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EFFECT OF BOILING AND FRYING ON THE PROXIMATE, MINERAL AND PHYTOCHEMICAL COMPOSITION OF RIPE PLANTAIN (*Musa paradisiaca*)

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ABSTRACT
The effect of boiling and frying on the proximate, phytochemical, antinutritional, and mineral content of ripe plantain (*Musa paradisiaca*) obtained from Lafia Modern Market, were evaluated. Proximate analysis showed that while raw plantain contained high quantities of moisture (13.13 %), proteins (11.15 %), fats (12.24 %) and ash (10.81 %), boiling and frying resulted in an increase in the carbohydrates (70.47-71.10 %) and calorific values (350.69-351.97 Kcal/100 g). Mineral analysis showed improved retention of Fe (2.598 mg/Kg in raw to 7.667 mg/Kg after boiling and 5.889 mg/Kg after frying) and Zn (0.639 mg/Kg in raw to 0.984 mg/Kg after boiling and 0.786 mg/Kg after frying), with decreased quantities of Cu (0.196 mg/Kg in raw to 0.106 mg/Kg after boiling and 0.105 mg/Kg after frying) and Cr (0.131 mg/Kg in raw to 0.112 mg/Kg after frying and not detected after boiling). The study demonstrates that plantain is rich in vital nutrients. Both boiling and frying slightly changed the quantities of the phytochemicals, but the changes were statistically insignificant ($p > 0.05$). Frying was found to increase dietary calories while reducing proteins. Boiling, on the other hand, preserves carbohydrates and proteins and improves retention of minerals, making it a better cooking method compared to frying.

Keywords: Proximate, *Musa paradisiaca*, Plantain, Minerals, Phytochemicals, Anti-nutrients

INTRODUCTION

Global food security and nutrition hinges on a very limited number of staple crops, leading to increasing concern about the need for dietary adequacy and nutritional diversity (Muhammad & Oluwaniyi, 2022; Khoury *et al*., 2014). Many and diverse plant resources are found in Nigeria, but their potential contribution to food security and health promotion is limited due to poor characterisation and limited information about their nutritional and therapeutic properties (Adepoju *et al*., 2012).

Plantain (*Musa paradisiaca*) is a major staple food consumed in sub-Saharan Africa for its rich calories and nutrients (Oyeyinka & Afolayan, 2019). It has been reported to provide more than 25 % of carbohydrate intake and about 10 % of the daily caloric intake for more than 70 million people in Africa (Kayode *et al*., 2013). Plantain belongs to the *Musaceae* family (Ayorinde *et al*., 2022). It originates from the tropical parts of Africa, Central America, South America, and Asia (Adamu *et al*., 2017). It is a perennial crop that grows to about 2-9 inches with an underground rhizome. Depending on the cultivar, each fruit is about 3 to 10 inches long (Abd-Ghafar *et al*., 2019; Makanjuola *et al*., 2013). It is produced in West Africa, and over 2 million metric tons are cultivated annually in Nigeria alone (Akinsanmi *et al*., 2015). It is rich in carbohydrates and contains moderate amounts of protein and phytochemicals (Agbemafle *et al*., 2017). It also contains various essential minerals that collectively contribute to its nutritional and health-enhancing characteristics (Agbemafle *et al*., 2017; Adepoju *et al*., 2012).

In Nigeria, plantain is used as a versatile dietary component through various cooking methods, including boiling, frying, roasting, and steaming (Agbemafle *et al*., 2017). Although boiling and frying are the most common preparation techniques, the quality and availability of nutrients and phytochemicals are significantly influenced by the preparation method used (Ayorinde *et al*., 2022). Related previous work carried out on plantain include a study of the effect of boiling on the phytochemicals and micronutrients of unripe peeled and unpeeled plantain by Inyang *et al*. (2025), an analysis of the proximate, vitamins and minerals of raw, boiled, fried, and roasted plantain by Nwawuba and Onyenibe (2021), a comparative analysis of how boiling affects the proximate and mineral contents of the pulp and peel of unripe plantain by Ayorinde *et al*. (2022), an evaluation of the proximate, minerals and antinutritive composition of plantain fruit peel and flesh by Oyeyinka and Afolayan (2019), an evaluation of the effect of cooking methods and ripening stages on proximate and mineral contents of plantain by Agbemafle *et al*. (2017), and a study of the proximate and mineral composition of raw, sundried, fermented and roasted plantain by Adepoju *et al*. (2012). These related studies provide insights into nutritional changes associated with sun-drying, boiling, roasting, frying, and fermentation; they were limited in scope, often

