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Production of Instant Plantain Flour, Sensory Evaluation and Physico-chemical Changes During Storage

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ABSTRACT

*Instant plantain flours were prepared from ripe and unripe plantain (*Musa paradisiaca*) fingers, by cooking and subsequent oven-dehydration at 76°C and at between 88 and 92°C, respectively. The products were stored at 5 ± 1°C and at 22 ± 4°C. Sensory evaluation and some physico-chemical parameters indicated a high degree of product acceptability and stability during storage. Flours prepared from ripe plantain were more acceptable, had higher moisture contents, lower pH, higher total sugar contents, lower ascorbic acid contents and lower levels of sodium, potassium, phosphorus, calcium and iron, than flours prepared from unripe plantains. The products appear to have some commercial potential on their own or as bases for other foods such as baby weaning foods, puddings, soups and gravies.*

INTRODUCTION

Plantain is a permanent crop which grows prolifically in the warm and humid southern parts of Nigeria where optimum growth conditions of 27°C and 2000 mm rainfall per annum (Phillips, 1977) are easily attained.

Both the physiologically ripe and unripe crops are consumed after roasting or boiling in water. Traditional milling methods are also used in Nigeria to convert the raw plantain into a raw, non-instant flour, specifically, for use in the preparation of a starchy Nigerian dish. In periods of bumper harvests, any plantain fingers not utilized are usually lost to microbial attack and senescence. This is due to inadequate storage conditions and processing.

Therefore, in the present studies, plantain was processed into instant flours by cooking, oven-drying and milling. Some chemical and physical properties of the flour samples were measured to assess the efficacy of the production method in maintaining good shelf-life of the products during storage. Such products with good keeping qualities could find uses in baby foods, puddings and gravies thereby helping to utilize the surpluses in years of bumper harvest.

MATERIALS AND METHODS

Source of materials

Mature ripe and unripe plantain fingers were obtained from farmers at Ehor in Nigeria, immediately after harvest.

Production of instant plantain flour

Whole plantain fingers were washed in deionized distilled water, peeled and each finger was cut into halves. All the pooled halves were boiled for 10 min in deionized distilled water in aluminium cooking pots. The cooked samples were sliced (1·5 mm) and oven-dried (Memmert, no. 601162) at 76°C for 10 h. Another batch was dried at 88 and 92°C for 10 h. (This latter batch was meant to be dried at 88°C, but oven temperature flunctuated between 88 and 92°C.) Flour samples were prepared from the dried slices by grinding in a Waring Blender. The particles were able to pass through a sieve with an aperture size of 425 μm. The samples were stored in clean dry cans, for subsequent use.

Storage of plantain flour

Batches of each flour (50 g) in dry glass 100 ml beakers tightly sealed with aluminium foil were stored at 5 ± 1°C, for 5 months. Analyses for moisture, pH, reducing sugar and ascorbic acid were done monthly.

Analyses for sodium, potassium, phosphorus, calcium and iron were also done on the pre-storage (0-month) samples. Another set was stored at ambient conditions (22 ± 4°C) for 5 months for subsequent use in the sensory evaluation (colour, taste, aroma), reconstitution in water, and in monitoring the presence or absence of moulds in the stored products.

Reconstitution in water

Reconstitution in hot (100°C) and cold (25°C) water was assessed by each of ten panellists. Seven grams of each flour were mixed with 100 ml of water by stirring with a glass rod in a glass beaker and ease of reconstitution noted.

Observation of mould growth

Mould growth was assessed by visual inspection and by microscopic examination using a standard method (Frazier *et al.*, 1968). However, panellists were not involved in the microscopic examination for mould growth.

Sensory evaluation

Visible colour assessment was by visual inspection against a white background, while product aroma was monitored by sniffing effluent air. The taste was determined by oral mastication of 2 g each of the dry and reconstituted flour, after mouth rinsing with distilled deionized water, to avoid or minimize interference effects. All the sensory tests were done with ten panellists, under ambient conditions (ambient light, 23 ± 2°C and free from any detectable extraneous odours).

