Journal of Food Technology 8 (4): 191-199, 2010
ISSN: 1684-8462

Evaluation of Type of Process on Functional Properties and on Nutritional and Anti-nutritional Composition of Yams (*Dioscorea cayenensis-rotundata*)

[1]Nestor Kouakou Kouassi, [2]Charlemagne Nindjin,
[1]Achille Fabrice Tetchi and [1]Georges N'guessan Amani
[1]Laboratory of Biochemical and Technology of Tropical Products,
Faculty of Foods Sciences and Technologies, University of Abobo-Adjame,
02 Bp 801 Abidjan 02, Abidjan, Cote d'Ivoire
[2]Swiss Centre for Scientific Research (Csrs), Laboratory of Nutrition,
01 Bp 1303 Abidjan 01, Abidjan, Cote d'Ivoire

Abstract: The nutritional, anti-nutritional composition and functional properties of yam flours obtained from different processes with four varieties of *Dioscorea cayenensis-rotundata* extensively consumed in Cote d'Ivoire were evaluated. The results showed that nutritional and anti-nutritional composition of yams are lower and decrease greatly during boiling than baking. The lower values of least gelatinization concentration obtained with flour of cooked yam than raw yam flour is due to the loss of amylose which is associated with starch granules gelatinization during the cooking. This gelatinization is characterized by granule starch of high size and a heterogeneous distribution. The great solubility and the weak capacity of swelling during heating of flour of boiled yam are due to the fact that the gelatinization of starch had been higher in the boiling. This great gelatinization in boiled yam is associated to the high level of glucose rate during digestion and could induce metabolic disorders.

Key words: Yam, cooking methods, nutritional and anti-nutritional composition, functional properties, metabolic disorder, glucose level

INTRODUCTION

Root and tuber crops are grown widely in the tropical and subtropical regions of the world. They are plants yielding starchy roots and tubers which contain 70-80% of water, 16-24% of starch and trace quantities of proteins and lipids (Huang *et al*., 2006). Because of their high starch content, root and tuber crops are the important staple foods and are also used as ingredients in fabricated foods across the world. In those plants, the underground and aerial tubers produced from yam (*Dioscorea* sp.) play an important role in food consumption of many populations from tropical regions of different continents (Kouassi *et al*., 1988).

In Cote d'Ivoire, several species of yam are cultivated and yam represents the first carbohydrate food despite the competition of other starchy products such as rice, cassava, corn and plantain. Among the cultivated yams, only varieties of *Dioscorea cayenensis-rotundata* species are ommonly consumed and valued for the different traditional meals (Brunnschweiler *et al*., 2006).

According to Akin-Idowu *et al*. (2009), yellow yam (*Dioscorea cayenensis-rotundata*) is an important specie of cultivated yam based on the significant role it plays in the diet of many people in coastal West Africa, selected countries in East and Central Africa and in the Caribbean region. Numerous later studies focused on yams (*Dioscorea cayenensis-rotundata)* in Cote d'Ivoire have been done in order to determine the physico-chemical and functional properties of their starch such as calorimetric characteristics and paste properties for industrial applications (Degbeu *et al*., 2008; Amani *et al*., 2004, 2008; Rolland-Sabate *et al*., 2004). Before yams are consumed by human, there are generally processed.

Previous studies emphasized the role of cooking method as a factor able to modify properties of yam flours (Kamenan *et al*., 1987; Akin-Idowu *et al*., 2009). In cooking, Chien-Chun reported that the thermal behaviour of starch in starchy food is the important information when evaluating and estimating process design, unit operation and the quality of final starchy products. Also,

Corresponding Author: Nestor Kouakou Kouassi, Laboratory of Biochemical and Technology of Tropical Products, Faculty of Foods Sciences and Technologies, University of Abobo-Adjame, 02 Bp 801 Abidjan 02, Abidjan, Cote d'Ivoire

the thermal properties of starch granules are affected by several factors including variety, amylose content and type of modification (Liu *et al*., 2006). In Cote d'Ivoire, the processing method of yam include cooking (i.e., boiling, baking and frying), drying and grinding into flour. Despite an increasing interest on these tuber crops (*Dioscorea cayenensis-rotundata*) on nutritious and qualities levels in the country, published data on the variation of components of these yams during cooking methods is very scanty. As a part of few studies that are being carried out to know the variation of some nutritional compositions on these yams during boiling or baking (Kamenan *et al*., 1987; Kouassi *et al*., 2009), no data existing concerned variation of anti-nutritional composition, functional properties and other nutritional components by processing. Thus, this study is the continuity of the others and its objective was to appreciate the variation of nutritional, anti-nutritional component and functional properties of commonly consumed yam during boiling and baking process to fill this serious gap in the knowledge.

