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Changes in composition and certain functional properties of ripening plantain (*Musa spp.*, AAB group) pulp

Sunday Y. Giami* & Dismas A. Alu

Department of Food Science and Technology, Rivers State University of Science and Technology, Port Harcourt, Nigeria

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Compositional changes in plantain (*Musa spp.* AAB group) pulp during ripening and the effect of the stage of ripeness on certain functional properties of the flour were determined. The unripe pulp had relatively low polyphenol oxidase activity, low total polyphenol content but high ascorbic acid and carotenoid levels and showed the least browning potential. Ripening increased the crude protein and total ash but decreased the carbohydrate and fat content of the pulp. Nitrogen solubility was pH-dependent with a minimum at pH 5·0. The flour sample from the unripe fruit had the highest nitrogen solubility values (41–70%) in the pH range investigated (2–12), produced foam that was more stable, and showed comparatively better water and fat absorption properties than those of the fully ripe or overripe samples.

INTRODUCTION

Plantain (*Musa spp.*, AAB group; Stover & Simmonds, 1987) is an important staple starchy fruit in Central and West Africa which, along with other bananas, provides approximately 60 million people with more than one-quarter of their food energy requirements (Wilson, 1987). Both the unripe (green) and ripe plantains are utilised as food, mainly in the cooked form, but a general preference exists for ripe plantains. During ripening, plantain changes from a hard, essentially starchy green fruit to a soft, sweet, yellow one. The nutritional composition of ripening plantains have been examined with respect to minerals (Izonfuo & Omuaru, 1988), carbohydrate and amino acids (Ketiku, 1973; Marriott *et al.*, 1981); however, information on changes in endogenous biochemical parameters during the ripening of plantain is limited (Omuaru *et al.*, 1990).

Previous studies have shown that plantain, like other fruits, is susceptible to browning when the pulp is cut or sliced (Giami, 1989, 1991). The browning potential of various fruits and vegetables has been shown to be directly related to the ascorbic acid level, polyphenol content, the polyphenol oxidase (PPO) activity or a combination of these factors (Golan *et al.*, 1977; Walter & Purcell, 1980). Other reports show that many fruits which are high in carotenoids, such as papaya and mango, are characterised by a low browning potential (Arya *et al.*, 1983; Sharon-Raber & Kahn 1983).

Essential in determining potential uses for plantain flour is the identification of its functional properties. Functional properties and functionality of plantain flour in bakery products have been reported (Ogazi, 1984; Gwanfogbe *et al.*, 1988; Bamidele *et al.*, 1990). These studies were done using plantain flour from the green (unripe) plantain fruits. Studies on functional properties of plantain flour obtained from plantain fruit at different stages of ripeness are lacking.

The purpose of this study was to provide information on compositional changes, particularly, browning potential, carotenoid and ascorbic acid contents, and PPO activity that accompany the ripening process of plantain pulp, and the effect of stage of ripeness on certain functional properties of the flour. Such information is of importance in the optimum utilisation of the pulp as a staple food and the flour as a functional ingredient in fabricated foods.

MATERIALS AND METHODS

Materials

Mature and healthy plantain (*Musa sp.* AAB group) bunches were obtained from the International Institute of Tropical Agriculture (IITA), high rainfall station at Onne, Rivers State, Nigeria. The cultivar used in this

* To whom correspondence should be addressed.

study was 'Agbagba' (a false horn plantain) and has been described by Swennan and Vuylsteke (1987). All reagents used were of analytical grade.

Sample preparation

The fruits were brought to the laboratory at a green (unripe) stage and left to ripen at room temperature (29–30°C). The stage of ripening was based on peel colour as outlined by Marriott and Lancaster (1983), modified to accommodate the slightly different ripening of plantain compared to dessert bananas, as used by Burdon *et al.* (1991). The stages recognised were as follows: 1, green; 2, tinge of yellow; 3, more green than yellow; 4, more yellow than green; 5, tinge of green; 6, yellow; 7, 20–50% surface brown; and 8, 60–90% surface brown. Fruits were used for this study at three different stages of ripening: 1, green (unripe); 6, yellow (fully ripe); and 8, 60–90% surface brown (overripe). Each plantain was washed and hand-peeled and the edible portion (pulp) was sliced longitudinally with a stainless-steel knife into 3-cm-thick samples and the slices were diced. Several samples were cut out from a number of plantains, thoroughly mixed to ensure uniformity for sampling and randomly divided into two groups. Pulp tissue from one group was used for the determination of ascorbic acid, carotenoids titratable acidity browning potential and PPO activity. The second group was oven-dried (50°C, 24 h) milled to pass through a 0·25 mm screen and the flour used for determinations of proximate composition total polyphenols and functional properties.

