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RESEARCH ARTICLE

Effect of boiling time on some biochemical parameters of yam specie (*Dioscorea alata* variety "Bètè-Bètè") tubers

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Abstract

The effects of different boiling times (10 min, 20 min, 30 min) on proximate composition of flour from tubers of "Bètè-bètè" yam variety (*Dioscorea alata*) were determined. Mean moisture, starch, total sugar, reducing sugar, crude protein, crude fat and total ash contents of flour from raw tuber " Bètè-bètè" were 8.77 ± 0.87 % dw, 74.87 ± 1.18 % dw, 4.27 ± 0.10 % dw, 0.85 ± 0.10 % dw, 8.84 ± 0.20 % dw, 0.33 ± 0.28 % dw and 4.64 ± 1.53 % dw respectively. On comparing the raw and boiled, the results indicated boiling time led to a significant ($P<0.05$) reduction in starch, crude protein and crude fat compound contents, whereas the moisture, reducing sugars and total sugars contents increased significantly ($p<0.05$). The total ash content of the flours from yam tuber was not affected significantly ($p<0.05$). A boiling time of 20 min was recommended for tuber of "Bètè-bètè" yam variety (*Dioscorea alata*).

Introduction

Yam is one of the staple foods in Côte d'Ivoire and other tropical African countries. It is an excellent source of starch, which provides calorific energy (Coursey, 1973). The most cultivated species in Côte d'Ivoire are *Dioscorea alata* and *Dioscorea cayenensis-rotundata* complex. They are the most economically important of all cultivated species since they give the highest yields (Doumbia *et al*., 2006). Yam is an important source of carbohydrate for many people of the sub-Sahara region, especially in the yam zone of West Africa (Akissoe *et al*., 2001). Babaleye (2003) reported that yam contributes more than 200 dietary calories per capita daily for more than 150 million people in West Africa and serves as an important source of income to the people. Besides, Yam tubers are usually consumed in the forms of chunks, flour, fufu, and slices resulting from any of the processes of boiling, drying, fermentation, frying, milling, pounding, roasting, and steaming (Iwuoha, 2004). It has a seasonal production that makes mandatory its storage for use as food or seed. After harvest, tubers enter into dormancy. Once the dormancy is broken, sprouting occurs and prolonged storage is no longer possible. Moreover, yam like other root and tuber crops such as cassava and taro, suffers from post-harvest losses estimated at 30% (Doumbia, 1990) caused partly by external agents, such as insects, rodents and moulds. The storage time of yam under fresh shape is five (5) months and even on a longer time according to Osagie (1992). These losses serve as an impetus for processing this staple food into a product of longer shelf life. Yam flour can be easily stored for a long period (12-18 months) if the flour is free from moisture; hence yam is commonly processed into flour by drying yam slices and milling.

Some researchers have however studied the effect of processing variables on the quality of yam flour such as: effect of tuber storage and pre-and post-blanching treatments on physicochemical properties of dry yam flour; effect of blanching and drying on the colour and functional properties of yam flour; effect of drying methods on rheological characteristics and colour of yam flours; effect of varied processing variables (yam thickness, parboiling temperature and time) on the moisture content, pasting property, sensory quality and microbiological quality of yam (Babajide *et al*., 2006; Akissoe *et al*., 2003; Jimoh *et al*., 2009). However, there is little or no information on biochemical differences existing between flours from tubers of "Bètè-bètè" yam variety at different boiling time and the impact of boiling on these biochemical parameters. Therefore, this study was conducted to determine the effect of boiling time on the some biochemical parameters of flours from tuber of "Bètè-Bètè" yam variety belonging *Dioscorea alata*.

MATERIALS AND METHODS

Raw materials

The "Bètè-Bètè" yam variety belonging to *Dioscorea alata* species was used in the present study. Tubers were harvested at physiological maturity from fields in the south of Côte d'Ivoire. They were immediately transported in a heap aired store and stored in which the temperature and the relative humidity rate were 26.56 ± 3 °C and 82 ± 5% respectively.

