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Chemical and biochemical aspects of developing culinary banana (*Musa* ABB) '*Kachkal*'

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The variations in chemical constituents and activities of acid phosphatase, α-glucan phosphorylase and polyphenol oxidase at five different stages of development of a culinary banana were determined. Moisture, crude fat, crude protein and most of the minerals were higher during the earlier stages of development and declined towards maturity. Potassium was the most abundant mineral with estimated values in the range of 4.10–5.55 g per 100 g dry weight. An active synthesis of starch throughout the growth period occurred. During this period total soluble sugar declined. The amylose:amylopectin ratio in the starch fraction remained constant. The activity of α-glucan phosphorylase in the direction of starch synthesis showed a synchronizing increase while that of acid phosphatase declined throughout. There was a gradual decrease in phenol content during development which did not show correlation with corresponding change in polyphenol oxidase activity.

INTRODUCTION

Of the various banana cultivars throughout the world, about half are eaten raw and ripe and the other half as cooked vegetable (Simmonds, 1966). The cooking type banana reportedly forms a major staple in some countries like Tanzania (Seenappa *et al.*, 1986). It is also the raw material for various processed foods such as chips, figs and banana powders. Various reports are available on changes in chemical composition of banana cultivars during ripening (Palmer, 1971). Since bananas are usually picked green and ripened off the plant, there has been little incentive to study the chemical changes in the fruit during development. Lodh *et al.* (1971) have reported on the chemical changes in the banana fruit during various stages of development. However, literature on the changes in chemical composition of culinary or cooking type banana during development is seldom available. The present study was initiated to determine the chemical composition and some enzyme activities during development of a culinary banana (*Musa* ABB), locally known as '*Kachkal*'.

MATERIALS AND METHODS

The fruit samples were harvested at five different stages, i.e. 37, 44, 51, 58 and 65 days after fruit emergence (DAF). At each stage, one fruit from the first, third and fifth hand from the bunch was collected and made into a composite sample for analysis.

Chemical analysis

The proximate composition of the dried, ground sample was determined according to the procedures of the AOAC (1975). Crude protein was calculated using the factor 6.25. Total phosphorus (Fiske & Subbarow, 1925) and iron (Wong, 1928) were determined colorimetrically and calcium was determined according to the AOAC method (AOAC, 1970). Sodium and potassium were estimated in an atomic absorption spectrophotometer (Model SP 2900). Total soluble sugar was estimated by the anthrone method (Yem & Willis, 1954) and starch as described by Chopra & Konwar (1976). Amylose content was determined by the method described by Sawbhagya & Bhattacharyya (1979). Total phenol content was estimated with the Folin–Ciocalteau reagent following the method of Bray & Thrope (1954).

Enzyme assay

Acid phosphatase was isolated and assayed accordingly to Ikediobi *et al.* (1988). α-Glucan phosphorylase was extracted and the activity in the direction of starch synthesis was determined according to Lee (1960). The method described by Hsu *et al.* (1988) was employed for the isolation and assay of polyphenol oxidase. Specific

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Table 1. Proximate composition and mineral contents of culinary banana during development (g per 100 g on oven dry basis)

Stage	Moisture	Crudeprotein	Crudefat	Ash	Na	K	Ca	P	Fe
37	92.50	4.30	1.20	5.90	0.195	5.55	0.061	0.330	0.005
	(0.714)	(0.212)	(0.042)	(0.070)	(0.001)	(0.012)	(0.001)	(0.001)	(0.00)
44	92.00	4.60	1.25	6.00	0.137	4.93	0.056	0.300	0.005
	(0.353)	(0.187)	(0.007)	(0.00)	(0.001)	(0.030)	(0.001)	(0.00)	(0.00)
51	89.60	7.00	1.30	5.80	0.117	4.25	0.038	0.230	0.005
	(0.374)	(0.212)	(0.018)	(0.070)	(0.001)	(0.021)	(0.001)	(0.012)	(0.00)
58	87.60	3.50	0.82	6.00	0.125	4.00	0.024	0.220	0.006
	(0.734)	(0.308)	(0.012)	(0.070)	(0.00)	(0.014)	(0.00)	(0.007	(0.00)
65	82.80	3.20	0.80	5.80	0.120	4.10	0.021	0.200	0.012
	(0.374)	(0.00)	(0.007)	(0.070)	(0.001)	(0.014)	(0.001)	(0.00)	(0.00)

Figures are the mean values of three replications. Figures in parentheses indicate ± standard error.

activities were determined on the basis of mg protein in the crude extracts estimated according to Lowry *et al.* (1951).

RESULTS AND DISCUSSION

Chemical composition

The moisture content decreased gradually during development of this culinary banana. Crude protein and crude fat content showed an initial increase up to 51 DAF and decreased towards maturity (Table 1). The previous report by Simmonds (1966) on the proximate composition of banana is consistent with our observation that they predominate in moisture and carbohydrates. The observed decrease in protein content with maturity may be attributed to protein breakdown, the resulting amino acids being utilized in gluconeogenesis. A similar trend of protein content in developing banana was also observed by Lal *et al.* (1974). The ash content was more or less constant during development (Table 1). Barring iron, the various minerals that were estimated declined gradually during development. The ash was particularly rich in potassium, as was also reported by Izonfuo Welford-Abbey & Omuaru (1988). The phosphorus content of this culinary cultivar was higher than that of other cultivars reported earlier (Sharma, 1976; Padmaja & Kosky, 1977). Similarly the iron content at maturity was also considerably higher than those reported by Padmaja & Kosky (1977) for other cultivars.

