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Effect of Cooking Time on the Proximate and Mineral Composition of Breadfruit (*Artocarpus altilis*) Grown in Abidjan, Côte D'ivoire

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Abstract: The study examined the effect of cooking on the nutrients and minerals of breadfruit (*Artocarpus altilis)* flour in order to assess its nutritional benefits. The cooking led to a significant ($p<0.05$) decrease in moisture, crude fat (CF) and crude protein (CP) contents. By contrast dry matter (DM), total and reducing sugars (TS; RS), carbohydrate and energy values increased significantly ($p<0.05$). The change in cooking time increased significantly ($p<0.05$) TS and RS and decreased CP. The moisture, CF, DM and carbohydrate contents were not affected by the change in cooking time. The mineral contents such as calcium (Ca), iron (Fe), sodium (Na), zinc (Zn), phosphorus (P), potassium (K) and magnesium (Mg) were increased significantly ($p<0.05$) with cooking and were affected by the change in cooking time. The cooking and the change in cooking time had no significant effect on total ash (TA) and K:Na ratio. Significant correlations were observed between DM and Zn, DM and Ca, TS and K, TA and TS, Ca and Mg, Fe and Zn. The flours exhibited different properties as depicted by the PCA that discriminated raw breadfruit flour (RAF) from cooked breadfruit flours (AF10, AF15 and AF20). The use of cooking in processing of breadfruit flours appeared beneficial for improving its nutritional statute.

Key words: Breadfruit, *Artocarpus altilis*, proximate, minerals, cooking time

INTRODUCTION

Breadfruits belong to the Family *Moraceae* and consist of over 50 species. The name breadfruit is a common name for fruits belonging to the genera *Artocarpus* (Morton, 1987) although it usually refers to *Artocarpus altilis* (Ragone, 2006). *Artocarpus altilis* grows easily in a wide range of ecological conditions with minimal input of labour or materials and requires little attention or care (NTBG, 2009). It is widely distributed in the tropics although native of Malaysia, Papua-New Guinea and Philippines (Morton, 1987) where it is an important food (Taylor and Tuia, 2007). Singh (2009) reported that a single tree produces between 150 kg and 200 kg of food per season. According to Orwa *et al.* (2009), *Artocarpus altilis* fruit is also used as fodder, fuel, timber, gum, dye for textiles and medicine.

In Côte d'Ivoire, *Artocarpus altilis* fruits are consumed as snack by many rural inhabitants and could be use as food security crop. Although it is used as food in Côte d'Ivoire, this crop is regarded as unimportant produce so that it is neglected. Indeed, *Artocarpus altilis*, generally, are not grown in Côte d'Ivoire as a food crop. They usually grown wild and are left unprotected. *Artocarpus altilis* has however, been reported to be a good source of nutrients (Graham and Negron de Bravo, 1981; Adewusi *et al.*, 1995; Englberger *et al.*, 2007; Adebowale *et al.*, 2005; Orwa *et al.*, 2009). In order to promote its cultivation and use as food, knowledge of its nutrients and some anti nutrients composition need to be generated. Breadfruit's family is normally consumed after cooking. This study was therefore carried out to determine nutrients and minerals of pulp flour of *Artocarpus altilis* found in Côte d'Ivoire in order to assess its nutritional benefits when used as food. In the study, the effect of cooking on the nutrients and mineral of breadfruit flours (obtain after cooking the pulp) was assessed.

MATERIALS AND METHODS

Sampling: *Artocarpus altilis* fruits were collected from Abidjan (Republic of Côte d'Ivoire). The fresh, firm and mature fruits were harvested and transported to the laboratory for flour processing before analyses.