Sample Preparation

Two (2) kg "Bètè-bètè" yam tuber were washed with clean water. They peeled and cut into small slices (3x3x3 cm thickness) using a stainless steel knife. The slices were rewashed with clean water in order to remove much mucilaginous material. After washing, they were divided into four lots of 500 g each. Three lots were boiled at100°C for 10 min, 20 min and 30 min in a pan containing 1 L of water distilled. At the end of boiling, the three lots with treatment and the remaining one part with no treatment and were dried in an oven at 45°C for 48 hours. The dried slices were ground into powder, sieved with 250 µm mesh sieve and then stored in airtight containers for analysis AOAC (1995).

Proximate Composition Analysis

Dry matters were determined by drying in an oven at 105ºC during 24 h to constant weight (AOAC, 1990). Crude protein was calculated from nitrogen (Nx6.25) obtained using the Kjeldahl method by AOAC (1990). Crude fat was determined by continuous extraction in a Soxhlet apparatus for 8 h using hexane as solvent (AOAC, 1990). Total ash was determined by incinerating in a furnace at 550ºC (AOAC, 1990). Method described by Dubois *et al.* (1956) was used to determine total sugars while reducing sugars were analyzed according to the method of Bernfeld (1955) using 3.5 dinitrosalycilic acids (DN S).

Starch content was determined with the method of Dubois and *al*. (1956). Hot ethanol was used to extract starch from the flour sample. The digest (from the residue) was quantified calorimetrically for starch, using phenol-sulphuric acid as the colour developing reagent; absorbance was read at 490 nm. The starch content was expressed as follows:

$$\% \text{ Starch} = ((A-I)*DF*V*0.9*100)/(B*W*10^6)$$

Where:

A= Absorbance of sample

I =Intercept of standard curve

D.F = Dilution factor

V = Total extract volume.

B = Slope of the standard curve.

W = Sample weight.

Minerals analysis

Minerals 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 analysis

All analyses were performed in triplicates. Results were expressed by means of ± SD. Statistical significance was established using one-way analysis of Variance (ANOVA) models to estimate the effect of boiling times on some biochemical parameters of flour from yam at 5% level. Means were separated according to Duncan's multiple range analysis ($P \leq 0.05$), with the help of the software STATISTICA 7 (Statsoft Inc, Tulsa-USA Headquarters) and XLSTAT-Pro 7.5.2 (Addinsoft Sarl, Paris-France).

Results

Proximate Composition

The proximate composition of flour from raw and boiled yam specie (*Dioscorea alata* variety "Bètè-Bètè") tubers are shown in Table 1.

Moisture content

The moisture content of flour from raw and boiled tubers of "Bète-bètè" yam is shown in Table 1. The boiling was carried out at different times (10 min, 20 min and 30 min). The moisture content varied from 8.77 ± 0.87 % dw to 11.83 ± 1.05 % dw (dry weight) during boiling, representing 3.06 % increase. The highest moisture content was found to be 11.83 ± 1.05 % dw for the flour from the boiled tubers at 30 min, while the lowest moisture content was obtained with flour from the raw tubers (0 min). The Analysis of Variance (ANOVA) revealed that the boiling time main effect appeared significant at 0.05 level. There were significant variations at 0.05 level between the moisture contents of flour from raw and boiled tubers at different time. However, slight differences were observed between the flour from boiled tubers at both times (10 min and 20 min) and didn't significant at 0.05 level between them.

Total sugar content

The values of flour from tubers of "Bètè-bètè" yam variety during boiling is presented in table 1 They ranged from 04.27 ± 0.10 % dw to 12.51 ± 0.81 % dw during boiling, representing. 8.24 % decrease. The lowest total sugar content was obtained with flour from raw tubers of "Bètè-bètè" yam variety, while the flour from the boiled tubers at 30 min had the highest total sugar content. The boiling time main effect appeared to be stronger. Indeed, the statistical analysis revealed that boiling reduced significantly ($p<0.05$) the total sugar content at different times.

