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Biochemical and physical changes in fruits of four guava cultivars during growth and development

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Biochemical and physical changes in fruits of four guava cultivars during growth and development were studied. Investigation showed that protein content decreased markedly with fruit growth and development for all cultivars. The maximum level of reduction varied from 0·25 to 0·27%. Moisture content was significantly increased with fruit growth and development in all cultivars. The maximum level varied from 6·2 to 76·0%. Alcohol-insoluble solids (AIS) declined gradually during the initial growing period followed by rapid decline during later stages of development for all cultivars, which differed in their final value (8·67–13·33%). Water-soluble pectin for all cultivars increased gradually with fruit development. The maximum level varied from 0·34 to 0·64%. For all cultivars texture declined gradually during fruit development. The skin colour of the fruit changed gradually from dark green to yellow for all cultivars. Fruits picked before day 106 after fruit set had a reading of more than 30 psi (1 psi ≈ 7·9 kPa) which was outside the range of the pressure tester, and thereafter pressure declined rapidly for all cultivars. Fruit volume increased rapidly with fruit development for all cultivars. Softness and yellowness of fruit were associated with lower protein and AIS contents, higher moisture and appreciable amounts of water-soluble pectin.

INTRODUCTION

Guava is one of the most important commercial fruit crops in tropical and subtropical countries. Its skin and flesh colour varies between cultivars depending on the amount and type of pigments. The fruit softens very rapidly during ripening (Wilson, 1980) and becomes mushy and unfit for consumption. The firmness of guava is due to the presence of pectic substances. The softening is the result of degradative changes and solubilisation of pectin due to the activity of pectic enzymes (Huber, 1983). Immature guava fruits were dark green in colour, hard and woody in texture (Rodriguez *et al.*, 1971). The average molecular weight of peach water-soluble pectin decreases markedly as the peach ripens and more pectin is solubilised (Shewfelt *et al.*, 1971); also Jagtiani *et al.* reported that, as papaya fruits ripened, the activity of pectin methyl esterase increased and more pectin was solubilised. Chaturvedi (1974) reported that alcohol-insoluble solids (AIS) and protein contents of guava fruit, at different stages of maturity, decreased with fruit development.

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The study described here aimed to investigate biochemical and physical changes in fruits of four guava cultivars during growth and development.

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 developmental stages: 15, 33, 51, 70, 88, 106 and 126 days after fruit set.

Fruit volume determination

Fruit volume was determined by water displacement (ml).

Fruit colour and texture identification

Skin colour and texture of the fruits were identified by 15 semi-trained panel members organoleptically.

Shear-resistance assessment

Shear-resistance was assessed using a plunger type pressure tester (INSTRON, Model 1000, No. 2034, UK).

Water-soluble pectin determination

Water-soluble pectin was determined by the methods of Shewfelt *et al.*. (1971) and Voragen *et al.* (1983).

Protein and moisture determination

Protein and moisture were determined by the methods of AOAC (1965).

AIS determination

AIS were determined by the methods of AOAC (1965). Twenty grams were blended and added to 200 ml of boiling ethanol and boiled for 30 min. After cooling to room temperature, the mixture was filtered through a Buchner funnel. This was repeated several times until no free sugars were found in the extract. The residue was washed with ethanol and then with acetone and dried to constant weight in a vacuum oven at 50°C. Results were expressed as percentages of the sample.

Statistical analysis

Each sample was analysed in triplicate and the figures were then averaged. Data were assessed by analysis of variance (ANOVA) (Snedecor & Cochran, 1987) and by Duncan's multiple range test with a probability $P \leq 0.05$ (Duncan, 1955).

RESULTS

Figures 1–4 show changes in protein, moisture, AIS and water-soluble pectin in fruits of four guava cultivars during growth and development, respectively.