Determination of moisture content

This was determined by oven method (70°C to constant weight) (Aurand & Triebold, 1963).

Determination of pH

pH was determined on a slurry of reconstituted flour (5 g in 5 ml deionized distilled water) with a pre-standardized pH meter (Pye Unicam).

Determination of total sugar content

Total sugars were extracted (Joslyn, 1970), and measured by the anthrone method (AOAC, 1970).

Determination of L-ascorbic acid

L-ascorbic acid was determined spectrophotometrically (Schaffert & Kingsley, 1955).

Determination of mineral elements

Samples (1 g) were dry-ashed (500°C, 3 h). Aliquots of 4 ml 20% nitric acid were added to each of the ashed samples and heated to boiling in a fume chamber. The digest was filtered (Whatman No. 1), and the filtrate diluted to 250 ml. Sodium, phosphorus, potassium and calcium were determined by flame photometry (Gallenkamp Cat No. 22. FH-500) while iron was determined by atomic absorption spectrophotometry (Perkin Elmer, model 703), as described elsewhere (Ukhun & Uwatse, 1988).

Statistical analyses

Analyses of variance (ANOVA) for storage changes in the chemical parameters, where indicated, were done (Snedecor & Cochran, 1956). *T*-test analyses were also done, where indicated, in accordance with described methods (Skoog & West, 1975).

RESULTS AND DISCUSSION

Panellists were deliberately asked to describe in their own way each of the sensory attributes of the products assessed in the study, while also indicating, for each attribute, whether the described attribute was acceptable or not, apart from the overall acceptability which they were required to comment on. The conventional method of hedonic scoring was not adopted here because it was thought that the present method would give a more realistic appraisal of how potential consumers of the products would react to the products in the free market. In the reconstitution test, panellists were asked simply to indicate whether the reconstitution of the products in either the hot or cold water was satisfactory or not. They were also asked to inspect the products visually and to indicate whether or not they detected moulds in the products. All the products produced from the ripe plantain were acceptable to all the panellists using the indicated criteria. The overall acceptability was also 100%, before and after the 5-month storage. Most (at least 70%) of the panellists found the unripe flour samples acceptable, overall; for those who found the products unacceptable overall, the taste and aroma were the compelling factors.

Pre-storage (0-month), the temperature at which the plantain slices (76°C, 88–92°C) were oven-dehydrated did not affect the description, by the panellists, of the colour of the flours. After 5-months storage, some panellists introduced the word 'dull' in their description of the colour; this could mean incipient melanoidin formation in the stored products consequent upon incipient non-enzymic browning. The various shades of brown with which panellists described the unripe flour are obviously deeper hues of colour than the various shades of yellow with which they described the unripe flour products. This can be explained by the higher sugar content of the ripe flour (see Table 3 below) which could have accentuated caramelization reactions in the ripe plantain flour. The higher sugar content of the ripe flour than that of the unripe flour accounts for the 'sweet' description of the former product while a correspondingly higher polysaccharide content of the unripe flour accounts for the 'flat', 'weak', 'faint', 'mild', etc, terms used to describe it (see Table 3 below). It is inferred therefore, that ripening of plantain flour leads to the conversion of the constituent polysaccharides to sugars. The sweetness of ripe plantain is such that, ordinarily, no extraneous sugar need be added to the instant flour during its commercial production, or during its consumption by consumers. This should mean reduced cost and increased affordability to consumers.

All the panellists reported that the reconstitution of the flour was acceptable. They did not detect moulds in the products and microscopic examinations of the samples corroborated the results of the visual inspection.

Toxicologically, the absence of moulds in the products minimizes the risk of mycotoxicoses (Wogan, 1976; Steyn, 1971). The good keeping quality inferred in the sensory evaluation results can be ascribed largely to the very low moisture content attained (Table 1) (Diener & Davis, 1969; Troller, 1971; Uraih & Ogbadu, 1980) and to the efficacy of the processing methods used in the production of the instant flours.