Reducing sugar content

Concerning Reducing sugar content, the data in table 1 showed that ash it ranged from 0.85 ± 0.10 % dw to 2.47 ± 0.24 % dw for flour from raw and boiled tubers at 30 min respectively. The flour from raw tuber had the lowest reducing sugar content while the highest value was obtained with the flour from boiled tubers at 30 min. Otherwise, the analysis of variance showed that the boiling time had significant effect ($p \leq 0.05$) on reducing sugar content of flour from yam tubers. Indeed, the reducing sugar contents increased meaningfully ($p<0.05$) until 30 min after boiling.

Starch content

The starch content is presented in table 1. The values of starch content ranged from 74.87 ± 1.18 % dw to 72.33 ± 0.35 % dw for the flour from raw and boiled tubers at 30 min respectively. The flour from the raw tuber had the highest starch content whereas the flour from the boiled tuber at 30 min had the lowest starch content. The analysis of variance showed that the boiling had significant effect ($p \leq 0.05$) on starch content. It reduced meaningfully ($p \leq 0.05$) the starch content during the boiling time. However, slight differences were observed between the starch content of the flour from the boiled tubers at 20 min and 30 min, with respective rate of 73.50 ± 0.50 % dw and 72.33 ± 0.35 % dw. These values were not affected significantly at 0.05 level.

Crude fat content

The crude fat content is presented in table 1. The values of crude fat content ranged from 0.33 ± 0.28 % dw to 0.22 ± 0.02% dw for the flour from raw and boiled tubers at 30 min respectively. It appeared slight differences between the crude fat content of flour from "Bètè-bètè" yam tuber at different boiling times (10 min to 30 min). However, the crude fat contents of flour from yam tubers were not differed meaningfully ($p<0.05$) at different boiling times.

Crude protein content

The crude protein content is presented in table 1. The values of crude protein content ranged from 8.84 ± 0.20 % dw to 7.45 ± 0.14 % dw for the flour from raw and boiled tubers at 30 min respectively. The flour from the raw tuber had the highest crude protein content whereas the flour from the boiled tuber at 30 min had the lowest crude protein content. However, slight differences were observed between the crude protein content of the flour from the boiled tubers at 20 min and 30 min, with respective rate of 7.81 ± 0.12 % dw and 7.45 ± 0.14 % dw. These values were not affected significantly at 0.05 level.

Total ash content

The total ash content is presented in table 1. The values of total ash content ranged from 4.64 ± 1.53 % dw to 4.23 ± 1.53 % dw for the flour from raw and boiled tubers at 30 min respectively. It appeared slight differences between the crude fat content of flour from raw "Bètè-bètè" yam tuber and the flour from the boiled tuber at different boiling times (10 min to 30 min). However, the total ash contents of flour from yam tubers were not differed meaningfully ($p<0.05$).

Mineral composition

Table 2 summarizes the mineral composition of raw and boiled yam specie (*Dioscorea alata* variety "Bètè-Bètè″) tubers. Generally, the mineral contents were affected significantly ($p<0.05$) by the change in boiling time. Within these flours, calcium (12.90 ± 0.0 mg/100 g dry weight), iron (0.08 ± 0.14 mg/100 g dry weight) and sodium (6.50 ± 0.10 mg/100 g dry weight) had the lowest values, while phosphorus (220.00 ± 0.95 mg/100 g dry weight), potassium (661.90 ± 0.63 mg/100 g dry weight) and magnesium (53.70 ± 0.32 mg/100 g dry weight) had the highest values. The values of K/Na ratio ranged from 101.83 to 187 for the flour from raw and boiled tubers at 30 min respectively.

Principal component analysis

The principal component analysis of flour from raw and boiled yam tuber of "Bètè-bètè" variety related to the twelve physicochemical parameters permitted to show two axes explaining the essential variability that were axes 1 and 2. These axes expressed 98.09 % of the total variability observed, with 95.17 % and 2.92 % for axes 1 and 2 respectively.