MATERIALS AND METHODS

Materials: Samples of four commonly consumed yams varieties locally named Kponan, Assawa, Kangba and Yaobadou belonging to *Dioscorea cayenensis-rotundata* complex species were collected from experimental farm at the University of Abobo-Adjame (Abidjan-Cote d'Ivoire). Yams were harvested at maturity and immediately transported to the laboratory for the sample preparation.

Sample preparation: Within a day of harvest, yams were washed, peeled, washed, sliced into cubes (18 mm, 20-40 g) and divided in 3 groups. Slices in the first group were cooked in an oven (ARTHUR MARTIN-Electrolux) at 210°C for 20 min and slices in the second group were cooked into boiled water (ratio 1/1: kg L^{-1}) for 10 min. The third group were fresh slices. Uncooked yam and cooked yams slices were ground into flour, sieved (200 μm) as previously described by Kouassi *et al*. (2009) and stored in polyethylene screw-capped bottle at laboratory temperature.

Proximate composition analysis: Ground samples were analysed in triplicate for diosgenin, linamarin, alkaloids and minerals. Sapogenins were extracted with ethanol, hydrolysed by heating in 4 N sulphuric acid and the sapogenins precipitated were filtered off. Alkaloids were extracted with a mixture of diethylether and chloroform, isolated in 0.3 N hydrochloric acid and the precipitated with silico-tungstic acid. Linamarin were extracted with distilled water, filtered, hydrolysed in NaOH (2.5%). To the distillate were added with NH_4OH (6 N) and KI (5%) then linamarin were determined by alkaline titration with $AgNO_3$ (0.02 N) according to Sylvestre and Arraudeau. The pH values were determined electrometrically (pH METER P 107 CONSORT, Belgium) as described by Kamenan *et al.* (1987) and titratable acidity was measured by direct titration (Omonigho and Ikenebomeh, 2000). Minerals were determined on acidified ash using spectrophotometer (SCHIMADZU UV 102-02, Japan) for phosphorus levels and flame photometer (JENWAY PFP7, United Kingdom) for Na, K and Ca (AOAC, 1984). Alcohol-soluble sugars (glucose, glucose and sucrose) were determined with enzymatic kit method (Megazyme, Assay Procedure K-SUFRG 12/05).

Least gelatinisation concentration: The least gelatinisation concentration was estimated according the method of Coffmann and Garciaj (1977). Yam flours dispersions of 4-14% (w/v) were prepared with distilled water in test tubes and mixed for 2 min. The mixtures obtained were boiled for 1 h in a bain-marie and cooled at laboratory temperature. The least gelatinisation concentration of sample flours (i.e., the lowest concentration that gives a stable gel when tests tube is inverted) was determined.

Flours granule measurements and their distribution: Flours granules were examined with a photonic microscope (Olympus U-SPT, BX 40F, Tokyo, Japan) magnification×400 equipped with a drawtube that superimposes image of the specimen and the pencil image according to method described by Degbeu *et al.* (2008). Squared paper was used to estimate the granule size by counting the square millimeters contained inside the granule shape.

The diameters of each granule measured were corrected by a calibration factor (15.1 μm). A pinch of starch sample in water was prepared and the slide was placed on the stage of a compound microscope and observed. The length and the width of granules were determined as described above. One thousand counts were performed with 200 granules counted per slide for raw starch flour and 100 granules per slice for starch in cooked samples.

Swelling power and solubility: The flour suspension of 1% (w/w) was heated for 30 min over the pasting range 55-95°C by immersion in a water bath with gentle stirring. After cooling for 15 min at room temperature it was centrifuged (Centrifuge, 3-16P Germany) at 5000 rpm for 30 min. The supernatant was immediately separated from the sediment both were oven-dried (130°C for 2 h) weighed and the swelling power and solubility determined (Leach *et al*., 1959).

Statistical analysis: Proximate composition analysis was done in triplicate. Data was expressed as mean±SD deviation and results were evaluated by Duncan test analysis with the statistical software SPSS 11.5 for Windows. A significant level of $\alpha \leq 0.05$ was chosen. Figures were done with Excel 2007 software for Microsoft office (XP-Microsoft Corporation).