Flour processing: Ten fresh mature fruits were washed with clean tap water, peeled and sliced manually into cubes with sterile knife. The slices were then rinsed with distilled-deionized water and divided into five parts of 1 kg each. Three parts of the sliced were cooked at 100°C for 10 (AF10), 15 (AF15) and 20 min (AF20) in a pan containing 1 L of water. The remaining one part with no treatment (RAF) and the three parts with treatment were dried in an oven at 45°C for 2 days. The dried sliced were ground into powder, sieved with 250 µm mesh sieve and then stored in airtight containers for analysis AOAC (1995).

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Proximate analysis: Moisture, DM, TA, CF and CP contents were determined according to the AOAC (1990) method. The moisture content of the samples was determined by oven-drying (105°C for 24 h), while TA was quantified by dry-ashing (550°C). Crude fat was determined with the Soxhlet method using hexane extraction, followed by evaporation (105°C) to constant weight. Crude protein contents were calculated from nitrogen (N×6.25) obtained using the Kjeldahl method. Carbohydrate was determined as the remaining percent weight according to the formula:

$$[100 - (\text{moisture} + \text{TA} + \text{CF} + \text{cellulose} + \text{CP})]$$

The method described by Dubois *et al.* (1956) was used for the TS content analysis, while the RS content was determined according to the method of Bernfeld (1955) using 3.5 dinitrosalycilic acid (DNS).

Energy: Energy value (Kcal/100 g) of *Artocarpus altilis* flour was calculated according to AOAC (1990) method using the following formula:

$$(4x\%\ \text{carbohydrate})+(9x\%\ \text{CF})+(4x\%\ \text{CP})$$

Minerals analysis: Minerals of *Artocarpus altilis* Flour were determined employing AOAC (1990) method. Flour was digested with a mixture of concentrated nitric acid (14.44 mol/L), sulfuric acid (18.01 mol/L) and perchloric acid (11.80 mol/L) and analyzed using an atomic absorption spectrophotometer. The total phosphorus was determined as orthophosphate by the ascorbic acid method after acid digestion and neutralization using phenolphthalein indicator and combined reagent (APHA, 1995).

Statistical analyses: All determinations reported in this study were carried out in triplicates. Mean values and standard deviations were calculated. Analysis of variance (ANOVA) and correlations were also performed. Tukey's (HSD) test at $p<0.05$ was used for mean values separation. Pearson correlation coefficients (r) for relationships between various flour properties were calculated. The variations observed in proximate and minerals of the flours from breadfruit were examined by Principal Component Analysis (PCA) with the Minitab Statistical Software version 13.

RESULTS AND DISCUSSION

Proximate composition: The proximate composition of raw and cooked pulp of *Artocarpus altilis* are shown in Table 1. Differences in DM of raw and cooked pulps were significant ($p<0.05$). Indeed, cooking increased DM of *Artocarpus altilis* pulp flours, but cooking time did not affect moisture and DM. The comparison between flours from raw and cooked breadfruits revealed that, cooking significantly ($p<0.05$) reduced the moisture contents (from 10.7 to 8.15%). This biochemical parameter is important in the storage of flours, levels greater than 12% allow microbial growth. Low levels enable and give relatively longer shelf life (Aryee *et al.*, 2006). Chew *et al.* (2011) reported that reduced moisture content ensured the inhibition of microbial growth, hence is an important factor in food preservation. The reduction in moisture content as observed in this study may indicate good stability of breadfruit flours.

The cooking of breadfruit significantly reduced the CF content from 0.84 to 0.48%. However, the change in cooking time did not affect the CF significantly. It was noteworthy that the values were below 1%. Similar observations were recorded by Owuamanam *et al.* (2010) for *Colocasia exculenta* cv ede cocoindia ($0.82\pm6x\ 10^{-3}$ %) and Assemand *et al.* (2012) for banana (0.29-0.63%). Cooking reduced the CF, but the percentage level of reduction is dependent on the duration of cooking (Ezeocha and Ojimelukwe, 2012).