The circle of correlation (Figure 1) revealed two groups of enough distinct physicochemical variables. The first group consists of ashes, proteins, fat, Mg, Ca, Na, K and P. the second group included Moisture, reducing sugars and total sugars. The variables those were reducing sugars, Moisture, ashes, proteins, fat, Mg, Ca, K and P , contributed more to formation of axis1 (CP1). This axis is a good indicator of the proximate composition and some minerals of flour from "Bètè-bètè" yam tubers. As for the formation of axis 2, these are ashes, total sugars and Na expressing in the order of 33.84%, 13.70% and 17.80% of this axis.

Otherwise the matrix of correlation (Table 3) showed that the moisture content was negatively correlated to ash content ($r = -0.92$, $p<0.05$) and starch content ($r = -1.00$ $p<0.05$). Furthermore, the result of this study showed also that the starch content was negatively correlated to total sugars (($r = -0.95$, $p<0.05$) and to reducing sugar ($r = -0.97$, $p<0.05$).

The principal component analysis permitted to show three emerged groups of flour according to the two axes on the basis of their physicochemical properties : (1): FRBb (Flour from raw "Bètè-bètè"), (2): FBb "10 min" (Flour from "Bètè-bètè" yam tuber during 10 min), FBb "20 min"(Flour from "Bètè-bètè" yam tuber during 20 min) and (3): FBb "30 min" (Flour from "Bètè-bètè" yam tuber during 30 min) (figure 2).

This discrimination showed that FBb "10 min" and FBb "20 min" had intermediate contents of different parameters studied and these contents were similar relatively. They were different from those of FBb and FBb "30 min".