highlighting proximate and mineral contents alone, and rarely integrating phytochemicals and antinutrients as done by this work.
The present study also advances this body of knowledge by simultaneously evaluating the proximate, energy value, minerals, phytochemicals and antinutrients in raw, boiled and fried ripe plantain under controlled conditions. The study also employed rigorous statistical validation for a more comprehensive study of the association among the parameters.

MATERIALS AND METHODS

Sample Collection and Preparation

The matured ripe fruits of plantain analysed were obtained from the Lafia Modern market in Lafia Metropolis, Nasarawa State, Nigeria. Using distilled water, the fruits were properly rinsed, peeled and sliced. They were divided into three portions. One portion was chopped into smaller pieces, oven-dried for 72 h at 40 °C to properly dry and prevent the loss of volatile organic compounds and then pulverised using a food blender before further analysis. The second portion was boiled for 15 min at boiling temperature using 1 litre of distilled water, and then chopped, dried, pulverised and analysed like the first portion. The third portion was deep-fried in 1 litre of King vegetable oil for 15 min at a temperature of 240 °C with occasional turning to achieve even frying, and then chopped, dried, pulverised and analysed (Ayorinde *et al*., 2022; Oluwaniyi *et al*., 2017; Agbemafle *et al*., 2017).

Proximate Analysis and Energy Value

The proximate composition and energy values were determined as described by Muhammad and Oluwaniyi (2022), Ayorinde *et al*. (2022), and Oyeyinka and Afolayan (2019). The crude fat was determined by exhaustive extraction using n-hexane at 60 °C. The moisture content was determined by drying 2 g of the sample at 105 °C to constant weight. The ash content was analysed by incinerating 2 g of the plantain at 550 °C for 5 h. The crude protein was determined by Kjeldahl method using 2 g of the sample. The crude fibre was analysed by digesting 2 g of the plantain with H_2SO_4 and NaOH and then incinerated at 550 °C for 3 h. Total carbohydrate was calculated by subtracting the sum of percentages of all others from 100. The energy value (in Kcal/100 g) was calculated by summing the values obtained after multiplying percentages of protein, carbohydrate and fat by 4, 4 and 9, respectively.

Minerals Analysis

The dried samples were ashed at 550 °C to constant weight. The ashes were dissolved with de-ionised water, and then a few drops of concentrated HCl was added. Each resulting sample solution was analysed quantitatively for mineral elements (Cu, Zn, Cr and Fe) using an Atomic Absorption Spectrophotometer (Hitachi Z-5000) with acetylene as fuel. The standards were prepared from nitrates of the metals in concentrations of 0.1, 0.2, 0.4 and 0.8 mg/mL. The concentrations of the sample were extrapolated using the calibration curves (Adamu *et al*., 2017).

Phytochemicals and Anti-nutrients Quantification

Analysis of alkaloids, phenolics, oxalates, phytates and cyanide were carried out according to standard methods described by Inyang *et al*. (2025) and Muhammad and Oluwaniyi (2022).
Alkaloids quantification: 5 g of plantain was weighed into 250 mL beaker containing 200 mL of 20 % ethanolic acetic acid and kept for 4 h. The solution was filtered and the extract was concentrated to three-quarter of its volume using water bath. Concentrated ammonia was added drop-wise until precipitation is completed. It was allowed to settle and the precipitate was filtered and weighed.
Oxalates quantification: 1 g of the plantain was weighed into 75 mL of 0.3 M H_2SO_4. The solution was stirred, filtered and 25 mL of the extract was titrated while hot (80-90 ºC) against 0.05 M $KMnO_4$ solution to the point when pink colour that persisted for at least 30 seconds was observed. The oxalate content was calculated as follows:

$$\text{oxalate}\left(\frac{mg}{100\,g}\right) = \frac{T \times [Vme][DF] \times 2.4 \times 100}{ME \times Mf} \quad (1)$$

