THE EFFECT OF BOILING, FRYING, ROASTING AND RIPENING STAGES ON THE NUTRITIONAL QUALITY OF PLANTAIN (*Musa paradisiaca*)

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ABSTRACT

This study was to ascertain the effect of cooking methods and ripening stages on the nutritional quality of plantain. All the parameters were analyzed using standard methods of the Association of Analytical Chemists (AOAC, 2000). Analysis of variance (ANOVA) at 5% level of probability, to validate the results. The results showed that increased ripening led to decrease in pH value. The amount of protein in this study decreased with increased ripening stages. The amount of protein ranged from 3.50% to 7.00%. The amount of carbohydrate in this study ranges from 24.30% to 61.60%. The samples' moisture content increased from unripe – semi-ripe – ripe stages. There was a significant difference between the crude fat at different ripening stages. There was a significant difference in levels of Na at different ripening stages. K, Ca, Mg and Fe in the boiled, roasted and fried samples at the ripening stages of plantain were significantly higher than the unripe samples.

Keywords: *Musa paradisiaca*, Ripening stages, Cooking methods, Nutritional quality.

INTRODUCTION

The tropics and sub-tropical regions of our planet are major bastions for growing plantain (Musa spp), which is a veritable staple food for thousands of households in Nigeria and Africa at large (Awodoyin, 2013; Stover and Simmonds, 2017; Blomme *et al.*, 2019). Many studies have shown that plantains are a significant source of vitamins C, B6, potassium, antioxidants, carbohydrates and provitamin A carotenoids (Amah *et al.,* 2019; Bhuiyan *et al.,* 2020; Tsamo *et al.,* 2015). The iron content of plantain is 100% usable for human consumption (Akubor and Adejo, 2010; Suntharalingam and Ravindran, 2013). Due to the evolution of ethylene, it continues to ripen even after being harvested from the parent plant. A variety of permanent organoleptic, biochemical, physiochemical and physical changes occur during plantain ripening. The peel undergoes three colour changes during ripening: green, yellow, and dark brown. At the same time, pulp color changes from creamy white to yellow or yellow-orange. The change in the colour of pulp/peel is due to the activity of polyphenol oxidase which is abundant in plantain (Prasanna *et al.,* 2007; Offem, and Thomas 2013).

Baiyeri *et al.,* (2011) revealed that significant variations existed in the mineral and nutritional composition of plantain fruits following cooking and ripening treatments. Nutritional qualities of plantain fruits vary with the stage of ripeness and processing method employed. Ash and carbohydrate contents increased with ripeness whereas fat, dry matter content, Fe and β-carotene decreased with ripening. Banana and other plantain varieties have shown similar results. (Marriott and Lancaster, 2003). Their results suggest that optimal nutritional benefit of 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 Asenjo and Porrata (2016) that the average carotene content of plantains was found to be higher in the green fruits. Giami and Alu, (2014) as well as Ngoh-Newilah, (2005) demonstrated that the amount of carotenoid in plantain fruits might decrease by up to 50% while they were ripening. Ogazi (2012) 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 maximum in the steam-cooked plantain in comparison with the other cooking methods. In contrast, pro-vitamin A was lowest in plantain boiled directly in water. This observation could be as a result of leaching or volatilization losses through the cooking medium (water). Ogazi (2012) posited that, boiling or baking partially ripe fruits, leads to loss of roughly 10% of the accessible 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). Iron, copper, and zinc content in the pulp of plantains had been found to be reduced, after boiling (Ahenkora *et al.*, 1996). This study evaluates the effects of different cooking methods and plantain ripening stages on its nutritional value.