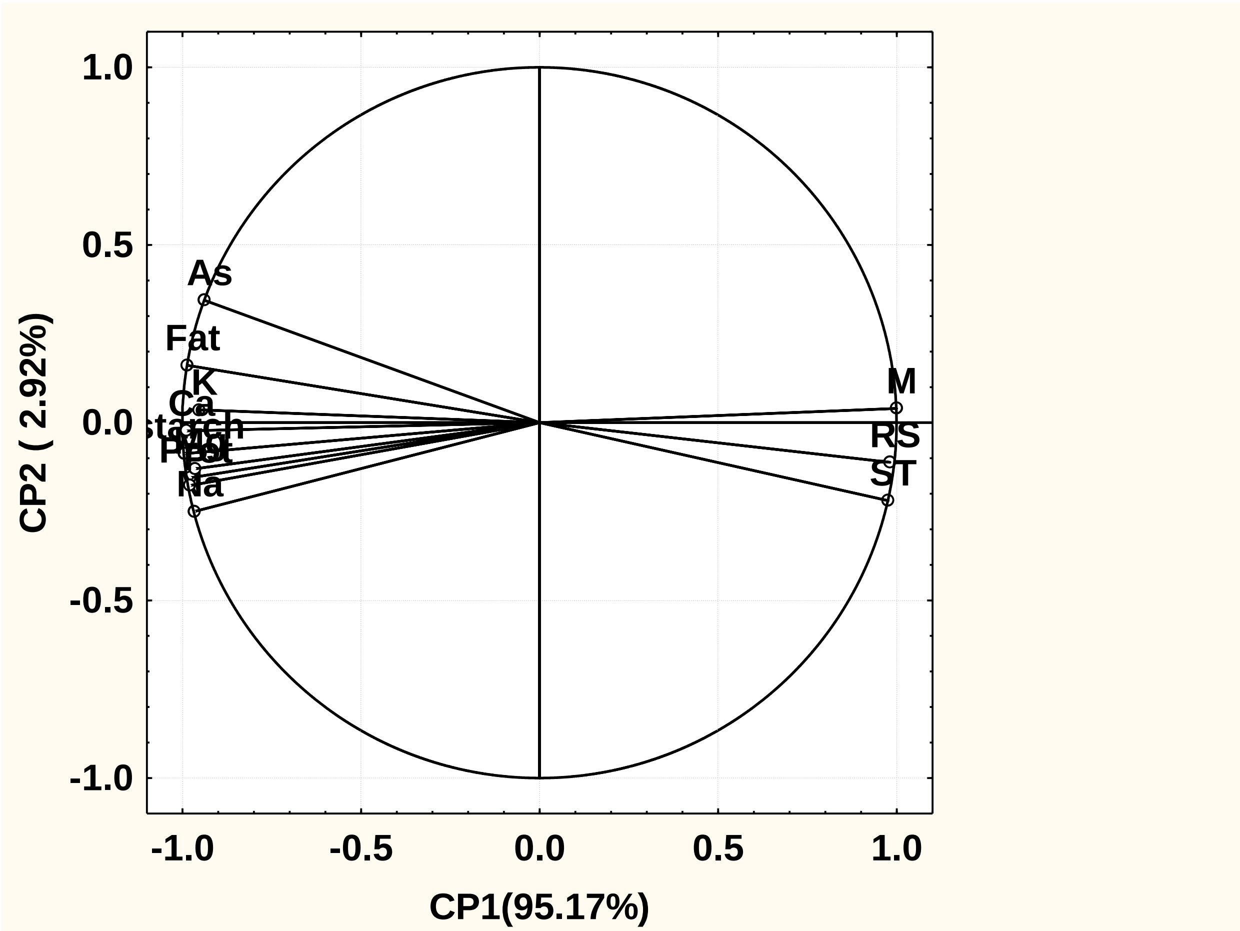

Fig. 1. Circle of correlation of the physicochemical properties of flour from "Bète-bètè" yam tubers on axes 1 and 2. TS: Total sugars; RS: Reducing sugars; As: Ashes; Prot: proteins; Mg: magnesium; Ca: calcium; Na: Sodium; K: Potassium; P: Phosphorus; M: moisture.