The moisture contents of the instant plantain flours (Table 1) are much lower than those quoted for many commercial dehydrated foods. The very

TABLE 1

Range of Moisture Contents (%, means ± SEM of 6 readings) of Instant Plantain Flours Stored at Two Temperatures for 5 Months (i.e. between 0 and 5 months)

Samples	*Storage temperatures*	
	5 ± 1°C	*22 ± 4°C*
Ripe plantain flour (76°C)	1·2 ± 0·4—1·7 ± 0·6	1·2 ± 0·3—1·4 ± 0·5
Ripe plantain flour (88–92°C)	1·1 ± 0·1—1·4 ± 0·3	0·9 ± 0·2—1·2 ± 0·2
Unripe plantain flour (76°C)	0·8 ± 0·2—1·4 ± 0·3	0·8 ± 0·2—1·3 ± 0·4
Unripe plantain flour (88–92°C)	0·6 ± 0·1—1·1 ± 0·4	0·6 ± 0·1—1·0 ± 0·6

low moisture levels were attained partly because of the use of very thin slices of the cooked plantain finger halves which must have increased heat penetration and moisture loss rates. There were limited increases in the moisture contents of the various plantain flour samples stored for 5 months under the storage conditions indicated in Table 1. The increases were statistically insignificant ($P > 0{\cdot}05$). It is observed in Table 1, however, that although the ripe plantain flours, generally, had higher moisture contents than the unripe plantain flours during storage, the unripe plantain flour samples underwent higher net storage increases in moisture contents than the ripe flour samples. This observation is consistent with predictably higher starch contents of the unripe plantain flours which should correspond to a higher hydrophilicity of the unripe samples. Generally, the very low initial moisture contents coupled with the inherent hydrophilic nature of the products (by virtue of their high starch or sugar contents) (Oyenuga, 1968) could mean that the instant flour would be prone to undesirable moisture adsorption and humectancy phenomena. Proper packaging of the products and, possibly, controlled atmosphere storage such as by the use of desiccants and hypobaric storage, could help to mitigate these problems.

The pH of all the instant plantain flours did not change significantly ($P > 0{\cdot}05$) during storage; this reflects the buffering capacity of the systems (Table 2). The small decreases in pH during storage are indicative of incipient accumulation of organic acids concomitant with processes such as sugar oxidation, Maillard and caramelization reactions. The unripe plantain flours consistently had higher pH values than the ripe plantain flours. This may have been due to organic acid syntheses during ripening (Rumpf *et al.*, 1972) of the plantain fingers from which the flour samples were prepared. Table 2 also indicates that the plantain flour samples which were prepared

TABLE 2
Range of pH Values (means ± SEM of triplicate readings) of Instant Plantain Flours Stored at Two Temperatures for 5 Months (i.e. between 0 and 5 months)

Samples	*Storage temperatures*	
	5 ± 1°C	*22 ± 4°C*
Ripe plantain flour (76°C)	5·7 ± 0·1—5·5 ± 0·0	5·7 ± 0·1—5·3 ± 0·1
Ripe plantain flour (88–92°C)	5·9 ± 0·1—5·6 ± 0·1	5·9 ± 0·1—5·4 ± 0·1
Unripe plantain flour (76°C)	6·7 ± 0·3—6·2 ± 0·1	6·6 ± 0·3—6·1 ± 0·0
Unripe plantain flour (88–92°C)	6·7 ± 0·0—6·7 ± 0·0	6·7 ± 0·0—6·2 ± 0·2

by oven dehydration at 88–92°C had slightly higher pH values than those prepared by oven dehydration at 76°C, pre-storage (0-month). The observations here contrast with those of Kallio *et al.* (1989) in their studies with birch syrup in which they reported decreasing pH values with increasing severity of thermal treatment. They ascribed reducing pH values to browning reactions. Apparently, in the present studies, the higher temperature of 88–92°C led to slightly higher losses of volatile acids or even to some defixation of otherwise fixed acids. During storage, however, the relationship between processing temperature and pH values was not quite as consistent, especially in the unripe flour samples. Changes in pH in these products during storage could be reflections of the balance between anabolic and catabolic processes, the trend of which may not always be quite predictable and consistent for a given set of conditions. On the whole, however, the instant plantain flours can be classified as very mildly acidic, and this, in conjunction with the levels of sugars and substances produced from browning and other reactions, could be the ultimate determinants of the flavours of the instant flours.