RESULTS AND DISCUSSION

The results of the minerals measurements are shown in Table 1. Potassium was the major mineral present in raw yam tubers with 592.57±0.45-611.83±0.57 mg/100 g on dry basis (db). After cooking, minerals levels decreased in yam but potassium remained the most important whatever the method of cooking and the variety of yam. Also, boiling decreased significantly minerals in yam ($p \leq 0.05$) than baking. Mineral contents in raw yam flour are remarkably similar ($p \leq 0.05$) to those of baked yams (Table 1). In boiling yam, the values obtained fall within the range of 461.23±1.00-500.97±0.75 mg/100 g db (potassium), 8.90±0.20-19.70±0.20 mg/100 g db (calcium), 2.23±0.21-6.97±0.15 mg/100 g db (sodium) and 63.93±0.12-83.73±0.25 mg/100 g db (phosphorus).

On dry basis, the results of alcohol-soluble sugars composition in raw yam showed that alcohol-soluble sugars levels are lower and sucrose is the major component with levels range from 0.62±0.01-2.21±0.01 mg/100 g (Table 2). The glucose and fructose are lower and are the same in the different varieties of *Dioscorea cayenensis-rotundata*. After cooking, their values fall significantly within the range of 0.03±0.00-0.04±0.00 mg/100 g db (glucose) and 0.06±0.00-0.18±0.01 mg/100 g db (fructose) in boiling (Table 2). The titratable acidity was low in raw yam with values ranging from 2.25±0.03-2.38±0.03 meq.g/100 g db. After cooking, pH (5.14±0.64-5.50±1.10) in raw yam increased around 6.20 on average and the titratable acidity decreased around 1.00 in cooked yam. The oxalic acid content of raw tubers ranged from 0.43±0.10-0.96±0.01 mg/100 g db (Table 3). In addition, the results showed that boiling reduced significantly oxalic acid than baking.

Diosgenin values in the raw samples range from 3.51±0.01 mg/100 g db-3.80±0.01 mg/100 g db. Also, this work estimated to 33.53 mg/100 g db on average of alkaloids (Table 4). Results showed that linamarin contents in the samples are very weak (0.09±0.01-0.10±0.00 mg kg^{-1} db). In general, anti-nutritional factors in the samples are very lower and data showed that boiling decreased significantly anti-nutritional component than baking (Table 4).

Table 1: Minerals components of the yams (mg/100 g db)

Varieties	P	K	Na	Ca
Assawa				
A	102.33±2.17^a	611.83±0.57^a	18.60±0.46^a	29.77±0.40^a
B	100.13±1.22^a	599.30±0.79^a	16.27±0.55^a	28.17±1.11^a
C	83.73±0.25^b	500.97±0.75^b	6.97±0.15^b	19.70±0.20^b
Kangba				
A	92.57±0.55^a	599.83±0.38^a	12.13±0.15^a	18.80±0.44^a
B	90.70±1.66^a	592.67±0.06^a	11.23±0.42^a	17.43±1.46^a
C	69.53±0.50^b	472.37±0.40^b	4.43±0.40^b	8.90±0.20^b
Yaobadou				
A	82.50±1.41^a	595.23±0.21^a	10.17±0.15^a	23.20±0.20^a
B	80.33±1.82^a	586.33±0.32^a	9.30±0.62^a	21.37±1.29^a
C	63.93±0.12^b	461.23±1.00^b	2.23±0.21^b	10.87±0.15^b
Kponan				
A	93.33±0.31^a	592.57±0.45^a	14.63±0.47^a	27.63±0.60^a
B	91.63±1.40^a	592.57±0.45^a	14.63±0.47^a	27.63±0.60^a
C	72.00±0.20^b	499.50±0.46^b	4.97±0.15^b	14.97±0.15^b

Means with the same superscripts in the same column and variety are not significantly differ ($p<0.05$). A: Raw yam flour; B: Baked yam flour and C: Boiled yam flour

Table 2: Alcohol-soluble sugars components of the yams (g/100 g db)