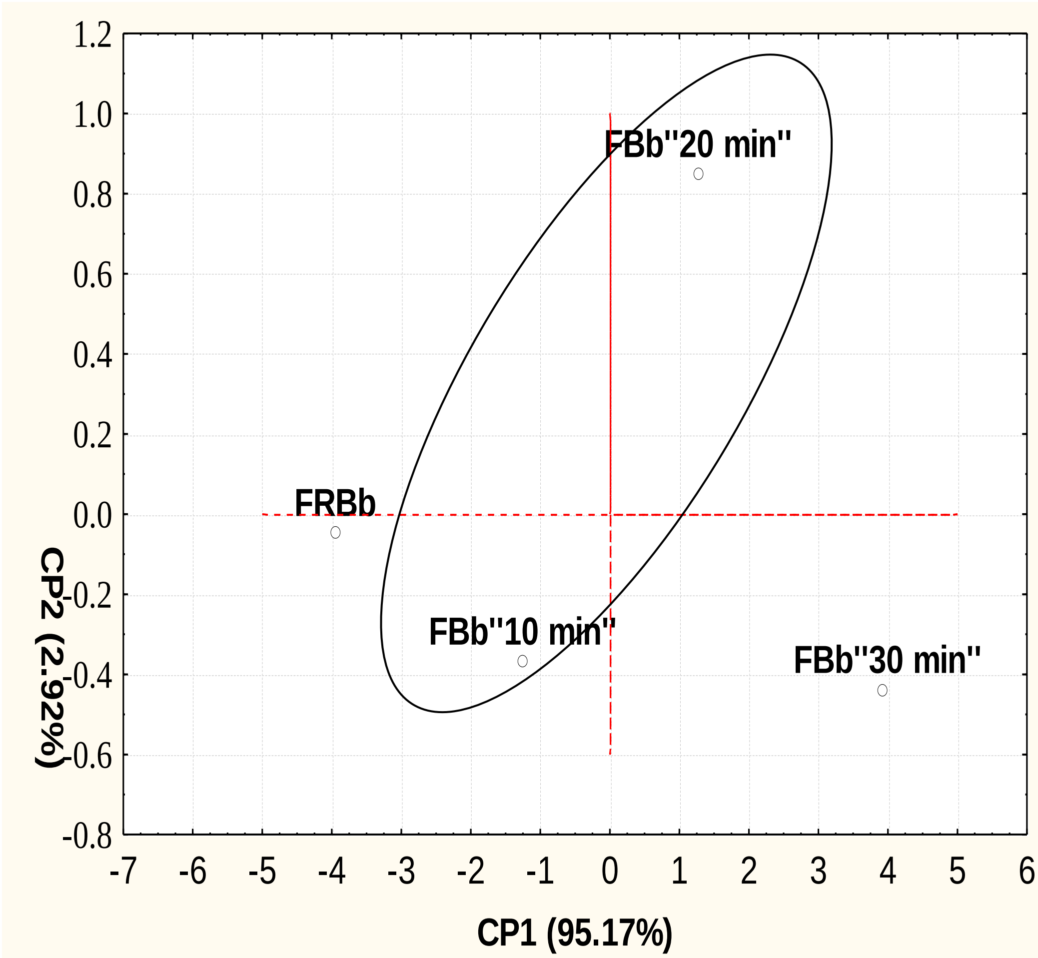

Fig. 2. Sample plot of principal components 1 and 2 of flours from raw and boiled "Bètè-bètè" yam tubers (*Dioscorea alata*). FRBb: Flour from raw "Bètè-bètè" yam tuber; FBb "10 min": Flour from "Bètè-bètè" yam tuber during 10 min; FBb "20 min": Flour from "Bètè-bètè" yam tuber during 20 min; FBb "30 min": Flour from "Bètè-bètè" yam tuber during 30 min.

Table 1: Proximate composition values of flours from raw and boiled yam specie (*Dioscorea alata* variety "Bètè-Bètè") tubers

Parameters	Flour from raw "Bètè-bètè" yam	Flours from boiled "Bètè-bètè" yam		
		10 min	20 min	30 min
Moisture (%)	8.77 ± 0.87^a	9.20 ± 0.78^b	9.80 ± 0.69^c	11.83 ± 1.05^d
Crude protein (%)	8.84 ± 0.20^b	8.60 ± 0.28^b	7.81 ± 0.12^a	7.45 ± 0.14^a
Reducing sugars (%)	0.85 ± 0.10^a	1.19 ± 0.11^b	1.67 ± 0.07^b	2.47 ± 0.24^c
Total sugars (%)	4.27 ± 0.10^a	7.35 ± 0.88^b	8.28 ± 0.45^c	12.51 ± 0.81^d
Crude fat (%)	0.33 ± 0.28^b	0.29 ± 0.02^a	0.27 ± 0.01^a	0.22 ± 0.02^a
Total ash (%)	4.64 ± 1.53^a	4.50 ± 1.80^a	4.50 ± 0.09^a	4.23 ± 1.53^a
Starch (%)	74.87 ± 1.18^b	74.83 ± 1.41^b	73.50 ± 0.50^a	72.33 ± 0.35^a

Each value is an average of three replicate.
Values are mean ± standard deviation.
Means not sharing a similar letter in a line are significantly different $p \leq 0.05$ as assessed by the test of Duncan.

Table 2: Mineral contents of flours from raw and boiled yam specie (*Dioscorea alata* variety "Bètè-Bètè") tubers

Mineral contents	Flour from raw "Bètè-bètè" yam	Flours from boiled "Bètè-bètè" yam		
		10 min	20 min	30 min
Na (mg/100 g dw)	6.50 ± 0.10[b]	5.10 ± 0.06[c]	3.00 ± 0.04[a]	2.70 ± 0.05[a]
Mg (mg/100 g dw)	53.70 ± 0.32[b]	44.60 ± 0.63[ab]	39.10 ± 0.89[a]	36.90 ± 0.50[a]
P (mg/100 g dw)	220.00 ± 0.95[d]	194.30 ± 0.64[c]	125.50 ± 0.44[b]	98.80 ± 1.21[a]
K (mg/100 g dw)	661.90 ± 0.63[a]	564.80 ± 0.52[d]	544.20 ± 2.92[c]	504.90 ± 0.35[b]
Fe (mg/100 g dw)	0.08 ± 0.14	-	-	-
Ca (mg/100 g dw)	12.90 ± 0.0[b]	12.00 ± 0.12[b]	10.10 ± 0.1[ab]	8.40 ± 0.15[a]
K/Na	101.83	110.74	181.4	187

