±0·27)^{d}	0·23 (±0·05)^{c}	0·99 (±0·27)^{c}	0·28
	33	2·10 (±0·21)^{d}	0·91 (±0·03)^{d}	0·23 (±0·04)^{c}	0·83 (±0·14)^{c}	0·25
	51	3·69 (±0·34)^{d}	2·60 (±0·05)^{c}	0·50 (±0·01)^{c}	0·59 (±0·08)^{c}	0·19
	70	5·80 (±0·45)^{c}	3·69 (±0·18)^{c}	1·16 (±0·06)^{bc}	0·93 (±0·08)^{c}	0·32
	88	7·00 (±0·61)^{bc}	3·80 (±0·16)^{c}	1·91 (±0·03)^{b}	1·30 (±0·03)^{bc}	0·50
	106	9·80 (±0·50)^{b}	4·34 (±0·15)^{b}	3·80 (±0·51)^{a}	1·64 (±0·06)^{b}	0·88
	126	16·9 (±0·09)^{a}	6·28 (±0·24)^{a}	4·30 (±0·88)^{a}	6·30 (±0·24)^{a}	0·68
Ganib	15	0·00 (±0·00)^{e}	0·00 (±0·00)^{c}	0·00 (±0·00)^{b}	0·00 (±0·00)^{e}	0·00
	33	1·30 (±0·13)^{e}	0·57 (±0·03)^{c}	0·16 (±0·02)^{ab}	0·60 (±0·06)^{de}	0·28
	51	4·10 (±0·23)^{d}	3·23 (±0·20)^{b}	0·27 (±0·04)^{ab}	0·64 (±0·04)^{de}	0·08
	70	5·08 (±0·09)^{cd}	3·36 (±0·95)^{b}	0·51 (±0·06)^{ab}	1·21 (±0·31)^{d}	0·15
	88	6·80 (±0·31)^{c}	3·38 (±0·50)^{b}	0·80 (±0·13)^{ab}	2·59 (±0·51)^{c}	0·24
	106	9·56 (±0·26)^{b}	3·97 (±0·17)^{ab}	0·83 (±0·07)^{ab}	4·76 (±0·18)^{b}	0·13
	126	13·7 (±0·41)^{a}	5·64 (±0·89)^{a}	1·90 (±0·13)^{a}	6·20 (±0·71)^{a}	0·34

Means not sharing a common following letter in a column are significantly different ($P \leq 0.05$) as assessed by Duncan's multiple-range test.

Table 2. Changes in ascorbic acid (mg per 100 g, mean ± SD) of guava cultivars during growth and development

Days after fruit set	Cultivar			
	Shambati	Pakistani	Shendi	Ganib
15	5·40^{d} (±1·56)	6·20^{e} (±0·54)	10·9^{b} (±3·08)	9·80^{d} (±0·69)
33	20·5^{d} (±0·39)	13·4de (±2·01)	15·3^{d} (±1·59)	14·0^{d} (±0·98)
51	26·0^{cd} (±0·23)	16·3de (±3·58)	20·2^{b} (±1·60)	18·1^{cd} (±4·20)
70	30·7^{cd} (±2·00)	26·3^{d} (±5·33)	23·8^{b} (±1·27)	30·4^{c} (±9·40)
88	48·7^{bc} (±7·70)	44·5^{c} (±11·4)	22·7^{b} (±1·21)	52·0^{b} (±1·63)
106	73·9^{ab} (±3·80)	65·5^{b} (±4·20)	85·5^{a} (±4·33)	82·0^{a} (±2·45)
126	88·2^{a} (±9·00)	106·4^{a} (±2·2)	113·3^{a} (±2·2)	94·3^{a} (±1·59)

Means not sharing a common following letter in a column are significantly different ($P \leq 0.05$) as assessed by Duncan's multiple-range test.