The following observations were made with respect to the total sugar contents of the instant plantain flours during the 5-month storage (Table 3):

(i) Losses of sugars which may be attributed to early Maillard browning reactions; usually, these do not lead to melanoidin accumulation except at the later stages of browning.
(ii) Higher levels of sugars in the ripe plantain flours, consistent with their sweeter taste.
(iii) Higher amounts of sugars in plantain flours oven-dehydrated at 76°C, than in those dehydrated between 88 and 92°C, due to predictably greater caramelization and pyrolytic decompositions at the higher temperature (88–92°C).
(iv) Generally, there were smaller losses of sugars in instant plantain flour samples stored at 5 ± 1°C than in those stored at 22 ± 4°C. The observed storage losses of sugar (Table 3) were statistically insignificant in the unripe samples ($P > 0{\cdot}05$) but significant in the ripe samples ($P < 0{\cdot}05$) stored at 22 ± 4°C.

Examination of both Tables 1 and 3 reveals that while moisture contents were rising (although unimpressively), sugar contents were falling, during storage. This could mean, particularly in the ripe plantain flour samples, that slightly elevated moisture levels enhanced storage sugar losses via early Maillard reactions. A similar observation of the accentuating effects of moisture on browning has been made by Ukhun (1987) in studies with raw cowpea flour. Other reactions that lead to the formation of strong conjugate

TABLE 3
Total Sugar Contents (g/100 g, dry matter) of Instant Plantain Flours Stored at Two Temperatures for 5 Months

Samples	*0 month*		*1 month*		*2 months*		*3 months*		*4 months*		*5 months*	
	5 ± 1°C	*22 ± 4°C*	*5 ± 1°C*	*22 ± 4°C*	*5 ± 1°C*	*22 ± 4°C*	*5 ± 1°C*	*22 ± 4°C*	*5 ± 1°C*	*22 ± 4°C*	*5 ± 1°C*	*22 ± 4°C*
Unripe plantain flour (76°C)	14·8 ± 2·5	14·8 ± 2·5	15·0 ± 2·7	14·9 ± 2·3	14·6 ± 1·9	13·8 ± 1·7	14·2 ± 2·4	12·2 ± 1·5	14·6 ± 3·1	11·0 ± 2·9	14·3 ± 3·5	11·5 ± 2·8
Unripe plantain flour (88–92°C)	13·6 ± 1·7	13·6 ± 1·7	13·3 ± 2·0	13·8 ± 1·9	13·4 ± 1·4	13·5 ± 2·6	13·2 ± 2·3	12·8 ± 3·1	13·4 ± 1·7	10·8 ± 1·1	13·1 ± 2·0	10·9 ± 1·5
Ripe plantain flour (76°C)	30·1 ± 0·9	30·1 ± 0·9	29·7 ± 1·5	31·2 ± 2·2	30·0 ± 1·7	28·8 ± 1·6	28·8 ± 1·6	28·0 ± 2·8	29·0 ± 0·7	24·1 ± 1·6	28·7 ± 3·1	20·1 ± 2·4
Ripe plantain flour (88–92°C)	26·7 ± 1·4	26·7 ± 1·4	25·3 ± 0·8	25·8 ± 3·1	26·1 ± 2·3	25·1 ± 2·3	26·2 ± 1·1	22·4 ± 1·6	26·1 ± 2·8	20·4 ± 2·3	25·5 ± 1·9	16·3 + 2·3

Results are expressed as means ± SEM of four readings.

bonds involving the sugars or that lead to their outright oxidation could also contribute to storage losses of sugars.