Where T = titre value of $KMnO_4$; V_m = Volume-mass equivalent (i.e 1 mL of 0.05 M $KMnO_4$ solution is equivalent to 0.00225 g anhydrous oxalic); DF = Dilation factor, V_T/A; V_T = Total volume of filtrate (75 mL), A = Aliquote used (25 mL); ME = Molar equivalent of $KMnO_4$; Mf = Mass of sample used

Phytates quantification: 4.0 g of the plantain was weighed into 100 mL of 2 % HCl. The solution was kept for 3 h and then filtered. 25 mL of the filtrate was titrated against a standard iron (III) chloride solution (0.002 M) using 0.3 % ammonium thiocyanate as indicator until a brownish-yellow colour which persisted for 5 min was observed.

$$\text{Phytate}\left(\frac{mg}{100\,g}\right) = \frac{V \times M \times 660 \times 100}{6 \times W} \quad (2)$$

Where: V = titre value of $FeCl_3$; M = molarity of $FeCl_3$; W = sample weight

Phenolics quantification: 2 g of the plantain was weighed into 100 mL n-hexane. The mixture was kept for 4 h and then filtered. The residue was extracted with 50 mL diethyl ether. The ether extract was again extracted into 50 mL of 10 % NaOH solution. The aqueous layer was acidified to pH 4.0 with 10 % HCL solution and then extracted into 5 mL dichloromethane. The organic layer was collected, dried, and then weighed.
Cyanide quantification: 4 g of the plantain was weighed into a solution containing 2 mL of analar orthophosphoric acid and 40 mL of distilled water. The mixture was stoppered and left overnight at room temperature to free bounded hydrocyanic acid. 5 mL of the resulting mixture was distilled into 40 mL of distilled water containing 0.1 g of NaOH pellets. The distillate collected was made up to 50 mL with distilled

water and then 20 mL of it was titrated against 0.01 M silver nitrate solution using 1 mL of 5 % KI solution until a faint but permanent turbidity was observed.

$$\text{cyanide}\left(\frac{\text{mg}}{100\ \text{g}}\right) = \frac{V \times M \times 27 \times 1000}{W} \quad 3$$

Where: V = titre value of $AgNO_3$; M = molarity of $AgNO_3$; W = sample weight

Statistical Analysis

The data were expressed as mean ± standard deviation of triplicate values. Analysis of variance (ANOVA) and statistical differences were calculated at $p < 0.05$. All data were analysed using SPSS version 24.

RESULTS AND DISCUSSION

Proximate Content

Table 1 shows the proximate content of the plantain before and after cooking and demonstrates how the methods of cooking affect the distribution of these nutrients. The result shows that boiling and frying have significantly ($p < 0.05$) reduced the moisture contents. The moisture content of fruits determines their shelf-life and the presence of their water-soluble vitamins and minerals (Oyeyinka and Afolayan, 2019; Agbemafle *et al*., 2017; Adepoju *et al*., 2012). High moisture content indicates low nutrients retention, low shelf-life and high susceptibility to microbial activities (Nwofia, *et al*., 2012; Uyoh *et al*., 2013). The moisture contents of the raw (13.13 %), boiled (9.16 %) and fried (9.70 %) plantain in this work are lower than 22.70, 19.67 and 15.35 % respectively reported by Agbemafle *et al.* (2017) for ripe plantain.

The methods of cooking were similarly found to influence the ash contents by significantly reducing it in both the boiled and fried plantain by about 4 %. This may be as a result of mineral leaching during the boiling process (Nweze & Uzoukwu, 2015) and diffusion during the frying process (Robert *et al*. 2017). The ash contents found for raw (10.81 %), boiled (6.58 %) and fried (6.86 %) plantain in this work are all higher than 3.31 % (raw), 3.14 % (boiled) and 4.52 % (fried) respectively reported for plantain by Agbemafle *et al*. (2017).

According to Nwawuba and Onyenibe (2021), protein content is better preserved by boiling when compared to frying. This has been shown by the slight but statistically insignificant decrease in protein content (11.15 to 10.66 %) when boiled compared to the significant reduction (11.15 to 8.76 %) when fried. Similarly, Adepoju *et al.* (2012) reported a slight decrease in protein content of plantain from 7.70 % (raw) to 7.50 % after boiling.