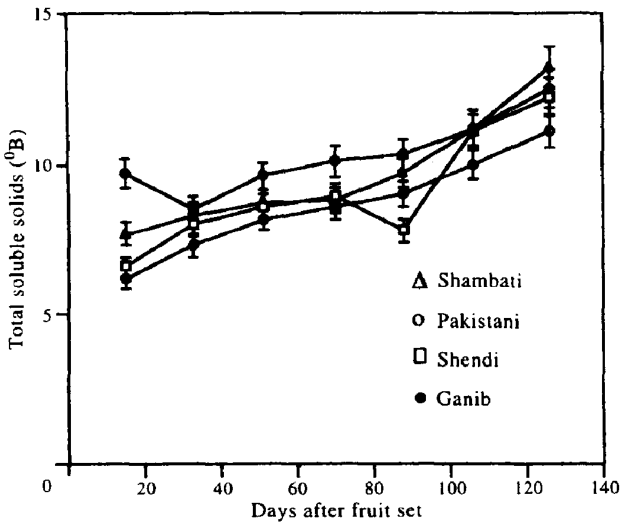

Fig. 1. Changes in total soluble solids (°B) during development and ripening of fruits of four guava cultivars. Bars represent standard deviation.

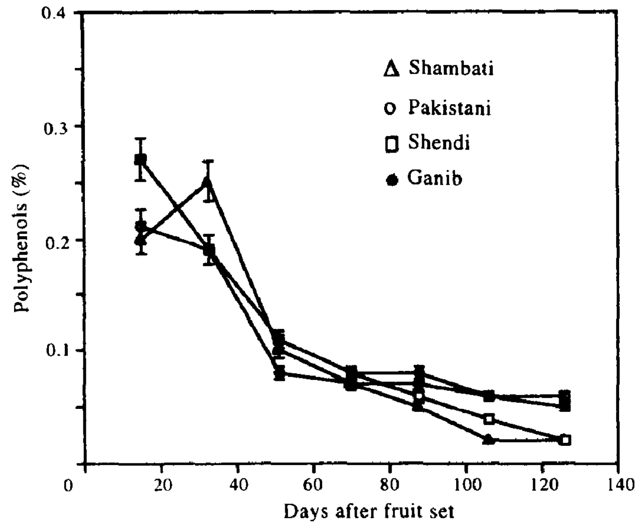

Fig. 2. Changes in polyphenols (%) during development and ripening of fruits of four guava cultivars. Bars represent standard deviation.

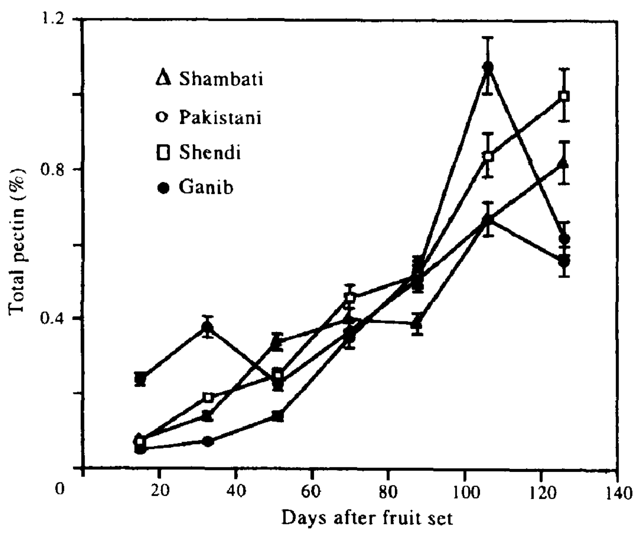

Fig. 3. Changes in toatl pectin (%) during development and ripening of fruits of four guava cultivars. Bars represent standard deviation.

Pakistani and Ganib cultivars, total pectin reached its maximum when fruits were 106 days old; thereafter it declined rapidly. When fruits were 15 days old, total pectin contents were 0·07%, 0·05%, 0·07% and 0·24% for Shambati, Pakistani, Shendi and Ganib cultivars, respectively. When the fruits were 126 days old, total pectin contents were 0·82%, 0·62%, 1·00% and 0·56%, respectively.

It was observed that a significant ($P \leq 0{\cdot}05$) increase in total pectin content starts after day 88 from fruit set (Fig. 3). Results obtained for Pakistani and Ganib cultivars are in agreement with those of Chyan *et al.* (1992), who reported that pectin content of guava fruit was higher in the mature stage than in the ripe stage, while, for Shambati and Shendi cultivars, the total pectin content was higher in the ripe stage than in the mature stage. The explanation for this difference may lie in chemical activity (as well as quantitative) differences between the pectic enzymes of the cultivars.

CONCLUSION

The fact that substances responsible for the calorie and vitamin characteristics of the fruit (e.g. sugars and ascorbic acid, respectively) reached their maximum values near 106 days from fruit set, emphasizes that guava fruit has excellent nutrient resources.

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