The CP content of AF20 (4.23%) was significantly lower ($p<0.05$) than that observed for RAF (5.69%), AF10 (4.64%) and AF15 (4.42%). Increase in cooking time resulted to progressive decrease in the protein isolate yield from the flour (Ohishi *et al.*, 2003; Akaerue and Onwuka, 2010; Nzewi and Egbuonu, 2011). The low level of protein in AF20 was due to leaching loss and solubility of nitrogen as explained by Edijale (1980) in his research on cowpea. It appeared that protein content of breadfruit flour was higher than that reported for bananas (1.09%) (Mahapatra *et al.*, 2012); white yam (5.15%) and sweet potato (3.64%) (Alaise and Linden, 1999), rice cultivars (0.08 to 0.39%) (Yu *et al.*, 2012) and red taro corm (1.41%) (Oladebeye *et al.*, 2008). Thus, incorporating breadfruit flour in diet could contribute in amino acid balance.

There was significant variation in TS (3.2 to 10.86%) and RS (1.79 to 615%) contents of breadfruit flour in response to different cooking times. The increase in cooking time led to a significant ($p<0.05$) enhancing in the TS and RS contents. This is not surprising because level in TS and RS may result from the simultaneous phenomena of hydrolysis and gelatinization of starch which occur in pulp during cooking (BeMiller and Whistler, 1997). Indeed, under the effect of heat, the starch grains will inflate and be burst to release their contents (amylose and amylopectin) (Bjorck *et al.*, 1990). These molecules then will be degraded to give TS and RS. The level of RS in cooked breadfruit flour was found to be higher (6.86%) than those of flours from taro (*Colocasia esculenta*) cv *Sosso Chad* (2.3%) and *Ibo ekona* corm (1.3%) (Njintang *et al.*, 2007). Flour high in sugars could be useful in formulation of some types of foods such as cake. Of this fact, breadfruit flour could find application in bakery or pastry. Indeed, sugars may be desirable in bakery products like bread and cake where the tenderizing effects positively affect texture and where sugars serve as substrate for fermentation of the dough (Aina *et al.*, 2012).

The results of the analysis showed that RAF contained 77.09% carbohydrate while the cooked breadfruit flour (AF20) contained 81.89% carbohydrate. These carbohydrate contents agree with the work of Onyenuga (1968), who reported that DM of most root and tuber crops is made up of about 60 to 90% carbohydrate. Carbohydrate contents of breadfruit flour also increased significantly ($p<0.05$) with cooking but its levels were not affected by cooking time. This observation may have been due to the fact that carbohydrates may have absorb water to bulk up via cross-linking reaction probably induced by heat generated by cooking (Nzewi and Egbuonu, 2011). The high percentage of carbohydrates in breadfruit flour makes it an energy food. Energy values of *Artocarpus altilis* pulp flours ranged from 338.16 Kcal/100g DM to 349.09 Kcal/100g DM. The levels of energy were significantly increased ($p<0.05$) by cooking when compared to the raw samples. These energy values are higher than that of *Dioscorea bulbifera* (305.01 Kcal/100 g DM) (Abara, 2011), but lower than those of *Artocarpus odoratissimus* (488 to 497 Kcal/100 g DM) (Tang *et al.*, 2013), wheat (*Triticum aestivum*) (396.17 to 398.83 Kcal/100g DM) (Ijarotimi, 2012) and *Dioscorea* spp., (382.61 Kcal/100 g DM) (Polycarp *et al.,* 2012). The increasing in the energy value with cooking was similar to that observed for the yam (*Dioscorea alata*); raw and cooked during 90 min (357.65 and 370.01 Kcal/100 g DM, respectively) (Ezeocha and Ojimelukwe, 2012).