Protein content (%) gradually decreased with fruit development for all cultivars (Fig. 1). When fruits were 15 days old, protein contents were 0·94, 1·00; 0·98 and 0·61% for Shambati, Pakistani, Shendi and Ganib cultivars, respectively. When they were 126 days old, proteins were 0·25, 0·27, 0·27 and 0·25% for the cultivars, respectively. It is observed that a significant ($P \leq 0.05$) decrease in protein content starts after day 88 from fruit set (Fig. 1). Moisture content (Fig. 2) significantly ($P \leq 0.05$) increased with fruit development for all cultivars. When fruits were 15 days old, moisture content were 20·2, 16·4, 19·4 and 14·5% for Shambati, Pakistani, Shendi and Ganib cultivars, respectively. When they were 126 days old moisture contents were 65·2 67·1 70·0 and 76·0% for the cultivars, respectively. AIS (Fig. 3) gradually decreased with fruit development for

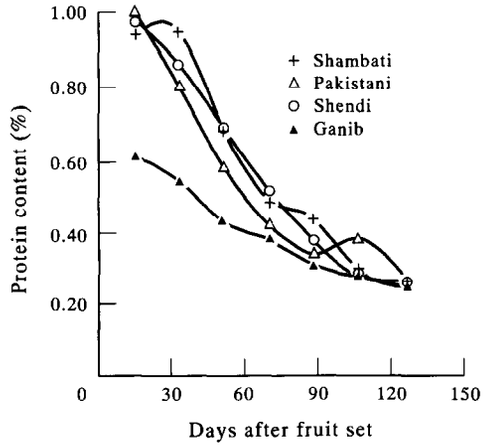

Fig. 1. Changes in protein (%) in fruits of four guava cultivars during ripening.

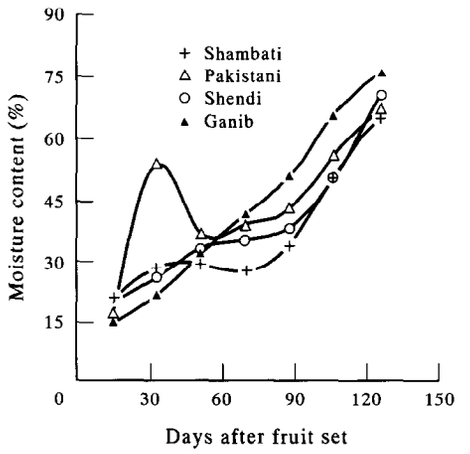

Fig. 2. Changes in moisture (%) in fruits of four guava cultivars during ripening.

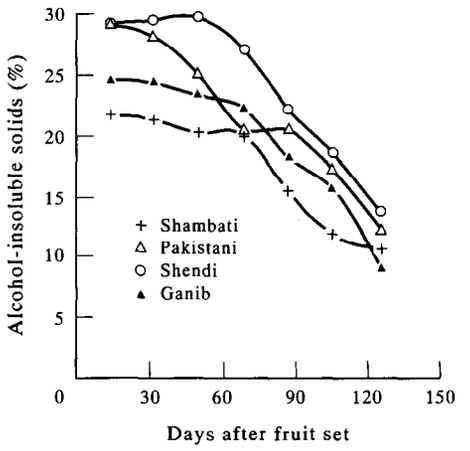

Fig. 3. Changes in alcohol-insoluble solids (%) of four guava cultivars during ripening.

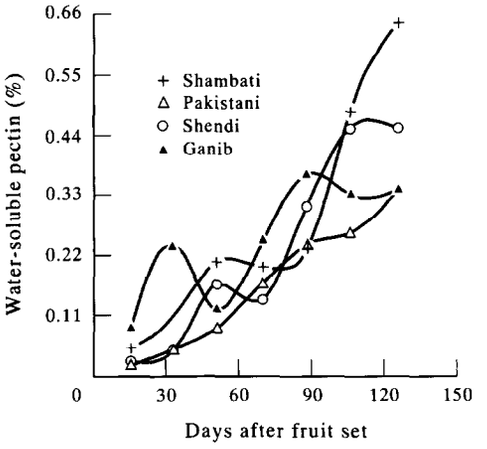

Fig. 4. Changes in water-soluble pectin (%) of four guava cultivars during ripening.