The fats content of the raw plantain (12.24 %) decreased significantly when boiled (3.05 %) and when fried (3.47 %). This is in agreement with the significant reduction in lipid content of plantain from 4.19 % (raw) to 1.38 % (boiled) and 2.29 % (fried) reported by Olufunmilayo *et al* (2019). However, it is contrary to the findings by Agbemafle *et al*. (2017) and Nwawuba and Onyenibe (2021) who reported increase in fats contents in the case of frying.

In this study, the crude fibre contents (0.17 %) decreased significantly when boiled (0.08 %) and when fried (0.11 %). This agrees with report by Ayorinde *et al.* (2022) on plantain. However, it is contrary to findings by Adamu *et al* (2017) and Agbemafle *et al* (2017), who both reported increase in crude fibre contents of plantain after boiling and after frying.

The carbohydrate content (52.50 %) was elevated both when boiled (70.47 %) and when fried (71.10 %). This is consistent with the report by Nwawuba and Onyenibe (2021) that carbohydrate content of food is concentrated when fried due to moisture loss and the report that it is preserved when boiled according to Iwanegbe and Durojaiye (2025). This result is also in agreement with the reported increase in carbohydrate contents from 47.42 % (raw) to 49.38 % when boiled and from 86.77 % (raw) to 87.08 % when boiled, according to Adamu *et al*. (2017) and Ayorinde *et al*. (2022) respectively.

The energy content of boiled (351.97 Kcal/100 g) and fried (350.67 Kcal/100 g) plantain was found to be higher than the raw plantain (264.76 Kcal/100 g). This could be as a result of the reduction in moisture content and the concentration of carbohydrates in the plantain when cooked.

From a dietary point of view, the carbohydrate content of either the boiled or fried plantain (approximately 71 g/100 g) contributed to about 24 % of the 300 g/day Recommended Daily Allowance (RDA) for adults (Vepowo *et al*., 2023; Agbamafle *et al*., 2017). The protein content of the boiled and fried plantain, respectively, contributed to 19.04 and 15.64 % of the 56 g/day RDA for men and 23.17 and 19.04 % of the 46 g/day RDA for women (Vepowo, 2023; Adepoju *et al.*, 2012). The calorific value of the boiled and fried plantain (351.32 Kcal/100 g average) provide 14.05–17.57 % of the 2000–2500 Kcal/day RDA for adults (Nwawuba and Onyenibe, 2021; Onwudiwe and Obue, 2016). Hence, plantain, when boiled or fried can be combined with other food as sources of carbohydrate and energy.

Table 1: Proximate composition of raw, boil and fried plantain

Sample	Moisture (%)	Ash (%)	Protein (%)	Fats (%)	Fibre (%)	CH_2O (%)	Energy (Kcal/100 g)
Raw	13.13±0.02^a	10.81±0.02^a	11.15±0.03^a	12.24±0.02^a	0.17±0.01^a	52.50^b	264.76^b
Boiled	9.16±0.01^b	6.58±0.02^b	10.66±0.06^a	3.05±0.02^b	0.08±0.02^b	70.47^a	351.97^a
Fried	9.70±0.14^b	6.86±0.08^b	8.76±0.07^b	3.47±0.02^b	0.11±0.01^b	71.10^a	350.67^a

Values are means ± standard deviations of triplicate determinations.
CH_2O = Total carbohydrates. a, b values in the same column sharing the same letters are not significantly different ($p < 0.05$)

Phytochemicals and Antinutrients

Table 2: Phytochemical and antinutritional content of raw, boiled and fried plantain

Sample (mg/100 g)	Alkaloid	Oxalate	Phytate	Phenolic	Cyanide
Raw	108.22±0.22^{ab}	32.67±0.11^{b}	39.09±0.12^{b}	192.00±0.21^{a}	0.09±0.01^{c}
Boiled	111.01±0.21^{ab}	24.66±0.13^{b}	37.10±0.13^{b}	107.88±0.12^{a}	0.04±0.01^{c}
Fried	99.90±0.12^{ab}	29.21±0.12^{b}	40.19±0.11^{b}	97.00±0.11^{a}	0.04±0.01^{c}

Values are means ± standard deviations of triplicate determinations.
a, b, ... values in the same column sharing the same letters are not significantly different ($p < 0.05$)