Many physiological and therapeutic functions have been ascribed to ascorbic acid (Cohen & Duncan, 1967; Birch & Parker, 1974). Ascorbic acid was not detected in the ripe plantain flours (Table 4). Therefore, the flours will benefit from ascorbic acid fortification. Immediately after processing (0-month, as in Table 4), ascorbic acid contents of 17·4 ± 0·2 and 10·1 ± 0·5 mg/100 g respectively, were detected in the flours prepared from unripe slices oven-dehydrated at 76°C and between 88 and 92°C. It appears that ripening of plantains leads to the conversion of L-ascorbic acid to sugars since according to Muller & Tobin (1980), L-ascorbic acid is basically a hexose derivative.

The ascorbic acid contents of the unripe plantain flour processed at 88–92°C were significantly lower (*T*-test, $P = 0{\cdot}01$; d.f. = 14; Skoog & West, 1975) than those processed at 76°C. This is easily attributable to the thermal

TABLE 4
Ascorbic Acid Contents (mg/100 g, dry matter) of Instant Plantain Flours Stored at Two Temperatures for 5 Months

Samples	*0 month*		*1 month*		*2 months*		*3 months*		*4 months*		*5 months*	
	5 ± 1°C	*22 ± 4°C*	*5 ± 1°C*	*22 ± 4°C*	*5 ± 1°C*	*22 ± 4°C*	*5 ± 1°C*	*22 ± 4°C*	*5 ± 1°C*	*22 ± 4°C*	*5 ± 1°C*	*22 ± 4°C*
Ripe plantain flour (76°C)	0	0	0	0	0	0	0	0	0	0	0	0
Ripe plantain flour (88–92°C)	0	0	0	0	0	0	0	0	0	0	0	0
Unripe plantain flour (76°C)	17·4 ± 0·2	17·4 ± 0·2	17·2 ± 0·7	16·4 ± 1·1	17·3 ± 0·6	14·1 ± 1·3	17·5 ± 0·3	13·7 ± 0·2	17·4 ± 0·4	11·1 ± 0·6	17·2 ± 1·5	11·4 ± 0·7
Unripe plantain flour (88–92°C)	10·1 ± 0·5	10·1 ± 0·5	10·3 ± 1·1	10·2 ± 1·4	10·0 ± 0·8	9·6 ± 0·3	10·4 ± 0·7	9·3 ± 0·5	9·8 ± 1·2	9·5 ± 1·0	9·9 ± 1·0	9·2 ± 0·6

Results are expressed as means ± SEM of five readings.

lability of ascorbic acid which has been reported in several other products (Farhangi & Guy-Valadon, 1981; Ukhun *et al.*, 1988, amongst many others). The levels of ascorbic acid in the unripe instant plantain flours could enhance the shelf-life of the products through an antioxidant effect (Harbers *et al.*, 1981).

Storage losses of ascorbic acid in the unripe plantain flour samples are evident in Table 4. This observation is in agreement with previous reports on storage lability of ascorbic acid (Wilson & Shaw, 1987; Moshonas & Shaw, 1989, amongst others).