dw: dry weight
Each value is an average of three replicate.
Values are mean ± standard deviation.
Means not sharing a similar letter in a line are significantly different $p \leq 0.05$ as assessed by the test of Duncan.

Table 3: Pearson correlation coefficient for physicochemical parameters of flour from "Bète-bètè" yam tubers

Variables	M	As	ST	RS	Pro	Fat	starch	Na	Mg	P	K	Ca
M	1.00											
Ash	-0.92	1.00										
TS	0.97	-0.99	1.00									
RS	0.98	-0.96	0.98	1.00								
Prot	-0.98	0.87	-0.92	-0.96	1.00							
Fat	-0.98	0.98	-1.00	-0.98	0.93	1.00						
starch	-1.00	0.90	-0.95	-0.97	0.99	0.97	1.00					
Na	-0.98	0.82	-0.89	-0.91	0.97	0.91	0.98	1.00				
Mg	-0.97	0.86	-0.91	-0.89	0.93	0.94	0.96	0.98	1.00			
P	-0.99	0.86	-0.92	-0.96	1.00	0.93	0.99	0.98	0.94	1.00		
K	-0.95	0.91	-0.94	-0.89	0.88	0.96	0.93	0.93	0.98	0.90	1.00	
Ca	-0.99	0.92	-0.96	-0.99	0.99	0.97	0.99	0.95	0.92	0.99	0.90	1.00

NB: in thick. The significant correlation values on the threshold of 5%
TS: Total sugars; RS: Reducing sugars; As: Ashes; Prot: proteins; Mg: magnesium; Ca: calcium; Na: Sodium; K: Potassium; P: Phosphorus; M: moisture.

DISCUSSION

The result of one-way Analysis of Variance (ANOVA) showed that boiling time affected significantly ($p \leq 0.05$) the moisture content of flour from yam tuber. Indeed, the boiling increased significantly ($p \leq 0.05$) the moisture content of flour from a mean value of 3.06 % during boiling time. This increase after cooking is referred to water absorption during boiling process (El Sohaimy, 2013). It may be also attributed to the cell damage due to the effect of boiling. Similar increase in moisture content during the boiling time was observed by Bell (1981) in yam tubers; Harada *et al.* (1985) in potato tubers and Amon *et al.* (2011) in taro tubers. The moisture levels were however within the acceptable limit of not more than 10 % for long term storage of flour (Polycarp *et al*., 2012). It should be pointed out that when these products are allowed to equilibrate for periods of more than one week at 60 % relative humidity and at room temperature (25 to 27 °C), moisture content might increase (Adegunwa *et al*., 2011). Indeed, the result revealed that the moisture content of the flours from raw tubers and boiled tubers at the both times (10 min and 20 min) were all below 10 %, thereby giving the flours a better shelf life. This biochemical parameter is important in the storage of flour, levels greater than 12% allow for microbial growth. Chew *et al*. (2011) reported that reduced moisture content ensured the inhibition of microbial growth, hence is an important factor in food preservation.

The boiling reduced meaningfully ($p \leq 0.05$) the starch content of flour from yam tuber at different boiling times. This reduction is may be due to the hydrothermal degradation and extraction of starch in boiling water (El Sohaimy, 2013). Indeed, boiling caused swelling and distortion of all starch granules. The starch is the most important chemical component in the flours. It provided the major source of physiological energy in human and monogastric diets; its occurrence in high amounts in these grains underscores their potential energy supply. Apart from its energy contribution, starch in most of the processed food systems is known to contribute to the texture, and as a result, to the organoleptic properties of food (Tharanathan and Mahadevamma, 2003).