Mineral contents: The mineral contents of raw and cooked *Artocarpus altilis* flour are presented in Table 2. The analysis revealed the presence of sizeable amounts of several minerals. Some of them were affected significantly ($p<0.05$) by cooking and the change in cooking time. Indeed, mineral contents increased with cooking. The high mineral contents of cooked breadfruit flours were due to the effect of heat. In point of the fact, it is established that some antinutrients interfered on the availability of minerals by complexing them as suggest by Anigo *et al.* (2009) and Alonso *et al.* (2001). The degradation of these antinutrients by heat, release these minerals in the matrix or cooking medium.

Potassium was found to be the predominant mineral in the *Artocarpus altilis* flours. Its content in the raw and cooked pulps ranged from 704.52 to 870.60 mg/100g DM. Increasing of K with cooking is in accordance to the results of Rajni *et al.* (2012) on raw and boiled chickpea flour (664 mg/100 g DM and 854 mg/100 g DM, respectively). Generally, the K contents of both the pulp and nuts flours were higher than in cassava (103.7-554 mg/100 g DM) (Charles *et al.*, 2005). It has been reported to be an important mineral maintaining electrolyte balance in humans (NTBG, 2009) and its presence in the flours is very useful. From the results of this study, *Artocarpus altilis* could constitute a rich source of K.

As far as concern P, the results showed that its level in RAF was 141.32 mg/100 g DM. Cooking for 10 and 15 min significantly ($p<0.05$) increased the values from 217.4 to 236.67 mg/100 g DM and cooking for 20 min further reduced it significantly ($p<0.05$) to 203.8 mg/100 g DM. These observed values (141.32 to 236.67) were higher than those recorded for raw and cooked *Colocasia esculenta* (20,8 and 13,6 mg/100 g DM, respectively) (Lewu *et al.*, 2010), Ghanian breadfruit flours (134 à 140 mg/100 g DM) (Appiah *et al.*, 2011) and tissue of *Dioscorea bulbifera* (150.00 mg/100 g DM) (Abara, 2011), but lower than those of maize (300 mg/100g DM) and rice (290 mg/100 g DM) (Ihekoronye and Ngoddy, 1985) and *B. sapida* pulp (240 mg/100 g DM) (Akintayo *et al.*, 2002). However, based on the results of this study, *Artocarpus altilis* could be use as a source of P. This mineral performs a wide variety of essential functions such as its role in the liberation and utilization of energy from food. Phosphorus is the second most abundant mineral in the body after Ca.

Calcium and Mg contents in breadfruit increased with cooking for 10 and 15 min and decreased with 20 min cooking. The Ca level (60.9 mg/100 g DM) of RAF

Table 1: Proximate composition and energy values of flours from raw and cooked breadfruit (*Artocarpus altilis*)

	Flours			
Parameters	RAF	AF10	AF15	AF20
Moisture (%)	10.7±0.36[a]	8.19±0.02[b]	8.18±0.03[b]	8.15±0.08[b]
DM (%)	89.3±0.34[a]	91.81±0.72[b]	91.82±1.46[b]	91.85±0.67[b]
CF (%)	0.84±0.2[a]	0.53±0.07[b]	0.48±0.02[b]	0.48±0.03[b]
CP (%)	5.69±0.85[b]	4.64±0.57[b]	4.42±0.25[b]	4.23±0.03[a]
TS (%)	3.2±0.66[a]	7.54±0.05[b]	11.13±0.04[c]	10.86±0.05[d]
RS (%)	1.79±0.19[a]	5.54±0.05[b]	6.86±0.03[c]	6.15±0.10[d]
Celullose (%)	2.37±0.17[b]	1.75±0.25[a]	1.45±0.15[a]	1.45±0.05[a]
Carbohydrate (%)	77.09±1.46[a]	81.44±0.81[b]	81.70±0.86[b]	81.89±0.66[b]
Energie (Kcal/100 g DM)	338.16±0.16[a]	349.09±0.09[b]	348.80±0.44[b]	348.80±1.4[b]

The obtained values are averages±standard deviation of triplicate determinations. On the lines of each parameter, the averages affected of no common letter are significantly different between them on the threshold of 5% according to the test of Tukey.

