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The effects of ripening and cooking method on mineral and proximate composition of plantain (*Musa* sp. AAB cv. 'Agbagba') fruit pulp

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In West and Central Africa, plantain fruits are eaten after cooking or after some other forms of processing. The cooking or processing method employed influences the biochemical and nutritional composition thereafter. In this study, the fruits of Falsehorn plantain (*Musa* sp. AAB, cv. 'Agbagba') at the green harvest stage, light green (more-green-than-yellow), yellowish green (more-yellow-than-green) and fully-ripe (yellow) stages of ripeness were analysed for nutritional composition after boiling, steaming or roasting, alongside the unprocessed (raw) fruits as the control. The fruits were analysed in triplicate samples for fat, protein, carbohydrate (CHO), dry matter content (DMC), β-carotene (vitamin A precursor), ash, Fe, K and Zn contents in a 4 x 4 factorial in a completely randomized design (CRD). Results showed significant variations in the mineral and proximate composition of the fruits following natural ripening, and the cooking (processing) method employed. Ash, CHO and K contents of the fruits seemingly increased with ripeness, whereas fat, DMC, Fe and β-carotene decreased particularly at full ripe state. Majority of the proximate and mineral constituents (fat, protein, CHO, DMC, vitamin A, Fe and K) were relatively higher at the light green and the greenish yellow (semi-ripe) stages. Similarly, ash, fat, protein, DMC, Fe and K were significantly (P < 0.05) higher in the roasted fruits, but steamed fruits had the highest concentration of β-carotene. Except for CHO content, boiling significantly (P < 0.05) decreased most of the proximate and mineral contents of the fruits. It was observed that fruits roasted at the semi-ripe stages had the highest concentration of nutrients, and the CHO content in roasted fruits was correspondingly low. It is conclusive from this study that roasting followed by steam-cooking better conserved nutrients of plantain fruits, thus adjudged the best cooking methods. To optimize nutrients derivable from eating plantain fruits, roasting semi-ripe (light green or slight yellow stage) fruits was the best option.

Key words: Plantain, ripeness, processing, nutritional qualities.

INTRODUCTION

Plantain (*Musa* spp. AAB) is an important starchy staple that contributes to subsistence economies in West and Central African (WCA) sub-region. It has been estimated that plantain provides nearly 60 million people in Africa with more than 200 calories per day (Stover and Simmonds, 1987). Plantain cultivation is attractive to farmers due to the low labour requirement for its production as compared to cassava, maize, rice and yam (Marriott and Lancaster, 1983).

In WCA and the Caribbean, plantain is of great socio-economic and nutritional significance. It generates considerable income for smallholders who produce them in compound farms either in mixtures or sole plots. Nearly 90% of the total plantain produced worldwide (63 million tonnes) are consumed locally in the producing countries leaving merely 10% for export (Awodoyin, 2003), and only a very small proportion is processed to storable products (Adeniji and Empere, 2001).

Plantain fruits may be consumed unripe (green),

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yellowish-green (fairly ripe), or fully ripe after boiling, roasting or deep frying, or taken with vegetable sauce after turning the flour in boiling water to form a unique textured dough called 'Amala'; a delicacy for the Yorubas of the south-western Nigeria. Unripe fruits when boiled can be pounded into 'Fufu' and eaten with soup (Ogazi, 1996). Ripe fruits can also be eaten raw or after dip-frying.

It is often common to fry plantain fruits particularly at the fully ripe stage. Dip-frying, however, has been implicated in the reduction of certain micronutrients in plantain pulp including iron, copper and zinc (Ahenkora et al., 1996), and some provitamin A carotenoids (Rodroguez-Amaya, 1997). Moreover, high consumption of fried foods is linked to cardiovascular diseases (Brownell and Leibman, 1998) as these foods contain cancer and obese-causing molecules like acrylamide and trans fats that raise levels of low-density lipoproteins (LDL); the artery clogging 'bad' cholesterol.

Ripening of banana fruits occurs at room temperature ($25 \pm 2°C$) by placing the fruits on racks or in boxes with ethylene or smoke infusion (Pantatisco and Mendoza, 1971). A more common practice is to allow slow ripening under ambient conditions. Some sellers artificially induce ripening before marketing of fruits, especially in cities where fairly ripe fruits command higher premium.