The storage losses in the present study were not significant ($P > 0{\cdot}01$) in all the samples stored at 5 ± 1°C and in all the unripe samples oven-dehydrated at 88–92°C. The storage losses were significant ($P < 0{\cdot}05$) in unripe samples oven-dehydrated at 76°C and stored at 22 ± 4°C. In percentage terms, unripe plantain flour samples (88–92°C) stored at 5 ± 1°C suffered about 1·8% loss of ascorbic acid at the end of the 5-month storage while the same samples (88–92°C) stored at 22 ± 4°C suffered about 9% loss of ascorbic acid during the same period. For the 76°C unripe flour samples, the losses were about 1 and 34% at storage temperatures of 5°C and 22 ± 4°C, respectively. The inference then is that, although the higher dehydration temperature of 88–92°C inflicted higher losses of ascorbic acid immediately after processing and pre-storage (0-month), it had the beneficial effect of ameliorating subsequent storage losses particularly in samples stored at 22 ± 4°C. Possibly and speculatively, ascorbic acid oxidase and similar enzymes and pro-oxidant metals, such as iron as reported in Table 5, were markedly deactivated and activation energy for ascorbic acid destruction either remained unchanged or was in fact elevated at the higher processing temperature. Possibly, also, conjugate bonds of ascorbic acid are significantly weakened by high pre-storage processing temperatures, thereby enhancing ascorbic acid extractability in the spectrophotometric determination. Thus, even if losses are sustained during storage, the enhanced release of conjugated ascorbic acid could be helping to offset some of these measured storage losses.

While there are no Recommended Dietary Allowances for sodium, the level of sodium in the instant plantain flours, recorded in Table 5, could help to meet some of the 2 g sodium, per day, which is considered adequate (Amen, 1973). Using Table 5 and assuming a 100% bio-availability *in vivo*, about 1 kg and 670 g, respectively of the ripe and unripe flours will supply the 2 g desirable level of sodium.

Compared with other foods (Pyke, 1975), the instant plantain flours can be regarded as good sources of potassium. The levels of phosphorus in the instant plantain flour are slightly higher than those in vegetables such as spinach, cabbage and lettuce (30–95 mg/100 g) but lower than those in meat,

TABLE 5
Levels (mg/100 g, dry matter) of some Mineral Elements in Instant Plantain Flours

Samples	*Na*	*K*	*P*	*Ca*	*Fe*
Ripe plantain flour (76°C)	0·2 ± 0·0	880·7 ± 15·3	97·1 ± 5·2	28·9 ± 2·7	1·2 ± 0·8
Unripe plantain flour (76°C)	0·4 ± 0·1	890·2 ± 17·1	104·5 ± 6·3	32·6 ± 3·3	1·3 ± 0·6
Ripe plantain flour (88–92°C)	0·2 ± 0·0	831·4 ± 20·9	90·8 ± 3·7	27·6 ± 2·4	1·5 ± 0·4
Unripe plantain flour (88–92°C)	0·3 ± 0·0	846·5 ± 30·4	101·1 ± 5·6	30·2 ± 1·9	1·7 ± 0·3

Results are expressed as ± SEM of triplicate readings.

fish, cheese and eggs whose phosphorus contents range from 200–550 mg/100 g food. The phosphorus content of the plantain flour compares favourably with the level in milk (Pyke, 1975). Based on the results in Table 5, the plantain flours are moderately good sources of iron (Pyke, 1975). The maximum daily requirement for iron is 18 mg according to Amen (1973). Going by the lowest iron content of the instant plantain flours (Table 5), about 1·5 kg of the flour should supply the stipulated maximum daily requirement for iron.

With calcium contents of between 27·6 ± 2·4 and 32·6 ± 3·3 mg/100 g (Table 5), the instant plantain flours are poor sources of calcium along with foods such as oatmeal, brown flour, potato, rice, sugar and cooking fat, in a classification by Pyke (1975). At best, the plantain flour will supply part of the 0·7–1·4 g daily requirement for calcium (Amen, 1973).

The slight but consistently higher levels of the elements in the unripe plantain flour than in the ripe flour, appear to be related to slightly higher leaching losses during cooking. It is possible that the unripe plantain slices, from which the unripe flours were prepared, offered more impediment to leaching of the elements because of their firmer texture.

CONCLUSIONS

Instant plantain flours have been produced. Quality parameters important to, and easily discerned by, consumers, were maintained, even after a 5-month storage. The flours therefore represent potentially important foods on their own, and as bases for others such as weaning baby foods, puddings, soups and gravies, especially, if fortified with nutrients that might be present in inadequate amounts in the products. This should help in reducing post-harvest wastage of plantain fingers.

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