Analytical procedures

Compositional analysis

Browning potential was estimated using the method described by Walter and Purcell (1980) as modified by Omuaru *et al.* (1990). Diced pulp tissue was homogenised, centrifuged and filtered. The absorbance of the filtrate at 450 nm was measured initially and after 180 min at room temperature in a Bausch and Lomb Spectronic 20 photometer. The change in absorbance (ΔA_{450}) within the time interval was used as a measure of browning potential. PPO activity was determined colorimetrically as described by Walter and Purcell (1980) using catechol as a substrate. The PPO activity was expressed as change in absorbance at 450 nm per min per g of pulp tissue (fresh weight). Proximate chemical composition and ascorbic acid by the colorimetric method were determined using AOAC (1984) methods, except that 1% oxalic acid was substituted for 3% metaphosphoric acid in the ascorbic acid determination. Total polyphenols were determined using the vanillin–H_2SO_4 assay as described by Wilson and Blunden (1983). The results were expressed as mg phloroglucinol equivalents per 100 g dry weight of plantain flour. Determination of total carotenoids was by the procedure outlined by Thomas and Janave (1975) with reference to a standard graph based on β-carotene. Titratable acidity, expressed as percentage malic acid, was determined by titration with 0·1 M NaOH using phenolphthalein as the indicator to an end-point of pH 8·0; pH was measured with a pH meter (PYE Unicam model 290).

Determination of functional properties

Nitrogen solubility was determined in the pH range 2–12 at room temperature (29–30°C) using the method of Narayana and Narasinga Rao (1982) as described previously (Giami & Bekebain, 1992). Water and fat absorption capacities were determined as described by Beuchat (1977) and the values expressed as grams of water or oil absorbed by 1g of plantain flour. Foam capacity and stability were determined as described by Narayana *et al.* (1982) at pH 7·0. Volume of foam at 30s after whipping was expressed as foam capacity and the volume of the foam over 10–60 min as foam stability for the respective time periods. Bulk density was determined according to the method described by Narayana and Narasinga Rao (1984). A calibrated centrifuge tube was weighed and samples were filled to 5 ml by constant tapping until there was no further change in volume. The contents were weighed and from difference in weight the bulk density of the sample was calculated.

Statistical analysis

All the experiments were conducted in triplicate and the means ± standard deviations are reported. Data were subjected to analysis of variance and Duncan's multiple range test (Steel & Torrie, 1960) to determine the significance of differences between sample means.

RESULTS AND DISCUSSION

The Proximate composition of the unripe, fully ripe and overripe plantain pulp used in this study is presented in Table 1. The plantain pulp is composed essentially of water and carbohydrates; fat and protein contents are low. The carbohydrate content of the

Table 1. Proximate composition of plantain pulp at different stages of ripeness (g per 100 g)[a]

Components	Stage of ripeness		
	Unripe	Fully ripe	Overripe
Moisture	60·0 ± 1·1	62·9 ± 1·8	68·2 ± 2·1
Ether extract	0·41 ± 0·05	0·31 ± 0·02	0·12 ± 0·01
Crude fibre	3·50 ± 0·12	2·01 ± 0·04	1·15 ± 0·06
Total ash	1·65 ± 0·03	2·65 ± 0·05	3·20 ± 0·13
Crude protein (N × 6·25)	1·89 ± 0·06	2·50 ± 0·02	2·84 ± 0·04
Carbohydrate (by difference)	32·6 ± 1·2	29·6 ± 1·0	24·5 ± 1·0

[a] Values are means of triplicate determinations ± standard deviation; values, except moisture, are expressed on a dry weight basis.

Table 2. Changes in PPO level and other endogenous factors in plantain pulp at different stages of ripeness[a]

Components	Stage of ripeness		
	Unripe	Fully ripe	Overripe
PPO activity (units/g fresh wt)	21·1 ± 0·4c	85·3 ± 2·0a	44·3 ± 1·2b
Browning potential (ΔA_{450} in 3 h)	0·35 ± 0·02c	0·67 ± 0·05a	0·47 ± 0·03b
Ascorbic acid (mg/100g)	18·7 ± 1·0a	15·0 ± 0·6b	11·4 ± 0·04c
Total polyphenols (mg/100 g)	19·9 ± 1·0c	60·8 ± 2·1a	51·0 ± 1·1b
Total carotenoids (mg/100 g)	14·2 ± 0·04a	9·9 ± 0·03b	6·7 ± 0·02c
Titratable acidity (%, as malic acid)	0·42 ± 0·02c	1·34 ± 0·06a	1·26 ± 0·01b
pH	5·90 ± 0·02a	4·92 ± 0·03b	5·12 ± 0·01b

[a] Values are means of triplicate determinations ± standard deviation. Means with the same following letter within the same row do not differ ($P < 0·05$).

unripe pulp was found to be 32·6% and decreased to 29·6% in the fully ripe pulp and 24·5% in the overripe pulp. Ketiku (1973) identified starch as the principal carbohydrate constituent of both the unripe and ripe plantain pulp; therefore cooking is normally necessary before the fruit is eaten. Crude protein contents of the fully ripe and overripe pulp increased by 32·3 and 50·3%, respectively. Asiedu (1987) reported an increase of 24·1% in crude protein content of plantain pulp during ripening and attributed such an increase to the conversion of enzymes and/or protein synthesis. It has been reported that protein synthesis is required for the ripening of fruits (Palmer & McGlasson, 1971).