MATERIALS AND METHODS

Sampling and Sample Preparation

Plantain samples at varied stages of ripening were bought from local markets in Abraka, Delta State Nigeria. They were washed to remove dirt. Twelve strands of plantain (four unripe, four semi-ripe (fairly ripe) and four fully ripe) were peeled, the pulp of the composite sample (obtained from each set of four strands at varied ripening stages was boiled to a temperature of 100 ^{0}C for 20, 15 and 10 minutes respectively. After which the boiled pulp was oven dried at 60 ^{0}C for 24hours and crushed into finer particle sizes using mortar and pestle. The pounded samples were placed in a container for further analysis. The fried samples were obtained similarly after washing, peeling and slicing into variable small sizes and were thereafter fried in Vegetable oil below 150 ^{0}C. The time recorded for frying at each ripening stage (unripe, semi-ripe and fully ripe) was 8, 11 and 15 minutes respectively. The plantain samples were oven dried for 24 hours and crushed into finer particle sizes with mortar and pestle. They were stored in clean air-tight plastic containers for further analysis. Roasted plantain samples were washed and the coat of the plantain strands peeled off. The charcoal grill was preheated to 170 ^{0}C. The peeled strands of plantain were placed on the charcoal grill. They were turned over intermittently to ensure even roasting. The fully ripe, semi-ripe and unripe plantain samples were roasted for 10 minutes, 12 minutes and 15 minutes respectively.

Determination of Parameters

The accepted procedure for analysis of the Association of Analytical Chemist (AOAC, 2000) was employed in the determination of several properties of the plantain samples.

For pH, 10 g of the sample was weighed and dissolved in 100 ml of distilled water in a volumetric flask. The pH meter was standardized using pH buffer 7.0. The pH probe was rinsed with distilled water, wiped, dried and dipped into the sample solution to measure the pH value.

Moisture content was obtained by the oven dry method at 105 ^{0}C (AOAC, 925.09). 5 g of the sample was weighed and put in a clean and dry petri dish. The petri dish had been weighed. The latter was placed in a hot air oven to dry for 3 hours at a temperature of 105 °C. After drying the petri dish was transferred into a desiccator to dry after which the weight was taken. This experiment was carried out in triplicate and the moisture content was calculated using the formula:

$$\%\, moisture = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where: W_{1} = initial weight of empty petri dish; W_{2} = weight of petri dish + food before drying and W_{3} = initial weight of petri dish + food after drying.

Ash content was obtained by weighing a clean and dried crucible. About 2 g of the sample was weighed directly into the crucible which was transferred into a pre-heated muffle furnace at a temperature 550 °C for 2 hours. The ashed sample was transferred into a desiccator and allowed to cool. The process was carried out in triplicate and percentage ash content was calculated using the formula:

$$\%\, total\ ash = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

Where: W_{1} = initial weight of empty Petri dish; W_{2} = weight of Petri dish + food before igniting and W_{3} = Final weight of Petri dish + food after igniting.

Crude fat was determined via Soxhlet extraction by petroleum ether (AOAC, 920.39). This method involves the gravimetric estimation of fat from a dry powdered solid after a continuous extraction with light organic solvent e.g. petroleum ether for 1 hour.

Amount of protein in the samples was obtained by the Macro Kjeldahl technique (AOAC, 955.04D). Crude fibre was determined by the standard AOAC, 962.09 method. Carbohydrate contained in the samples was obtained by the Anthrone method. The percentage of phosphorus in the samples was determined by the standard AOAC, 965.17 method. Amount of essential minerals in the samples was determined by digesting 1 g of sample in 10 ml mixture of 1:2:2 v/v of analar grade Perchloric acid ($HClO_4$), nitric acid (HNO_3), concentrated sulphuric (VI) acid, (H_2SO_4) in a fume cupboard. The digested sample was given time to cool after the digestion interval. 20 ml of distilled water was transferred to the conical flask containing the digested sample. In other to bring the metal into solution, the solution in the flask was heated for 15 minutes until a white fume was observed. The flask was allowed to cool and filtered through Whatman No. 42 filter paper with pore size of 125 mm into a 100 ml Pyrex, Type 1 Class A borosilicate volumetric flask and then made to mark with distilled water. The solution was then transfer to 100ml plastic bottle for mineral analysis using Flame Atomic Absorption Spectrophotometer (Varian Spectra AA 600 model).

Statistical Analysis

Version 20 of Statistical Package for Social Sciences (SPSS) Software was used to perform Analysis of Variance (ANOVA) on the data. Variations between the means of the data were not significant at $p > 0.05$.

RESULTS AND DISCUSSION

Tables 1 -3 is a presentation of the properties of the samples in lieu of the cooking method at a specific stage of ripening. Table 4 is a comparative view of the parameters and processing methods for the samples at a glance.