Understanding the chemical changes associated with ripening would form a basis for expanding the utilization of plantains. Earlier studies on the biochemical composition of plantain fruits (Ketiku, 1973; Asiedu, 1987; Izonfuo and Omuaru, 1988; Baiyeri, 2000; Baiyeri and Unadike, 2001) reported significant variability in nutrient composition of ripe and unripe fruits. Baiyeri (2000) found significantly higher doses of N, P, K, Mg and Ca in fully ripe plantain pulp (when compared to the unripe), but lower concentrations of Fe, Cu, Zn and Na in the ripe state. Results of similar studies (Baiyeri and Unadike, 2001; Baiyeri et al., 2009) reported higher ash content in ripe fruits suggesting that tissue breakdown during ripening causes some mineral elements to be free and more available.

In recent times, research has been directed towards combating micronutrients and vitamin A deficiency through nutritional breeding and biofortification (Lusty et al., 2006). Globally, vitamin A deficiency is the most common form of malnutrition after protein deficiency (World Bank, 1993). Vitamin A has a role in vision, as well as immunology, reproduction and embryo development. In south-eastern Nigeria, 50% of children and 61% of women suffer chronic anaemia mainly due to iron deficiency (UNICEF, 1989), while the deficiency of zinc has been implicated in poor growth, hypogonadism and anaemia (Ihekoronye and Ngoddy, 1985). Potassium is actively involved in muscle contraction and maintenance of ionic and osmotic balance of intra- and extracellular fluids. Besides being an energy food, plantain as one of the major staple foods in WCA has the potential to

provide modest amounts of these nutrients (Ogazi, 1996).

Unlike bananas which are conventionally consumed raw as dessert, plantains are mostly eaten after cooking. Boiling, steaming, roasting and dip-frying are the major cooking methods employed in plantain fruit utilization. This study was conducted to evaluate the effects of three healthy cooking methods (boiling, steaming and roasting) and a control (raw fruits) at four fruit ripening stages (dark green, light green, yellowish green and fully-ripe yellow) on the proximate qualities and some essential nutrients (iron, potassium, zinc and pro-vitamin A contents) of plantain fruit pulp. It is anticipated that the information obtained could influence the consumption pattern and nutritional benefits of plantain.

MATERIALS AND METHODS

Trial location

The experiment was conducted at the Analytical Laboratory of the Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka. Nsukka is a savannah agro-ecological zone located on latitude 06 52'N, longitude 07° 24'E and 447.2 m above sea level. Laboratory ambient temperature oscillates around $29 \pm 2°C$.

Design of the experiment

The experiment was a 4 x 4 factorial in completely randomized design (CRD). Factor A consists of four cooking methods: boiling, steaming, roasting and the no-cooking (raw) of fruits as control. Factor B was stages of fruit ripeness, which are deep green (harvest stage greenness), light green stage (more-green-than-yellow), light yellow stage (more-yellow-than-green) and the fully ripe yellow stage following the ten ripening stages described in Baiyeri (2005).

Sampling and analysis

Fruit samples for analysis were obtained from the second and third proximal hands of each bunch, and washed under running tap. The fruits were sorted according to their stages of ripeness, and were analyzed at the unripe, semi-ripe and fully ripe stages after cooking treatments (boiling, steaming or roasting). Fruit pulps of known weights were either boiled (for 30 min) in a beaker containing 200 ml of water, or roasted over hot charcoal until they were ready for consumption, or steamed in polyethylene wrap. These together with their raw (uncooked) samples as control were oven dried at 65°C until permanent dry weights were obtained. Dry samples were ground to pass through one millimetre mesh sieve using Thomas Wiley laboratory mill (model 4). The Fe, Zn and K contents of the fruits were determined following standard procedures described by Pearson (1976), whereas β-carotene content was assessed using an UV-visible spectrophotometer at 761 nm (SpectrumLab 21$_A$ model). The proximate compositions of the dried fruit samples were determined following AOAC (1990).

Data analysis

Data were collected across the treatment combinations in triplicates procedures for factorials in completely randomized design (CRD). Principal component analysis was performed across the variates to

Table 1. Combined effects of fruit ripeness and cooking method on mineral and proximate composition of 'Agbagba' fruit pulp.