DM : Dry Matter CF : Crude Fat CP : Crude Protein

TS : Total Sugars RS : Reducing Sugars

Table 2: Mineral contents of flours from raw and cooked breadfruit (*Artocarpus altilis*)

	Flours			
Mineral contents	RAF	AF10	AF15	AF20
TA (g/100 g DM)	3.31±0.01[a]	3.45±0.55[a]	3.77±0.27[a]	3.80±0.25[a]
P (mg/100 g DM)	141.32±6.55[a]	217.4±5.0[c]	236.67±4.84[b]	203.8±8.20[c]
K (mg/100 g DM)	704.52±9.79[a]	825.70±6.60[c]	870.60±2.80[d]	769.60±2.4[b]
Ca (mg/100 gDM)	60.9±2.1[a]	81.90±2.1[c]	85.40±4.60[c]	70.86±2.14[b]
Mg (mg/100 gDM)	88.7±1.7[b]	110.7±3.38[c]	112.4±3.62[c]	76.5±5.50[a]
Na (mg/100 g DM)	70.5±1.80[b]	69.27±2.83[b]	69.05±1.18[b]	60.36±1.94[a]
Fe (mg/100 g DM)	2.91±0.11[a]	3.88±0.18[b]	3.95±0.35[b]	3.6±0.36[ab]
Zn (mg/100 g DM)	2.24±0.14[a]	3.12±0.08[b]	3.24±0.14[c]	3.23±0.12[c]
K:Na	10.00±2.00[a]	11.91±0.09[ab]	12.60±0.40[ab]	12.75±0.25[b]

The values are averages±standard deviation of triplicate determinations. Different letters within the same row stand for significant differences ($p<0.05$) different between them on the threshold of 5% according to the test of Tukey.

TA : Total Ash K : Potassium P : Phosphorus Ca : Calcium
Mg : Magnesium Na : Sodium Fe : Iron Zn: Zinc

Table 3: Pearson correlation coefficients between various proximate and minerals of flours from raw and cooked breadfruit (*Artocarpus altilis*)

	DM	CF	CP	TS	RS	TA	Zn	Na	K	P	Ca	Mg	Fe
DM	1.00												
CF	-0.99	1.00											
CP	-0.96	0.98	1.00										
TS	0.90	-0.94	-0.96	1.00									
RS	0.97	-0.98	-0.96	0.96	1.00								
TA	0.76	-0.83	-0.88	0.96	0.85	1.00							
Zn	0.99	-0.99	-0.98	0.94	0.98	0.82	1.00						
Na	-0.46	0.51	0.63	-0.59	-0.43	-0.68	-0.50	1.00					
K	0.96	-0.99	-0.99	0.98	0.99	0.90	0.98	-0.56	1.00				
P	0.94	-0.94	-0.88	0.87	0.96	0.71	0.94	-0.20	0.92	1.00			
Ca	0.90	-0.89	-0.81	0.79	0.91	0.61	0.89	-0.07	0.85	0.98	1.00		
Mg	0.30	-0.25	-0.11	0.12	0.33	-0.08	0.27	0.69	0.19	0.55	0.66	1.00	
Fe	0.78	-0.74	-0.64	0.61	0.78	0.40	0.76	0.17	0.69	0.91	0.96	0.83	1.00

DM : Dry matter CF : Crude fat CP : Crude protein TA : Total ash RS : Reducing sugars
TS : Total sugars Zn : Zinc Na : Sodium K : Potassium P : Phosphorus
Ca : Calcium Mg : Magnesium Fe : Iron