Changes in PPO level and other endogenous factors in plantain pulp at three different stages of ripeness are presented in Table 2. PPO activity, browning potential and total polyphenols were low in the unripe pulp and increased with ripening until the overripe stage. Similar findings have been reported for a local variety of plantain, 'Ogbutu', by Omuaru *et al.* (1990) and Some banana varieties by Jayaraman and Ramanuja (1987). Our studies showed that browning potential was positively correlated with total polyphenols and PP. activity. Similar correlations were reported by Golan *et al.* (1977) for avocado and Walter & Purcell (1980) for sweet potatoes. Fully ripe plantain pulp, the most susceptible to browning, had lower levels of carotenoids and ascorbic acid compared with the unripe pulp which was the least susceptible to browning.

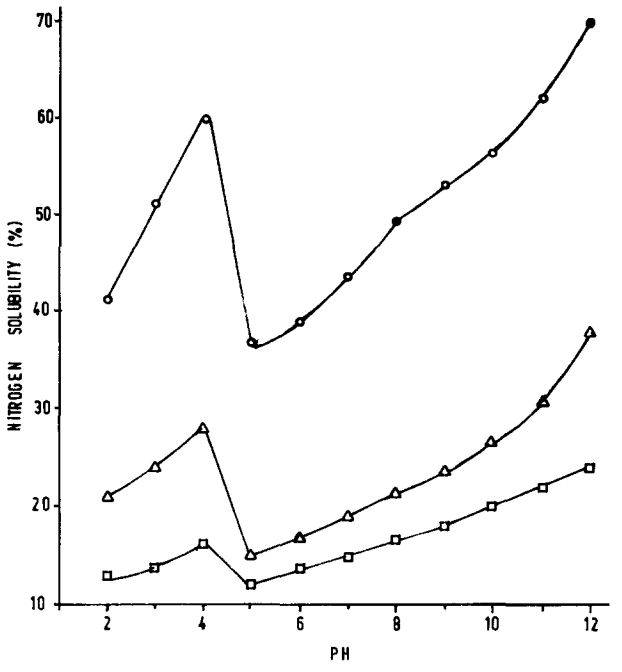

Fig. 1. Effect of pH on nitrogen solubility of flours of plantain at different stages of ripeness. (○) Unripe; (Δ) fully ripe; (□) overripe.

The nitrogen-solubility profiles of plantain flours at different stages of ripeness are shown in Fig. 1. Nitrogen solubility was observed to be pH-dependent. The solubility profiles of flours from fully ripe and overripe fruits did not differ widely, but flour from the unripe fruit exhibited the highest solubility values (41–70%) in the pH range investigated (2–12). The applicability of flour from unripe plantain in food preparations where maximum solubility of proteins is desired looks very promising. Compared to legume flours, such as cowpea flour or winged bean flours, which have been shown to have minimum nitrogen solubilities at pH 4·0 and pH 4·5, respectively (Narayana *et al.* 1982; Giami, 1993), the three types of plantain flours showed minimum nitrogen solubility at pH 5·0. Gwanfogbe *et al.* (1988) also reported that the solubility curve of protein in plantain flour showed an isoelectric point at or near pH 5·0.

The values for bulk density, water and fat absorption capacities of plantain flour decreased as ripening

Table 3. Some functional properties of flour of plantain at different states of ripeness[a]

Stage of ripeness	Bulk density (g/ml)	Water absorption capacity (g/g)	Fat absorption capacity (g/g)	Foam capacity[b] (ml)	Foam volume (ml) after	
					30 min	60 min
Unripe	0·32 ± 0·03	1·25 ± 0·12	1·15 ± 0·10	18·0 ± 1·5	15·0 ± 1·0	8·5 ± 0·5
Fully ripe	0·10 ± 0·02	0·85 ± 0·06	1·02 ± 0·14	6·5 ± 0·5	2·0 ± 0·5	0
Overripe	0·09 ± 0·01	0·67 ± 0·05	0·78 ± 0·02	2·0 ± 0·5	0	0
LSD[c] ($P = 0·05$)	0·06	0·13	0·15	2·61	9·00	—

[a] Values are means of triplicate determinations ± standard deviation.
[b] Determined at pH = 7·0.
[c] LSD—Differences of two means between samples exceeding this value are significant.

progressed (Table 3). Water and fat absorption capacities of 1·25g/g and 1·15g/g, respectively, were recorded for plantain flour from the unripe fruit.

Water absorption characteristics represent the ability of a product to associate with water under conditions where water is limiting, such as doughs and pastes. The results obtained suggest that flour from the unripe fruit would be useful in food systems such as bakery products which require hydration to improve handling characteristics.

In Nigeria, a potential use of processed plantain is the production of flour for use as a substitute for imported wheat. Studies by Bamidele *et al.* (1990) showed that a plantain/wheat flour blend containing 10% plantain flour produced acceptable bread. The plantain flours performed poorly in a functionality test for foamability (see Table 3). The foams formed by the three types of flours collapsed from 52 to 100% during the 60 min stability test. It has been shown that adding cotton-seed flour to plantain flour vastly improved the foaming properties (Gwanfogbe *et al.*, 1988).

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