Varieties	Sucrose	Glucose	Fructose
Assawa			
A	2.21±0.01^b	0.21±0.01^a	0.24±0.01^b
B	1.36±0.01^a	0.21±0.01^a	0.31±0.01^b
C	0.85±0.01^c	0.03±0.00^b	0.18±0.01^a
Kangba			
A	1.05±0.01^c	0.11±0.01^a	0.11±0.01^a
B	0.71±0.01^b	0.17±0.01^a	0.18±0.01^a
C	0.30±0.01^a	0.03±0.00^b	0.07±0.00^b
Yaobadou			
A	0.62±0.01^b	0.08± 0.01^a	0.10±0.01^a
B	0.37±0.01^c	0.10±0.00^a	0.15±0.01^a
C	0.20±0.01^a	0.02±0.00^b	0.06±0.00^a
Kponan			
A	2.02±0.02^c	0.19±0.01^a	0.20±0.01^a
B	1.01±0.02^b	0.20±0.01^a	0.30±0.01^a
C	0.42±0.01^a	0.04±0.00^b	0.11±0.00^b

Means with the same superscripts in the same column and variety are not significantly differ ($p<0.05$). A: Raw yam flour; B: Baked yam flour and C: Boiled yam flour

Table 3: Acid components of the yam

Varieties	Titratable acidity (meq.g/100 g db)	pH	Oxalic Acid (mg/100 g db)
Assawa			
A	2.38±0.03^a	5.50±1.10^a	0.96±0.01^b
B	1.17±0.05^b	6.22±0.08^b	0.34±0.01^a
C	1.10±0.02^b	6.39±1.66^b	0.03±0.00^c
Kangba			
A	2.25±0.03^a	5.14±0.64^a	0.43±0.10^a
B	1.03±0.03^b	6.20±0.04^b	0.14±0.01^b
C	0.95±0.03^b	6.23±0.64^b	0.02±0.00^b
Yaobadou			
A	2.25±0.03^a	5.41±1.08^a	0.85±0.01^a
B	1.09±0.02^b	6.13±0.10^b	0.25±0.00^c
C	1.00±0.02^b	6.22±0.64^b	0.08±0.01^b
Kponan			
A	2.31±0.02^a	5.36±0.64^a	0.90±0.10^b
B	1.17±0.03^b	6.04±0.14^b	0.14±0.00^a
C	1.07±0.03^b	6.54±1.09^b	0.02±0.00^a

Means with the same superscripts in the same column and variety are not significantly differ ($p<0.05$). A: Raw yam flour; B: Baked yam flour and C: Boiled yam flour

At weak temperature, the analysis showed that the swelling power of boiling yam flour was higher than the one of baked yam flour which is also higher than the raw yam flour (Fig. 1). This trend inverted with the increasing of temperature. Indeed at 95°C, the swelling power of boiled yam flours (27-30 g g^{-1}) is smaller than the one of baked yam flours (30-36 g g^{-1}) which is also smaller than the one of raw yam flours (38.5-42.5 g g^{-1}).

Table 4: Anti-nutritional components of yams

Varieties	Diosgenin (mg/100 g db)	Linamarin (mg kg^{-1} db)	Alcaloïds (mg/100 g db)
Assawa			
A	3.51±0.01^{a}	0.10±0.00^{a}	31.32±0.03^{a}
B	3.33±0.08^{a}	0.03±0.00^{b}	29.29±0.03^{a}
C	2.08±0.02^{b}	0.01±0.00^{b}	17.81±0.04^{b}
Kangba			
A	3.64±0.03^{a}	0.10±0.00^{a}	36.57±0.04^{a}
B	3.41±0.01^{a}	0.04±0.00^{b}	35.02±0.02^{a}
C	2.07±0.01^{b}	0.01±0.00^{b}	23.20±0.02^{b}
Yaobadou			
A	3.71±0.01^{a}	0.14±0.00^{a}	33.14±0.03^{a}
B	3.37±0.05^{a}	0.02±0.01^{b}	30.05±0.05^{a}
C	2.07±0.00^{b}	0.01±0.00^{b}	21.39±0.01^{b}
Kponan			
A	3.80±0.01^{a}	0.09±0.01^{a}	33.08±0.03^{a}
B	3.38±0.08^{a}	0.03±0.00^{b}	30.41±0.01^{a}
C	2.09±0.01^{b}	0.02±0.00^{b}	20.03±0.03^{b}

Means with the same superscripts in the same column and variety are not significantly differ ($p<0.05$). A: raw yam flour; B: baked yam flour and C: boiled yam flour