Table 2 shows the effect of boiling and frying on the phytochemical and antinutrtional contents of plantain. Varying quantities of phytochemicals and antinutrients before and after cooking were obtained. However, the values are not significantly different ($p > 0.05$) from one another and have been noted as slight, marginal or minor changes. Alkaloid content slightly increased after boiling but it reduced after the plantain was fried. Olufunmilayo *et al.* (2019) reported insignificant changes ($p > 0.05$) in quantities of oxalate and phytate in both unripe and ripe plantain after boiling and frying. Boiling has been found to slightly reduce the oxalate and phytate contents of the plantain from 32.67 to 24.66 mg/100 g and from 39.09 to 37.10 mg/100 g, respectively. Oxalates and phytates have been reported to chelate divalent minerals, which results to their precipitation and reduces their bioavailability (Muhammad & Oluwanity, 2022). Frying has been found to also slightly reduce the oxalates to 29.21 mg/100 g. However, the phytate content has been found to marginally increase to 40.19 mg/100 g after frying, indicating a slight concentration of phytates caused by moisture loss (Rojas-Gonzalez *et al.*, 2006).

One of the health benefits of phenolics is their antioxidant properties which inhibits the autoxidation of unsaturated fats and prevents heart disease (Muhammad and Oluwaniyi, 2022). According to Omotosho (2015), high-heat processing leads to the loss of phenolic compounds. The phenolic content of the plantain in this work slightly decreased from 192 mg/100 g (when raw) to 107.88 mg/100 g after boiling and 97 mg/100 g after frying, suggesting thermal degradation of poplyphenols. The cyanide content of the raw (0.09 mg/100 g), boiled (0.04 mg/100 g) and fried (0.04 mg/100 g) plantain were all found to be below the World Health Organisation standard limit of 10 mg HCN Eq/Kg (FAO/WHO, 1992).

Minerals

Table 3 shows the change in concentration of the minerals after the plantain has been cooked. Cu is vital in formation of melanin and skin pigmentation (Muhammad and Oluwaniyi, 2022). Both boiling and frying reduced the Cu content of the plantain in this study. This is in agreement with the decrease in Cu content of plantain after boiling reported by Ayorinde *et al.* (2022). However, this finding is contrary to the reported increase in Cu content of plantain after boiling by Adepoju *et al.* (2012). The Zn content in this work increased from 0.639 mg/Kg in raw to 0.984 mg/Kg after boiling and 0.786 mg/Kg after frying. This is consistent with the report that boiling improved Zn retention of plantain according to Wohi *et al.* (2017).

Table 3: Mineral analysis of raw, boiled and fried plantain

Sample (mg/Kg)	Cu	Zn	Cr	Fe
Raw	0.196	0.639	0.131	2.598
Boiled	0.106	0.984	Nd	7.667
Fried	0.105	0.786	0.112	5.889

nd = Not detected

Foetal growth and the replication of DNA and RNA are promoted by Zn while Fe is used in the oxygen transport system of the cells (Muhammad and Oluwaniyi, 2022). The Fe content increased more than twofold after boiling (7.667 mg/Kg) and after frying (5.889 mg/Kg) compared to before cooking (2.598 mg/Kg). This is in agreement with Robert *et al.* (2017), who report that Fe retention is improved by boiling. On the other hand, the Cr content (0.131 mg/Kg before cooking) reduced after frying (0.112 mg/Kg) and after boiling (below detection limit). This suggests it may be unstable under heat or may be leaching into cooking water during boiling. However, Nweze and Uzoukwu (2015) reported retention of Cr after boiling and frying plantain. In addition, the increase observed in the mineral contents after boiling may in part be attributed to reduced anti-nutrients interference caused by the drop in the quantities of oxalates and phytates as shown in Table 2.

CONCLUSION

The effects of cooking methods in the distribution and availability of nutrients is necessary in the search for the most preferred method of food processing that ensures access to vital nutrients and promotes informed and healthier dietary choices. The results show that boiling preserves proteins and carbohydrates while reducing anti-nutrients and enhancing minerals retention and bioavailability. Frying, while improving caloric density, decreases proteins and phenolics. From a dietary perspective, the results show that boiling contributes to the daily requirements in carbohydrates and energy including appreciable quantity of protein and levels of Fe and Zn. These findings support boiling as a preferred cooking method for optimal nutrients availability over frying.

Conflict of interest: The authors declared that there is no conflict of interest in this work.

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