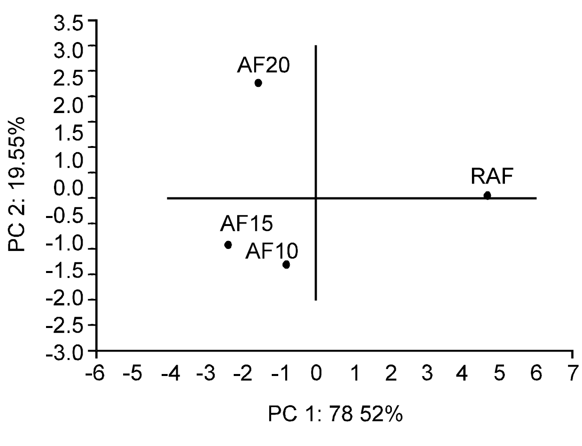

Fig. 1: Sample plot of principal components 1 and 2 of flours from raw and cooked breadfruit (*Artocarpus altilis*). RAF: Flour from raw breadfruit (*Artocarpus altilis*); AF10: Flour from breadfruit (*Artocarpus altilis*) cooked in water at 100°C during 10 min; AF15: Flour from breadfruit (*Artocarpus altilis*) cooked in water at 100°C during 15 min; AF20: Flour from breadfruit (*Artocarpus altilis*) cooked in water at 100°C during 20 min

increased up to 85.40 mg/100 g DM with cooking. The increasing of Ca with cooking was similar to that observed by Yagoub *et al.* (2008) when cooking seeds of *Hibiscus sabdariffa* (64 mg/100 g DM for raw and 74 mg/100 g for cooked). Despite this increase due to the effect of heat, Ca level remains relatively low compared to that from other sources such as *Prospis africana* (362.5 mg/100 g) (Aremu *et al.*, 2006) and *Dioscorea bulbifera* 209.00 mg/100 g DM) (Abara *et al.*, 2003). However given the Mg content (from 88.7±1.7 mg/100 g to 112.4±3.62 mg/100 g), *Artocarpus altilis* flour would be helpful in diet for supplementing Ca intake. Indeed, Mg is essential for appropriate Ca metabolism (Seelig, 1993; Kenney *et al.*, 1994). Furthermore, the results of this study show positive correlation between Mg and Ca ($r = 0.66$, $p<0.05$) contents both by Pearson correlation (Table 3) and PCA analyses (Fig. 2).

The Na contents in RAF was 70.5 mg/100 g DM, cooking for 20 min significantly decreased it to 60.36 mg/100 g DM. This result was similar to that reported for Ghanian breadfruit (*Artocarpus altilis*) (69 mg/100 g DM) (Appiah *et al.*, 2011), but lower than those recorded for *Dioscorea bulbifera* (550.00 mg/100 g DM and 102.00 mg/100 g DM) (Abara, 2011; Polycarp *et al.*, 2012, respectively). Morgan (1999) indicated that reducing

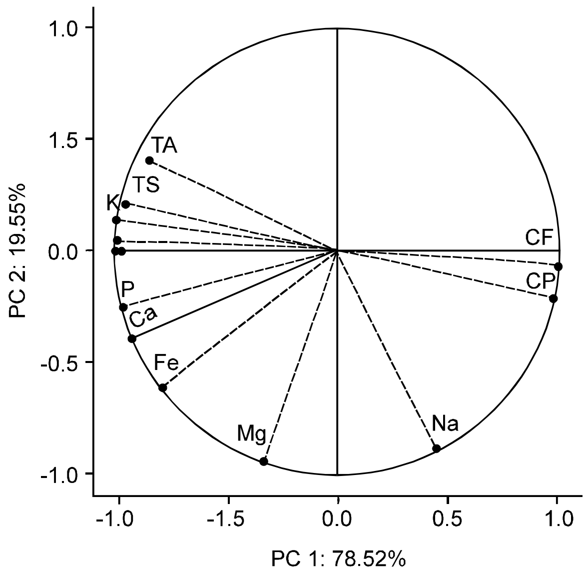

Fig. 2: Circle of correlation of chemical composition of flours from raw and boiled breadfruit (*Artocarpus altilis*).on axes 1 and 2. DM: Dry matter, CF: Crude fat, CP: Crude protein, TA: Total ash, RS: Reducing sugars, TS: Total sugars, Zn: Zinc, Na: Sodium, K: Potassium, P: Phosphorus, Ca: Calcium, Mg: Magnesium, Fe: Iron

intake of Na ameliorates the development of hypertension. Since the Na content of the *Artocarpus altilis* flour is low, it could be used as food without apprehension of health-risks.