Table 1: Properties of Unripe Plantain Samples

Physicochemical Properties	Boiled	Fried	Roasted	(Control)
pH	5.45±0.22	6.85±0.14	5.89±0.21	6.58±0.13
Moisture Content (%)	10.33±0.81	2.12±0.84	3.23±0.83	4.19±0.85
Ash (%)	4.36±0.93	3.25±0.91	6.25±0.96	1.30±0.92
Crude Fat (%)	2.50±0.10	13.00±0.20	4.50±0.00	4.500.00
Protein (%)	5.25±0.82	5.25±0.82	3.50±0.73	7.00±0.94
Crude Fibre (%)	6.21±0.48	4.05±0.44	5.11±0.47	4.79±0.45
Carbohydrate (%)	53.50±1.26	61.60±1.55	58.85±1.35	59.00±1.45
Phosphorus, P (%)	0.023±0.00	0.033±0.00	0.023±0.00	0.026±0.01
Sodium, Na (mg/kg)	68.13±0.07	52.31±0.18	56.66±0.27	43.49±0.26
Potassium, K (mg/kg)	162.00±1.72	117.14±1.61	108.74±1.42	100.81±1.45
Calcium, Ca (mg/kg)	300.60±0.07	498.99±0.18	218.44±0.14	368.74±0.28
Magnesium, Mg (mg/kg)	102.50±1.00	115.50±1.50	97.50±1.12	89.50±1.13
Iron, Fe (mg/kg)	250.08±1.02	62.94±1.65	188.05±1.01	84.23±1.64

Mean of three replicates with estimated standard deviation **(**Control = raw plantain samples)

Table 2: Properties of Semi-ripe Plantain Samples

Physicochemical Properties	Boiled	Fried	Roasted	(Control)
pH	4.54±0.06	4.60±0.07	4.70±0.08	5.51±0.09
Moisture Content (%)	10.97±0.18	7.76±0.17	4.03±0.41	2.68±0.26
Ash (%)	5.60±0.51	4.59±0.45	7.15±0.71	2.00±0.20
Crude Fat (%)	3.00±0.50	16.50±0.16	5.50±0.55	6.50±0.65
Protein (%)	5.25±0.44	4.38±0.43	3.50±0.35	6.13±0.61
Crude Fibre (%)	5.84±0.29	4.79±0.79	4.42±0.42	4.07±0.07
Carbohydrate (%)	32.50±0.02	26.50±0.08	54.50±0.05	38.20±0.06
Phosphorus, P (%)	0.010±0.01	0.031±0.00	0.030±0.00	0.012±0.01
Sodium, Na (mg/kg)	65.97±1.40	55.63±1.55	52.83±1.52	40.60±1.40
Potassium, K (mg/kg)	175.58±0.74	191.05±0.19	111.26±0.11	131.48±0.13
Calcium, Ca (mg/kg)	123.75±1.34	278.56±1.27	649.29±1.64	203.21±1.20
Magnesium, Mg (mg/kg)	94.50±0.76	108.00±0.10	112.00±0.11	85.00±0.85
Iron, Fe (mg/kg)	243.09±0.14	52.28±0.25	66.62±0.26	63.30±0.33

Mean of three replicates with estimated standard deviation **(**Control = raw plantain samples)

Table 3: Properties of Ripe Plantain Samples

Physicochemical Properties	Boiled	Fried	Roasted	(Control)
pH	4.24±0.19	3.90±0.30	4.34±0.43	5.38±0.35
Moisture Content (%)	11.82±0.76	9.38±0.39	4.50±0.45	2.35±0.23
Ash (%)	6.80±0.17	4.00±0.04	8.38±0.38	8.05±0.08
Crude Fat (%)	3.50±0.25	21.50±0.12	7.00±0.17	6.50±0.30
Protein (%)	3.50±0.88	4.38±0.24	2.63±0.32	5.25±0.12
Crude Fibre (%)	5.61±0.43	3.97±0.31	2.96±0.16	3.23±0.20
Carbohydrate (%)	37.05±0.53	24.30±0.34	38.10±0.18	41.05±0.15
Phosphorus, P (%)	0.008±0.00	0.009±0.00	0.009±0.00	0.012±0.00
Sodium, Na (mg/kg)	70.09±1.19	60.41±1.01	58.03±1.10	38.65±0.91
Potassium, K (mg/kg)	117.32±0.71	156.89±0.61	115.90±0.15	122.10±0.12
Calcium, Ca (mg/kg)	243.49±1.34	418.86±1.16	348.69±1.24	173.64±1.02
Magnesium, Mg (mg/kg)	95.00±1.41	123.00±1.21	92.00±1.20	92.00±1.02
Iron, Fe (mg/kg)	194.96±0.29	71.93±0.13	86.25±0.26	66.60±0.31