As far as temperature rises, the solubility of raw yam flours also rises but this is lower than the one of baked yam flours and both are lower than the solubility of boiled yam flours (Fig. 2). This situation changes at the high temperature. In fact, solubility in the cooking flour fraction was higher with 17-22.5% at 95°C (boiled yam), 14-17.5% (baked yam) than raw yam flour (14-16% at 95°C). About amylose, the results showed that it's in high proportion in raw yam flour and this decreased with cooking (Table 5) within the range of 5-6% (raw yam flour), 7-8% (baked yam flour) and 8-9% (boiled yam flour). About granules starch size and their distribution, data showed that the smallest diameter of granule starch are observed in raw yam flour. Diameter ranges from 25-75 μm with the peak in 50 μm. Raw granules with 50 μm diameters accounted around 90-95% of the total. In general after

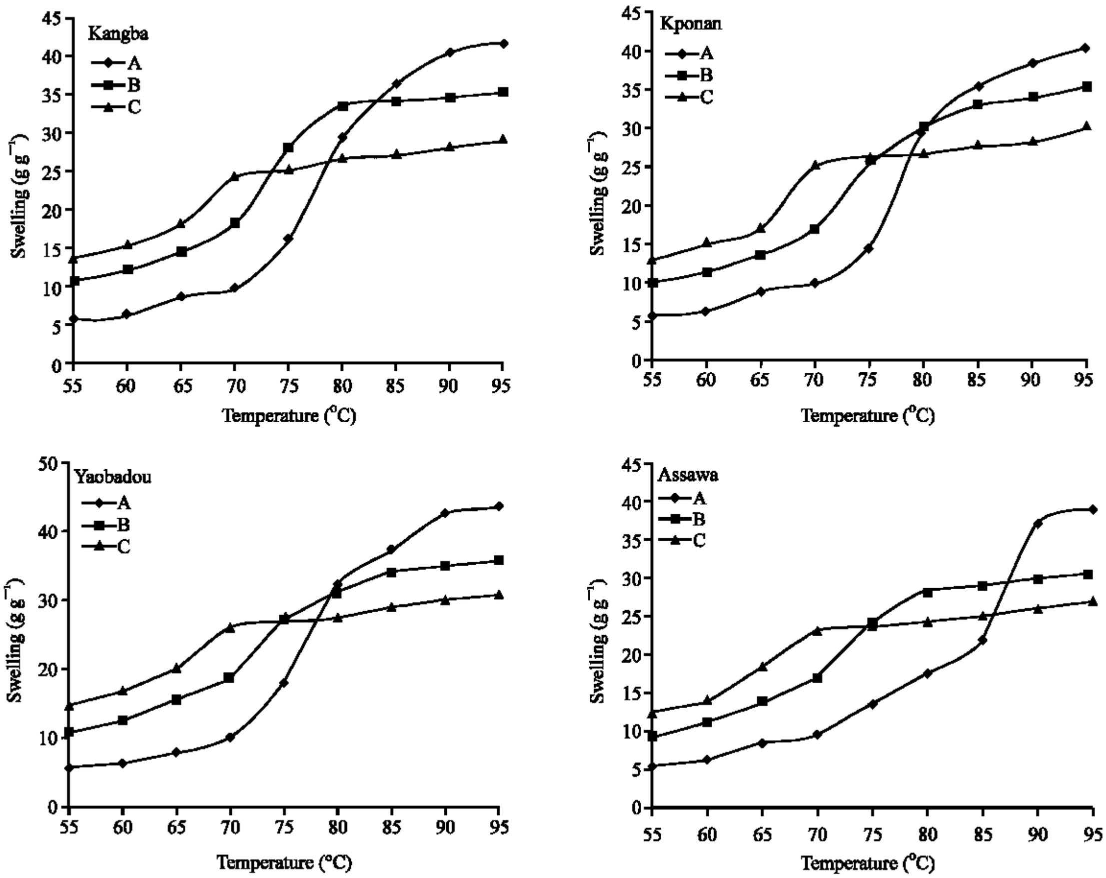

Fig. 1: Swelling power of yam flours according to temperature, A: Raw yam flour; B: Baked yam flour and C: Boiled yam flour