Iron and Zn contents of RAF increased with cooking for 10 and 15 min and decreased for 20 min, indicating that further cooking would be disadvantageous. This result was similar to those obtained for banana (Adeniji and Tenkouano, 2008) and chickpea (Rajni *et al.*, 2012). A positive correlation was observed between Fe and Zn (r = 0.76, $p<0.05$). According to Kordas and Stoltzfus (2004), the role of Fe and Zn in child development has generated much interest due to adverse effects of their deficiencies on cognition and behavior. The results obtained for Zn showed t hat the raw and cooked pulp flours of *Arthocarpus altilis* contained 2.24 mg/100 g DM and 3.24 mg/100 g DM, respectively. These values of Zn were higher than those of banana and pineapple (1.11 mg/100 g DM and 0.96 mg/100 g DM, respectively) (Falade *et al.*, 2005), *Colocasia esculenta* (1.30 mg/100 g) and *Dioscorea bulbifera* (1.52 mg/100 g) (Alinnor and Akalezi, 2010; Abara, 2011).

The K:Na ratio (range between 10.00 for raw breadfruit and 12.75 for cooked breadfruit) is close to the recommended value (5.0) (Szentmihalyi *et al.*, 1998). Potassium has a beneficial effect on Na balance. A high intake of K has been reported to protect against increasing blood pressure and other cardiovascular risks (Langford, 1983; Cappuccio and McGregor, 1991). Dietary changes leading to reduce consumption of K than Na have health implications. Diets with higher ratio K: Na is recommended and these are found usually in whole foods (Arbeit *et al.*, 1992). Foods naturally high in K than Na may have a K:Na ratio of 4.0 or more (CIHFI, 2008). The high K:Na ratio suggests that the flours from breadfruit (*Artocarpus altilis*) could be suitable in helping to ameliorate Na related health risk (Appiah *et al.*, 2011; Ijarotimi, 2012).

Principal component analysis: Principal Component Analysis (PCA) was used to visualize the variation in the properties among flours from different cooking times. This analysis showed two axes (axis 1 and 2) explaining the essential variability. The first and the second PCS described 78.52 and 19.55% of the variance, respectively. Together, the first two PCS represented 98.07% of the total variability. RAF was located at the right of the score plot, while AF10, AF15 and AF20 had a large negative score in the first Principal Component (PC1). RAF and AF20 had a large positive score, whereas AF10, AF15 had a negative score in PC2 (Fig. 1). Thus, flours were separated according to the first two axes on the basis of their properties and three groups emerged: (1) RAF; (2) AF10 and AF15; (3) AF20. This discrimination showed that AF10 and AF15 had similar properties that were different from those of AF20 and RAF. The correlation circle provides information about correlations between the measured properties (Fig. 2). The properties whose curves lie close to each other on the plot were positively correlated while those whose curves run in opposite directions were negatively correlated. Correlations between the properties of flours were also supported by Pearson's correlation coefficients (Table 3).

Conclusion: Breadfruit *(Artocarpus altilis)* has a great nutritional potential. It is a good source of carbohydrate and therefore could be useful to meet energy needs of its consumers. The use of cooking in processing *Artocarpus altilis* pulp flour improves the mineral content and some of nutrients. *Artocarpus altilis* pulp flour is a good source of potassium, phosphorus and magnesium. The tuberous nature of the fruit makes it as a potential staple that could be used to combat hunger and provide food security.

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