Stage of ripeness	Cooking method	Ash (%)	Fats (%)	Protein (%)	CHO (%)	DMC (%)	β-Carotene (mg/100g)	Fe (mg/100g)	K (mg/100g)	Zn (mg/100g)
	Boiling	2.00	1.17	2.92	84.41	40.30	0.0046	16.95	14.31	6.67
Deep green	Roasting	2.50	2.33	2.77	82.39	48.87	0.0066	12.71	18.46	6.53
(Stage 1)	Steaming	2.67	1.50	3.07	83.76	45.87	0.0159	11.65	21.00	6.71
	Control [Raw]	2.50	1.00	3.21	83.62	48.00	0.0071	12.71	18.46	7.56
	Mean	2.42	1.50	2.99	83.55	45.76	0.0086	13.50	18.18	6.87
	Boiling	2.17	1.83	2.48	85.35	41.23	0.0125	26.48	16.95	6.30
Light green	Roasting	3.00	2.33	3.50	82.82	55.20	0.0179	28.60	21.90	8.06
(Stage 3)	Steaming	2.67	1.83	3.07	83.76	46.43	0.0118	26.48	18.51	7.36
	Control [Raw]	2.33	2.17	3.21	83.45	38.87	0.0133	13.77	18.82	5.52
	Mean	2.54	2.04	3.07	83.85	45.43	0.0139	23.83	19.04	6.81
	Boiling	1.75	1.00	3.07	89.43	30.80	0.0091	12.71	16.07	5.82
Light yellow	Roasting	2.75	1.25	3.29	88.21	58.35	0.0169	29.66	23.96	7.75
(Stage 5)	Steaming	2.00	2.25	3.07	89.93	45.25	0.0202	9.53	18.93	7.46
	Control [Raw]	2.25	0.75	3.50	90.99	47.50	0.0186	10.59	18.50	7.84
	Mean	2.19	1.31	3.23	89.64	45.48	0.0162	15.62	19.36	7.22
	Boiling	2.83	0.33	2.48	87.85	34.67	0.0113	11.12	15.15	5.73
Full yellow	Roasting	3.00	0.67	3.21	86.62	44.60	0.0096	12.71	20.77	8.26
(Stage 6)	Steaming	3.00	0.00	3.36	88.80	46.17	0.0108	12.71	19.26	6.29
	Control [Raw]	3.00	0.33	3.21	85.62	35.03	0.0061	7.94	16.64	6.69
	Mean	2.96	0.33	3.07	87.22	40.12	0.0095	11.12	19.45	6.74
$LSD_{(0.05)}$ for interaction effect		ns	0.54	ns	1.58	7.79	0.0019	5.09	ns	1.13
$LSD_{(0.05)}$ comparing ripeness		0.34	0.27	ns	0.79	3.99	0.0010	2.55	ns	ns

CHO = Carbohydrate; DMC = pulp dry matter content; $LSD_{(0.05)}$ = least significant difference at 5% probability level; ns = non-significant difference.

identify the most influenced nutritional qualities of plantain fruits following ripeness and the cooking method employed. Data were analyzed with GENSTAT Release 7.22 DE (GENSTAT, 2008). Furthermore, the inter-relationship among the interacting ripening stages and cooking methods was expressed via the visualization output of GGE-biplot analysis (Yan, 2001).

RESULTS

Data on Table 1 show the combined effects of varying fruit ripening stages and cooking methods on some mineral and proximate composition of 'Agbagba' fruit pulp. The interaction effects as well as the main effect of ripeness were significant (P < 0.05) for most of the mineral and proximate components studied. Ash, carbohydrate and potassium contents of the fruits seemingly increased with ripeness, whereas iron, zinc and β-carotene decreased particularly at the full ripe state.

Ash was, however, not significantly influenced by the ripeness-by-cooking method interaction, but boiled fruits had the least ash content at all the fruit ripening stages. Fat content significantly (P < 0.05) decreased with ripeness and roasted fruits had the highest content of fat at the deep green and light green stages, as well as the fully ripe stage. At the light yellow stage, steamed fruits had the highest fat content. Boiled fruits had relatively low fat across the ripening stages.

Protein content was not significantly influenced by ripeness and the cooking methods employed, but it was correspondingly low in all the boiled fruits across the ripening stages. The carbohydrate levels were significantly (P < 0.05) higher at the fairly ripe stages. At all the fruit ripening stages, carbohydrate was relatively high in boiled and steamed fruits, but correspondingly low in roasted fruits. The dry matter content significantly (P < 0.05) decreased at the fully ripe stage and was correspondingly low in boiled fruits across the four ripening stages.