Table 1. Changes in fruit texture, pressure, skin colour and volume of guava cultivars during growth and development (means ± SD)[a]

Days after fruit	Shambati				Pakistani			
	Texture	Pressure (psi)[b]	Skin colour	Fruit volume (ml)	Texture	Pressure (psi)[b]	Skin colour	Fruit volume (ml)
15	Very hard smooth and waxy	Out of range	Dark green	3·9 ± 0·2 d	Very hard and not smooth	Out of range	Dark green	3·0 ± 0·05 g
33	Very hard smooth and waxy	Out of range	Dark green	7·0 ± 0·2 d	Very hard and not smooth	Out of range	Dark green	12·0 ± 0·05 f
51	Very hard smooth and waxy	Out of range	Green	16·5 ± 1·1 d	Hard	Out of range	Green	25·0 ± 0·02 e
70	Hard	Out of range	Green	46·9 ± 6·3 c	Hard	Out of range	Green	35·0 ± 0·02 d
88	Hard	Out of range	Yellowish green	59·2 ± 3·1 c	Hard	Out of range	Yellowish green	45·1 ± 0·05 c
106	Hard	7·0 ± 0·41 a	Greenish yellow	91·0 ± 14·5 b	Hard	6·0 ± 0·34 d	Greenish yellow	57·4 ± 0·100 b
126	Moderately soft	3·6 ± 0·21 b	Yellow	142·7 ± 5·6 d	Moderately soft	2·8 ± 0·13 b	Yellow	94·8 ± 0·13 d

[a]Means not sharing a common following letter in a column are significantly different ($P \leq 0.01$) as assessed by Duncan's Multiple range test.
[b]1 psi ≈ 6·9 kPa.

all cultivars. When fruits were 15 days old, AIS contents were 21·7, 29·1, 29·2 and 24·5% for Shambati, Pakistani, Shendi and Ganib cultivars, respectively. When they were 126 days old AIS contents were 10·3, 12·0, 13·3 and 8·7% for the cultivars, respectively. It is observed that a significant ($P \leq 0.05$) decrease in AIS content starts after day 88 from fruit set (Fig. 3). Water-soluble pectin (WSP) content gradually increased with fruit development for all cultivars (Fig. 4). When fruits were 15 days old, WSP contents 0·05, 0·2, 0·03 and 0·09% for Shambati, Pakistani, Shendi and Ganib cultivars, respectively. When they were 126 days old, WSP contents were 0·64, 0·34, 0·45 and 0·35% for the cultivars, respectively. It is observed that

Table 2. Changes in fruit texture, pressure, skin colour and volume of guava cultivars during growth and development (means ± SD)[a]

Days after fruit	Shendi				Ganib			
	Texture	Pressure (psi)[b]	Skin colour	Fruit volume (ml)	Texture	Pressure (psi)[b]	Skin colour	Fruit volume (ml)
15	Very hard and smooth	Out of range	Green	2·4 ± 0·37	Very hard and woody	Out of range	Dark green	3·0 ± 0·7 e
33	Hard	Out of range	Green	7·0 ± 0·82 d	Very hard and woody	Out of range	Dark green	8·6 ± 2·2 e
51	Hard	Out of range	Green	10·1 ± 0·43 cd	Hard	Out of range	Green	27·9 ± 4·4 d
70	Hard	Out of range	Light green	20·7 ± 1·30 c	Hard	Out of range	Green	42·5 ± 4·2 cd
88	Hard	7·13 ± 0·29 a	Yellowish green	54·6 ± 3·00 b	Hard	Out of range	Yellowish green	57·7 ± 2·9 c
106	Moderately soft	6·1 ± 0·29 a	Yellow	135·7 ± 7·60 a	Hard	Out of range	Greenish yellow	113·3 ± 9·4 b
126	Soft	2·97 ± 0·39 b	Deep yellow	136·5 ± 6·00 a	Moderately soft	5·33 ± 0·17 a	Yellow	131·7 ± 3·8 a

[a]Means not sharing a common following letter in a column are significantly different ($P \leq 0.01$) as assessed by Duncan's multiple range test.
[b]1 psi ≈ 6·9 kPa.

a significant ($P \leq 0.05$) increase in WSP content starts after day 88 from fruit set.