Total sugar and starch

In plantain and some members of the *Musa* ABB clone, hydrolysis of starch to sugar and the disappearance of acidity both proceed at a lower rate than in the sweet banana. The result is that, until a very advanced stage of ripeness, they have a comparatively starchy and acid flesh (Simmonds, 1966). These are usually palatable only after cooking.

The culinary cultivar '*Kachkal*', being a member of the *Musa* ABB clone, accumulated increasing amounts of starch throughout the growth period (Table 2). The average weight of the fruit changed from 38 g at 37 DAF to 136 g at 65 DAF. The immature fruit has a thick, smooth green peel with much less edible portion. With increasing accumulation of starch during maturity, the peel becomes thinner and dark green. During this period, the total soluble sugar gradually decreases, obviously due to utilization for starch biosynthesis. Similar trends of variation in starch and sugar in developing banana have been reported for other cultivars that are consumed after ripening (Lodh *et al.*, 1971; Lal *et al.*, 1974; Abdullah *et al.*, 1985). Thus there is a general agreement that, in developing banana, an active synthesis of starch occurs till the onset of ripening, during which the sugar content remains relatively low. The amylose:amylopectin ratio in the starch fraction of '*Kachkal*' appears to be more or less constant at different stages of development (Table 2), presumably due to synchronizing activities of enzyme systems involved in the synthesis of both α-1,4 and α-1,6 glycosidic linkages between glucose units.

Enzyme activities

α-Glucan phosphorylase can, in principle, act both as a glucan-degrading and a glucan-synthesizing enzyme (Waldmann *et al.*, 1986). Although glucan synthesis is favoured by equilibrium constant, the main *in vivo*

Table 2. Changes in total soluble sugar, starch (g per 100 g), amylose and amylopectin (percent of starch) contents of culinary banana during development

Stage (DAF)	Total soluble sugar	Starch	Amylose	Amylose–amylopectin ratio
37	1.70	20.00	31.00	0.45
	(0.035)	(0.141)	(0.625)	
44	0.90	34.20	31.05	0.45
	0.061	(0.494)	(0.614)	
51	0.60	45.50	30.20	0.43
	(0.00)	(0.308)	(0.122)	
58	0.50	55.80	31.91	0.47
	(0.035)	(0.285)	(0.252)	
65	0.50	55.80	34.25	0.52
	(0.00)	(0.294)	(0.247)	

Figures are the mean values of three replications. Figures in parentheses indicate ± standard error.

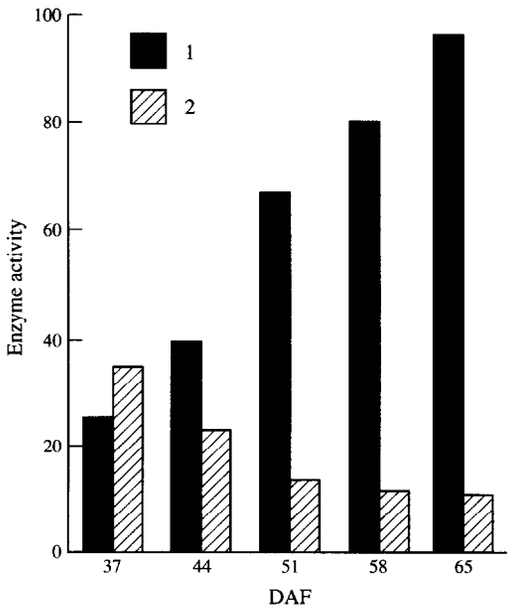

Fig. 1. Changes in the specific activities of (1) α-glucan phosphorylase (units/mg protein $\times 10^2$) and (2) acid phosphatase (units/mg protein) during development of culinary banana.

function is generally assumed to be phosphorolytic glucan degradation (Steup, 1988). Inorganic phosphate evidently plays a major role in these transformations, the level of which in turn is linked to the activity of another enzyme, acid phosphatase.

Evidently, the α-glucan phosphorylase activity in the direction of starch synthesis increased continuously from 37 to 65 DAF while that of acid phosphatase decreased during this period (Fig. 1). Starch content and phosphorylase activity showed a highly significant positive correlation ($r = -0.88$). Areas & Lajolo (1980) observed a reverse trend of phosphorylase and phosphatase behaviour in ripening banana where starch breakdown is the major event associated with ripening. In '*Kachkal*', at least a part of the starch biosynthetic activity may be attributed to the activity of α-glucan phosphorylase. Synthetic activity of the enzyme during banana development has been reported by earlier workers (Singh & Sanwal, 1976; Areas & Lajolo, 1981).

The polyphenol oxidase activity showed a non-uniform variation being maximum at 55 DAF (Table 3). The enzyme activity at different stages showed a negative correlation ($r = -0.62$) with the corresponding values of total phenol content.

It appeared that *Musa* ABB, '*Kachkal*' is a rich source of energy and minerals and fairly good source of protein. It is a common practice not to harvest the whole bunch of this culinary banana and instead to pluck the individual hands at different times. The analytical data may therefore be useful to assess the optimum time for harvest. The data on polyphenols and PPO activity may provide basic information on browning reactions associated with the processing of various banana products.

Table 3. Changes in total phenol (mg per 100 g fresh weight) and polyphenol oxidase (PPO) activity (units per mg protein) of culinary banana during development

Stage (DAF)	37	44	51	58	65
Total phenol	210	182	140	120	102
PPO activity	9.7	5.2	6.1	15.1	15.0

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