Mean of three replicates with estimated standard deviation **(**Control = raw plantain samples)

Table 4: Properties of the Samples at the Various Ripening Stages

Properties	Boiled Plantain			Fried Plantain			Roasted Plantain			Control		
	Unripe	Semi-ripe	Ripe	Unripe	Semi-ripe	Ripe	Unripe	Semi-ripe	Ripe	Unripe	Semi-ripe	Ripe
pH	5.45	4.54	4.24	6.85	4.60	3.90	5.89	4.70	4.34	6.58	5.51	5.38
Moisture Content (%)	10.33	10.97	11.82	2.12	7.76	9.38	3.23	4.03	4.50	4.19	2.68	2.35
Ash (%)	4.36	5.60	6.80	3.25	4.59	4.00	6.25	7.15	8.38	1.30	2.00	8.05
Crude Fat (%)	2.50	3.00	3.50	13.00	16.50	21.50	4.50	5.50	7.00	4.50	6.50	6.50
Protein (%)	5.25	5.25	3.50	5.25	4.38	4.38	3.50	3.50	2.63	7.00	6.13	5.25
Crude Fibre (%)	6.21	5.84	5.61	4.05	4.79	3.97	5.11	4.42	2.96	4.79	4.07	3.23
Carbohy-drate (%)	53.50	32.50	37.05	61.60	26.50	24.30	58.85	54.50	38.10	59.00	38.20	41.05
Phospho-rus, P (%)	0.023	0.01	0.008	0.033	0.031	0.009	0.023	0.03	0.009	0.026	0.012	0.012
Sodium, Na (mg/kg)	68.13	65.97	70.09	52.31	55.63	60.41	56.66	52.83	58.03	43.49	40.60	38.65
Potassium, K (mg/kg)	162.00	175.58	117.32	117.14	191.05	156.89	108.74	111.26	115.90	100.81	131.48	122.10
Calcium, Ca (mg/kg)	300.60	123.75	243.49	498.99	278.56	418.86	218.44	649.29	348.69	368.74	203.21	173.64
Magnesium, Mg (mg/kg)	102.50	94.50	95.00	115.50	108.00	123.00	97.50	112.00	92.00	89.50	85.00	92.00
Iron, Fe (mg/kg)	250.08	243.09	194.96	62.94	52.28	71.93	188.05	66.62	86.25	84.23	63.30	66.60

*Control = raw plantain samples

There was a gradual decrease in pH from unripe, semi-ripe to ripe stages of the samples for the control and the different cooking methods as shown on figure 1. ANOVA showed no significant difference in the pH. The result of this study is in agreement with the findings of Ebuehi (2005) who reported the pH value of 4.44 to 6.12 in Agbagba' plantain. Adeniji and Empere, (2001) in their study reported low level of pH with increase in ripening stages. Figure 1 illustrates the pH of the samples.

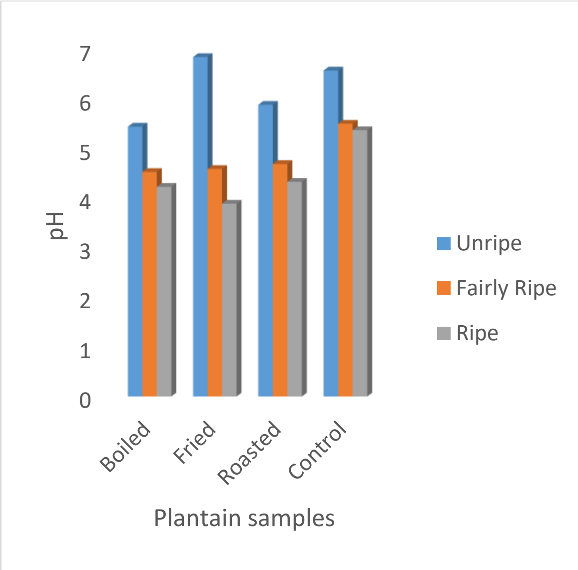

Fig. 1: pH of the samples.