Table 1 shows changes in fruit texture, pressure, skin colour and volume of Shambati and Pakistani cultivars during fruit growth and development. For both cultivars immature guava fruits were dark green in colour and very hard in texture. The fruit changes in colour were seen when the fruits were 106–126 days old. When fruits were 126 days they were yellow in colour and moderately soft. For both cultivars, when the fruits were 15–88 days old a reading of more than 30 psi (1 psi $\approx$ 6·9 kPa) was recorded. Thereafter resistance to shearing force significantly ($P \leq 0.05$) decreased. Fruit volume for both cultivars significantly ($P \leq 0.05$) increased with fruit growth and development. When fruits were 15 days old, the volumes were 3·9 and 3·0 ml for Shambati and Pakistani cultivars respectively. When they were 126 days old, the volumes were 142·7 and 94·8 for the cultivars, respectively.

Table 2 shows changes in fruit texture, pressure, skin colour and volume in Shendi and Ganib cultivars during fruit growth and development. Both cultivars gave results similar to those obtained for Shambati and Pakistani, but the cultivars differed slightly in their final values.

DISCUSSION

Results revealed that all cultivars at the early stages had a higher protein content, while in the enlarging stages protein content significantly decreased. This could be due to the fact that the fruits utilised protein for growth and development as indicated by a rapid increase in fruit volume with time. This may account for the fact that, in guava fruit, the ratio between protein catabolism and anabolism increased rapidly with fruit growth and development. Chaturvedi (1974) reported that protein content of guava fruit at different stages of maturity decreased with fruit development. For all cultivars WSP increased with time due to solubilisation of pectic substances by the action of pectic enzymes during fruit growth and development. This agrees with Shewfelt *et al.* (1971) who reported that, as the peach fruit ripened, more pectin was solubilised and Jagtiani *et al.* (1988) who reported that, as papaya fruits ripened, the activity of pectin methyl esterase increased and more pectin was solubilised. AIS, for all cultivars, gradually decreased with fruit growth and development. This could be due to the fact that cellulose, hemicellulose, pectins and starch were converted to soluble constituents by the action of the native enzymes, such as pectinase, hemicelluloses and cellulases. Huber (1984) showed that, during fruit ripening of strawberry, AIS content declined rapidly.

For all cultivars, immature fruits were dark green in colour and very hard in texture. When fruits were 106–126 days old, the skin became yellow in colour and moderately soft in texture. It has been suggested that rapid decrease in AIS and higher moisture content may contribute to the softening of fruits during growth and development as indicated by a rapid decrease in shear-resistance of the fruit. The pectic substances of guava fruits are cleaved by polygalacturonase (Augustin *et al.*, 1985) and Jagtiani *et al.* (1988) reported that pectic substances of papaya fruits are cleaved by the action of pectin methyl esterase during fruit ripening. It has been suggested that cellulase, in addition to pectic enzymes may contribute to the softening of fruit during ripening. Major increases in the activity exhibited by these enzymes immediately preceded the loss of firmness in the fruit (Wilson, 1980).

The present study revealed that, for all cultivars, softness and yellowness of fruits was associated with lower protein and, higher moisture content and appreciable amounts of WSP.

There was no easy method of determining the best time to harvest guava. External fruit appearance (skin colour, shape or size) can and in fact has been used by the growers as an index of maturity. Moisture content was found to be a better index of maturity, to be used along with size, colour, texture and the chemical indices of tannin and sugar contents. Guava fruits can be harvested for table consumption after day 126.

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