The total and reducing sugar contents in flour from raw and boiled tubers of yam increased from 8.24 % and 1,62 % in proportion respectively. This behaviour flour from tuber, usually in hydrothermal treatments could be explained by the hydrolysis that occurs in tubers transforming carbohydrates and starch in particular, soluble sugars (Trèche, 1989). This is in accordance with the observation of Sahoré and Amani (2005) on of *Dioscorea alata* tubers.

The boiling reduced meaningfully ($p \leq 0.05$) the crude protein content of flour from yam tuber at different boiling times. Decrease in cooking time resulted to progressive decrease in the protein isolate yield from the flour (Nzewi and Egbuonu, 2011). It appeared that protein content of yam tuber flour was higher than that reported on bananas (1.09%) (Mahapatra *et al*., 2012); white yam (5.15%) and sweet potato (3.64%) (Alaise and Linden, 1999) Thus, incorporating yam tuber flour in diet could contribute in amino acid balance.

The boiling reduced meaningfully ($p \leq 0.05$) the crude fat content of flour from yam tuber. However, the change in boiled time did not affect the crude fat significantly. In comparison to other flours, flours of yam tuber exhibit lower fat content, indicating that this corm is not a good source of fat. Similar observations were recorded by Yi-Chung *et al*. (2006) on the yam whole tubers who found the rate of 0.20 % dw *for Dioscorea batata* ("Hualien" cultivar).

Total ash content was not affected significantly ($p< 0.05$) by the change in boiling time. This result is contrary to that obtained by Edem *et al*. (1994) who reported that soluble minerals get lost by dissolving into boiling water.

The analysis revealed the presence of sizeable amounts of several minerals. Some of them were affected significantly ($p<0.05$) by boiling and the change in boiling times. Indeed, mineral contents decreased with boiling times. Calcium contents were lower than those recorded by Bell and Favier (1981) in yam whole tubers of *Dioscorea dumetorom* who reported 41.8 mg/100 g dw and 52.4 mg/100 g dw, respectively. Besides, these values were higher than those recorded by Sahoré and Amani (2005) in yam whole tubers of *Dioscorea dumetorom* and *Dioscorea bulbifera* who noted 5.3 mg/100 g fresh weight (fw) and 5.0 mg/100 g fw, respectively. As for the magnesium contents, our results were higher than those mentioned by Sahoré and Amani (2005) in yam whole tubers of *Dioscorea hirtiflora* and *Dioscorea bulbifera* who reported 23.1 mg/100 g fw and 22.4 mg/100 g dw for these two species respectively. The K/Na ratio (101.83 to 187) was close to the recommended 5.0 (Szentmihalyi *et al*., 1998). Dietary changes leading to reduce consumption of potassium than sodium have health implications. Diets with higher ratio K/Na are recommended and these are found usually in whole foods (Arbeit *et al*., 1992). Foods, naturally higher in potassium than sodium, may have a K/Na ratio of 4.0 or more (CIHFI, 2008). The high K/Na suggests that the flours from yam specie (*Dioscorea alata* variety "Bètè-Bètè") tubers corm could be suitable in helping to ameliorate sodium-related health risk (Appiah *et al*., 2011).

CONCLUSION

This study showed that boiling had both positive and negative effect on some biochemical parameter (moisture, starch, total and reducing sugar, crude protein, crude fat and ash) in flour from tubers of "Bètè-bètè" yam variety. Indeed, the negative effect will be derived from the reduction of the starch and crude protein contents and the increase of the moisture content while the positive effect was as a result of the increase of total and reducing sugar content. Otherwise, analysis of variance (ANOVA) indicated that the boiling time main effect appeared to be stronger for total and reducing sugar contents in flour from "Bètè-bètè" yam tuber. It is important to avoid overcooking since from the data obtained, it has been shown that the longer the cooking, the higher the loss in nutrients. A boiling time of 20 min was recommended for tuber of "Bètè-bètè" yam variety (*Dioscorea alata*).

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