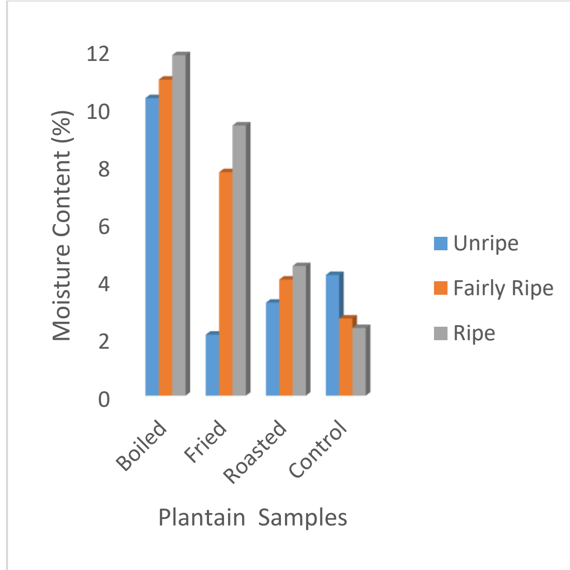

Fig. 2: Moisture content of the samples.

The moisture content of the samples increased from unripe – semi-ripe – ripe stages of the samples for the different cooking methods, except for the control, which decreased as shown on figure 2. The difference was however, not significant. Osmotic movement from the peel to the fruit pulp and carbohydrate breakdown caused plantain fruit to absorb moisture gradually as it ripened. This result is in agreement with Murray, (2005) and Gbolagade *et al.*, (2011) who reported significant increase with boiled plantain compared to the control. Abioye *et al.*, (2006) reported higher moisture content in boiled plantain.

Ash content is the inorganic residue remaining after the organic matter has been burnt away samples. The ash content in this study increased from unripe – semi-ripe – ripe stages of the samples (Fig. 3). The higher ash content observed in the boiled samples may be attributable to absorption of minerals from the cooking water into the plantain samples. This result disagrees with the report of Ojokoh and Gabriel, (2010) opined that ash content is the inorganic residue left over after organic matter is been burnt off during frying, is a very useful parameter in assessing the quality of edible material.

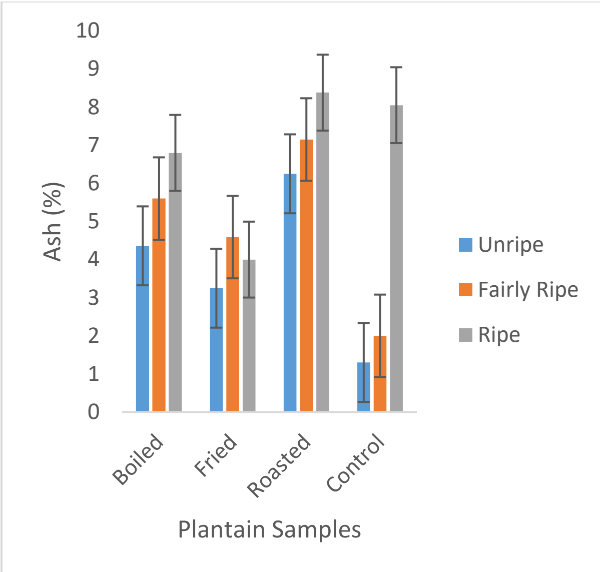

Fig. 3: Ash content of the samples.

The amount of crude fat in the samples increased from unripe – semi-ripe – ripe stages. Percentage composition of crude fat was found to be higher in the ripe samples than in the unripe samples (Fig 4) The result shows that there was a significant difference between the crude fat at different ripening stages, except for boiled samples. The findings of this study is supported by the results of Mudambi, and Rajagopal, (2007).

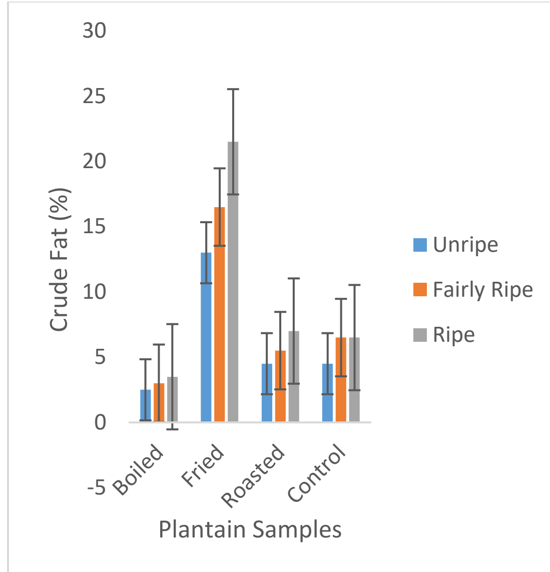

Fig. 4: Amount of crude fat in the samples.