Dry matter was significantly (P < 0.05) high in fruits roasted at the fairly ripe (light green and light yellow) stages.
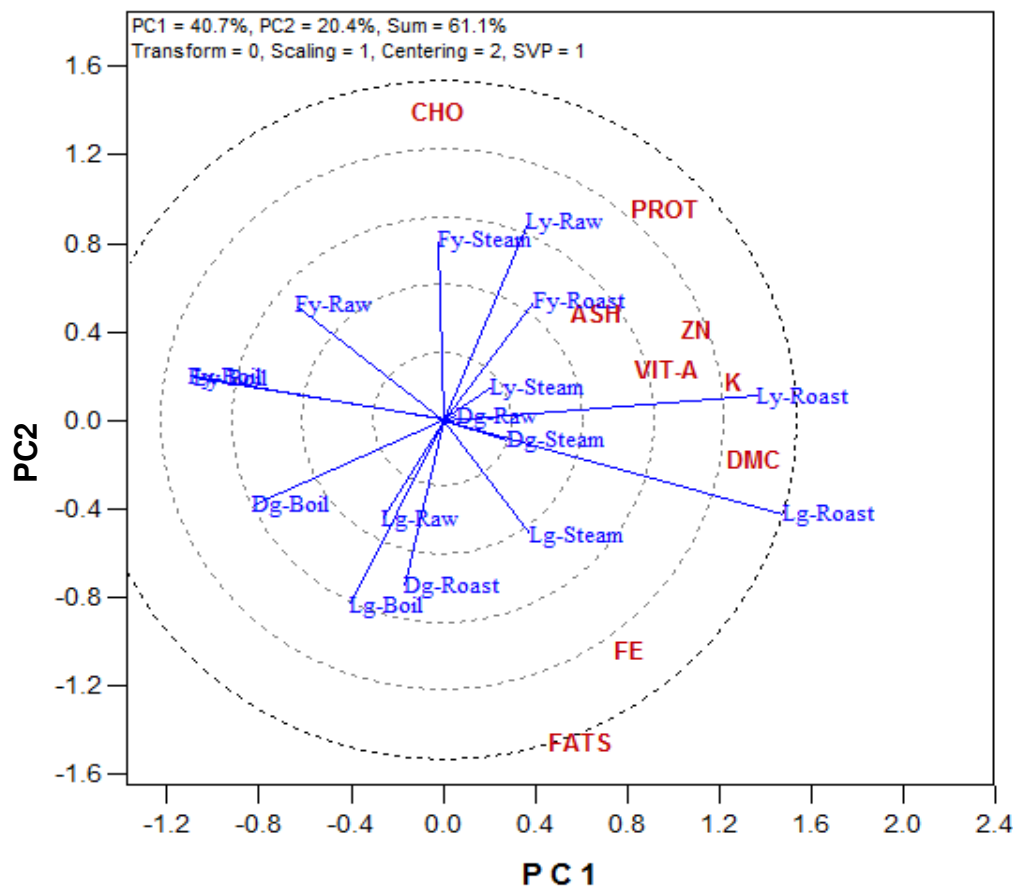
Figure 1. Biplot diagram showing the existing relationships between entries (ripeness-by-cooking treatments) and nutritional qualities. CHO = Carbohydrate; PROT = protein; FE = iron; ZN= Zinc; VIT-A = vitamin A; Ly = light yellow; Fy = fully yellow; Lg = light green; Dg = deep green stage of ripeness.

Beta-carotene significantly ($P < 0.05$) improved with ripeness but drastically declined at the full ripe stage. Boiling seemingly reduced the β-carotene content across the fruit ripening stages. Steamed fruits in most cases had relatively higher content of β-carotene. Fruit Fe content significantly ($P < 0.05$) decreased with ripeness particularly at the fully ripe stage. Cooking by boiling seemingly reduced the fruit Fe content. Roasted fruits had the highest concentration of Fe in most of the ripening stages. Potassium content of the fruits was not significantly influenced by fruit ripeness and the cooking method, but there was a progressive rise in K levels as ripening progressed. Roasted followed by steamed fruits had the highest content of K across the fruit ripening stages.

Zinc content was not significantly influenced by stage of fruit ripeness, but the highest concentration of Zn was recorded at the light yellow stage. Boiling particularly at the ripe stages significantly ($P < 0.05$) reduced the fruit Zn content. Roasted or steamed fruits had high content of Zn in most cases. Zinc content was correspondingly high in all roasted fruits and was highest when fruits were

roasted at full yellow stage, followed closely by roasting at light green stage.

A majority of the proximate and mineral composition had the highest value when the fruits were roasted at light green and/or light yellow stages (fairly ripe fruits). This is true for ash, fat, protein, dry matter, iron, potassium and zinc contents. Beta-carotene level was highest when fruits were steamed at fairly ripe (light yellow) stage, but particularly poor in fruits boiled at deep green stage.

The biplot analysis (Figure 1) explained 61% of the total variations existing in the combined effects of cooking methods and fruit ripening stage on the nutritional qualities of the fruit. The biplot clearly revealed the close relationship existing between the fruits roasted at yellowish green and light green (fairly ripe) stages. Fruits roasted at the fairly ripe stages had the highest concentrations of iron, dry matter, potassium, zinc and protein. Steam-cooked fruits at deep green or fairly ripe stage had close similarities with the roasted fruits. It was evident from the biplot that fruits boiled directly in water (as commonly practiced in WCA) irrespective of the

Table 2. Principal component analysis comparing the nutritional qualities of 'Agbagba' plantain fruit pulp as influenced by fruit ripeness and cooking processing.