There was a decrease in protein levels from the raw, fried, boiled and roasted samples at various ripening stages (fig. 5). This suggests the destruction of the protein due to application of heat, as high temperature denatures and destroys protein (Ihekoronye and Ngoddi, 2015).

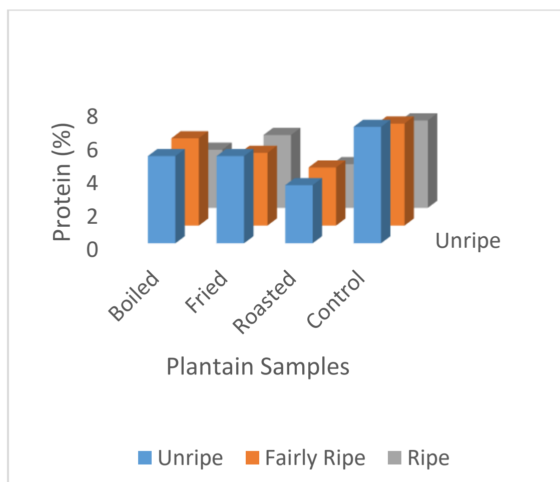

Fig. 5: Protein content of the samples

The percentage compositions of carbohydrate ranged from 24.30% - 61.60%. As fruit ripened, the amount of carbohydrate decreased. This suggests that soluble carbohydrates converted to simple sugars throughout this process. The carbohydrate content of fried plantain was 61.58 g/100g as reported by Oboh and Ogbebor, (2010).

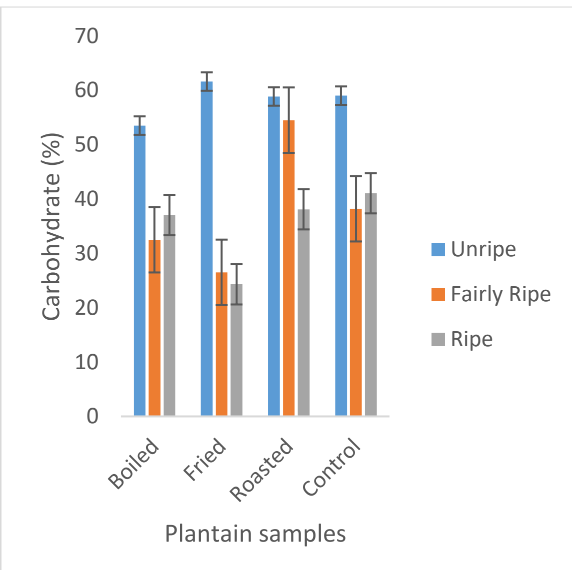

Fig. 6: Carbohydrate content of the samples

The result of essential minerals on table 4 show that there was a significant difference between the amounts of sodium in the plantain at varied ripening stages. Boiling resulted in higher amount of sodium; evaporation of water from solutions of sodium salts will leave behind the solid salt. Potassium content of the fried plantain samples ranged from 117.14 mg/Kg – 191.05 mg/Kg. This was unusually higher than the amount in the raw samples and the samples from the other cooking methods. This could be due to absorption of the mineral from the frying oil. Calcium content in the fried and roasted samples were higher than the levels recorded for raw and boiled samples. This finding agrees with the report of Agbemafie *et al.*, (2017). Magnesium levels were higher in the fried and roasted samples than in the boiled and raw samples. The boiled and roasted plantains had higher iron levels compared with the raw and roasted samples. Improved cooking techniques makes nutrients more available and reduces anti-nutrients present in food. Figures 7 – 12 provide an overview of amounts of essential minerals present in the samples. This result is in line with the findings of Nweze *et al.*, (2015) who reported that boiling of plantain resulted in significant reduction in its calcium, magnesium, phosphorus, iron, zinc and manganese content ($p < 0.05$). Baiyeri *et al.*, (2011) reported that boiling, particularly at the ripe stages, significantly reduced the sodium content of plantain. The latter is in contrast with the findings in this study as a higher concentration of sodium was observed in the boiled sample. Nweze *et al.*, (2015), reported a higher concentration for calcium and iron after boiling. This is most likely because the boiling water contains trace levels of these elements. There is a tendency of these samples to pick up these elements from the water used, thus the increase in concentration.

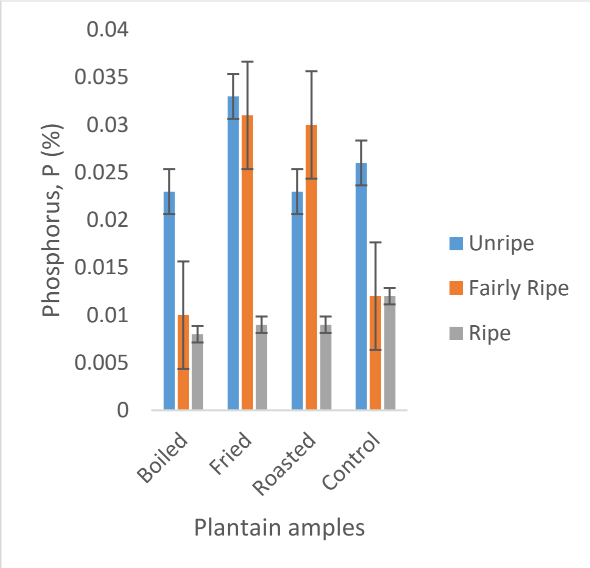

Fig. 7: Phosphorus content of the samples.

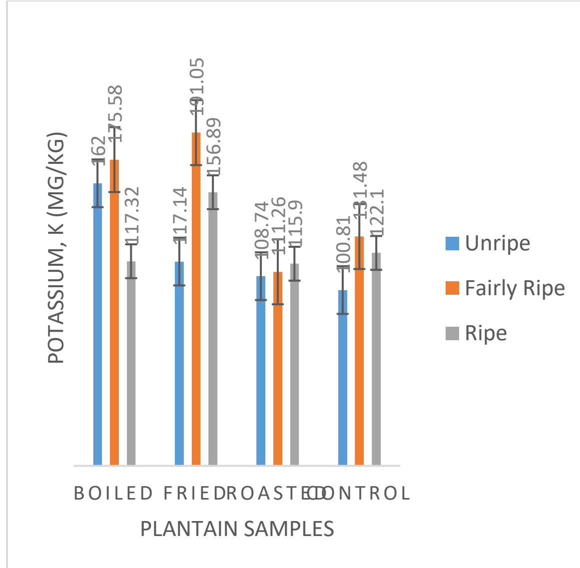

Fig. 9: Potassium content of the samples

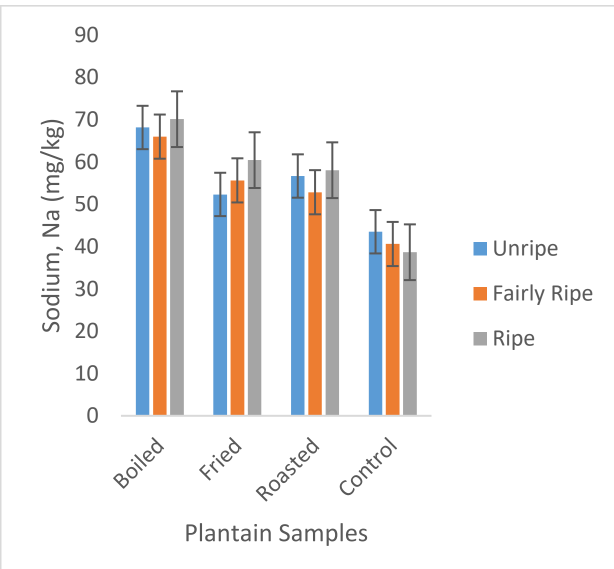

Fig. 8: Sodium content of the samples

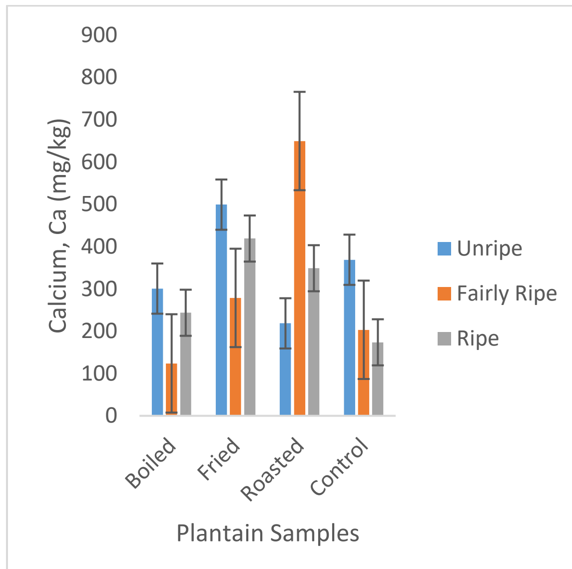

Fig. 10: Calcium content of the samples

The reverse was the case in the levels of magnesium, potassium, phosphorus and sodium. The levels of these minerals dropped significantly after boiling. This observation could be due to leaching or volatilization losses of these minerals through the cooking medium (water). Ebuehi, (2005) recorded significant losses in various minerals including Ca, Mg, P, Fe, Na and Cl in the roots and fresh leaves of cassava as a result of boiling. Boiling had been linked to a decline in certain micronutrients in plantain pulp, such as iron, copper and zinc (Ahenkora et al., 1996).

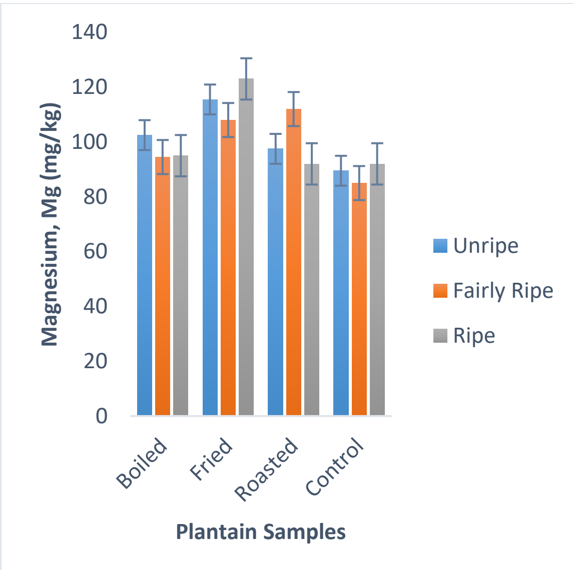

Fig. 11: Magnesium content of the samples

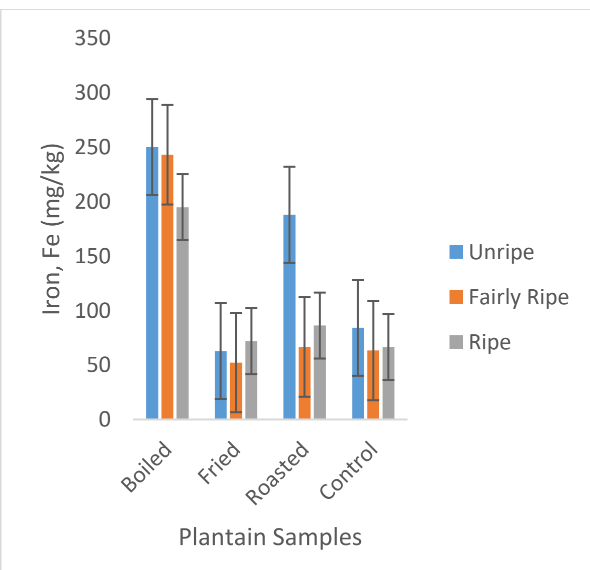

Fig. 12: Amount of iron in the samples

CONCLUSION

Plantain is an energy food and one of the major staple foods in most parts of the world. It has the potential to provide modest amounts of various food nutrients. In spite of the cooking method, mineral loses were minimal and these losses arose due to surrounding circumstances in the processing methods which could fairly be minimized by taking certain precautions during processing. There are indications that all the plantain samples are good sources of nutrients, however, the results show that Percentage composition of protein was found to be higher in the unripe samples than in the ripe-fried samples. The percentage compositions of carbohydrate ranged from 24.30% - 61.60%, with ripe-fried plantain having the least percentage composition while the highest was recorded in unripe-fried plantain. The result shows that increase in ripening stages leads to decrease in pH value. Plantains retain more nutrients when roasted or boiled than when fried.

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