Mineral/proximal property	Prin 1 (26.10%)	Prin 2 (23.65%)	Prin 3 (14.59%)
Ash (%)	0.15617	0.14625	-0.63010
Dry matter (%)	0.27364	0.31948	0.19973
Fats (%)	0.43324	0.04285	0.48333
Protein (%)	0.09441	0.34977	-0.37603
Carbohydrate (%)	-0.52889	0.28533	0.08656
Iron (%)	0.35601	0.02199	0.04822
Potassium (%)	0.32604	0.43014	-0.21065
Zinc (%)	-0.13095	0.06531	0.19069
Pro-vitamin A (%)	0.06051	0.53413	0.30570

ripening stage generally had lower values for the nutrients assayed.

The principal components analysis (PCA) shown in Table 2 revealed that fat and carbohydrate contents explained about 26.10% of the total variation that existed in the fruits as a result of ripening and processing treatments applied. Similarly, potassium, and pro-vitamin A contents explained about 23.65% of the total variation, but ash, alone, accounted for 14.59% of existing variability. PCA suggested that these traits (fat, carbohydrates, potassium, pro-vitamin A and ash) were the most responsive to ripening and cooking methods employed, and are thus, most discriminative for detecting the effects of ripening and cooking on nutritional qualities of plantain fruits.

DISCUSSION

The significant variations that existed in the mineral and proximate composition of the fruits following ripening and cooking treatments suggest that nutritional qualities of plantain fruits vary with the stage of ripeness and cooking/processing method employed. Ash and carbohydrate contents increased with ripeness whereas fat, dry matter content, Fe and β-carotene decreased with ripening. 'Agbagba' at the unripe and semi-ripe stages was rich in iron, potassium and zinc. Similar findings have been reported in banana and other plantain varieties (Marriott and Lancaster, 1983; Baiyeri and Unadike, 2001), suggesting that maximum dietary benefit of these minerals could be obtained when plantain fruits are consumed at the unripe stage.

Pro-vitamin A content tended to increase with ripeness but later decreased at fully ripe stage. This is in line with the report of Aseujo and Porrata (1956) that the average carotene content of plantains was found to be higher in the green fruits. Other researchers (Giami and Alu, 1994; Ngoh-Newilah, 2005) had also shown that carotenoid content (β-carotene) in plantain fruits could decline as much as 50 to 70% during ripening. Ogazi (1992) reported a progressive increase in sugar content of

plantains from 4.74% at the green stage to 39.19% at the fully ripe stage.

Most of the mineral and proximate qualities were significantly influenced by the cooking method employed. Ash, fat, protein, dry matter content, iron and potassium contents were found highest in the roasted fruits. Pro-vitamin A content was rather highest in the steam-cooked fruits as compared to other cooking methods. In contrast, pro-vitamin A was lowest in fruits boiled directly in water. This observation could be as a result of leaching or volatilization losses through the cooking medium (water). Ogazi (1992) reported that cooking of partially ripe fruits by boiling or baking destroys about 10% of the bioavailable vitamins, whereas fully ripe fruits lose 50 to 70% of the total vitamins during boiling. Significant losses in various minerals including Ca, Mg, P, Fe, Na and Cl were observed in the roots and fresh leaves of cassava as a result of boiling (Ebuehi, 2005). Boiling and dip-frying had been implicated in the redu-ction of certain micronutrients in plantain pulp including iron, copper and zinc (Ahenkora et al., 1996). In this study, steam-cooking of the fruit pulp in polyethylene wraps minimized nutrient losses from the fruit pulp. The polyethylene wrap provided a barrier between the pulp and the cooking medium thereby protecting the edible pulp from possible nutrient losses.

Fat, carbohydrate, potassium, β-carotene and ash contents were identified as the most varied nutritional components in this study, hence most influenced by the fruit ripeness and the cooking practices.

Conclusions

(1) Roasting conserved the largest amounts of nutrients, hence adjudged the best cooking method. During roasting, a surface crust is readily formed around the samples sealing intercellular spaces, thereby minimizing possible volatilization losses.
(2) Steaming of fruits in polyethylene wraps was equally a good practice but could be somewhat laborious and time consuming.

(3) To obtain the maximum available nutrients from plantain fruits, roasting at the fairly or semi-ripe stage stands the best option.

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