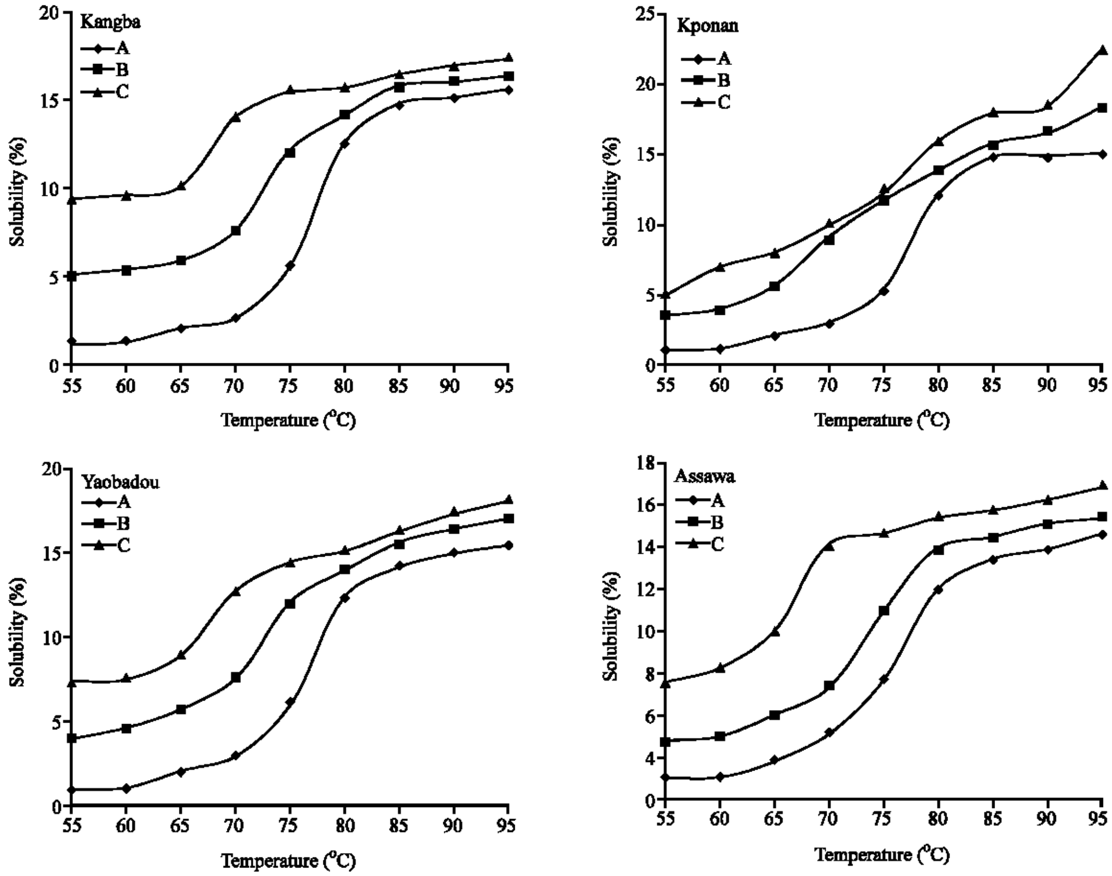

Fig. 2: Solubility of yam flours according to temperature. A: Raw yam flour; B: BAked yam flour and C: Boiled yam flour

Table 5: Least Gelatinisation Concentration (LGC) of yam flours

Varieties	LGC (%)
Assawa	
A	5
B	7
C	8
Kangba	
A	6
B	7
C	9
Yaobadou	
A	6
B	8
C	9
Kponan	
A	5
B	6
C	8

A: Raw yam flour; B: Baked yam flour and C: Boiled yam flour

cooking granules were irregular and heterogeneous forms with granules starch of <50 µm and >150 µm were the minority (10-15%). The range for the largest diameter was wider between 50 and 150 µm for Assawa boiled or baked (peak =100 µm corresponding to 20-25%), Yaobadou boiled and baked (peak = 100 µm corresponding to 20-30%), Kponan baked (peak = 125 µm corresponding to 30%) and Kangba baked (peak = 100 µm corresponding to 30%). This diameter varied between 12.5-150 µm (Kponan boiled) and 12.5-125 µm (Kangba boiled) with a peak of 75 and 50 µm, respectively for 25 and 30% of the total population (Fig. 3).

The present study aimed at characterizing the variation of composition and functional properties of yam during cooking from four varieties most frequently consumed in yam specie (*Dioscorea cayenensis-rotundata*). The results of the minerals measurements showed that yams are moderately good a source of minerals and potassium was the major mineral present in raw yam tubers (Table 1). This observation has been also reported by previous studies (Jacotot and Leparco, 1992; Wanasundera and Ravindran, 1994; Agbor-Egbe and Treche, 1995; Sahore and Amani, 2005). Potassium, calcium, sodium and phosphorus contents of the samples (*Dioscorea cayenensis-rotundata*) were lower than those reported by Wanasundera and Ravindran (1994) in *Dioscorea alata*. But according to FAO/WHO (1992) for all minerals, yams on average are richer than cassava and

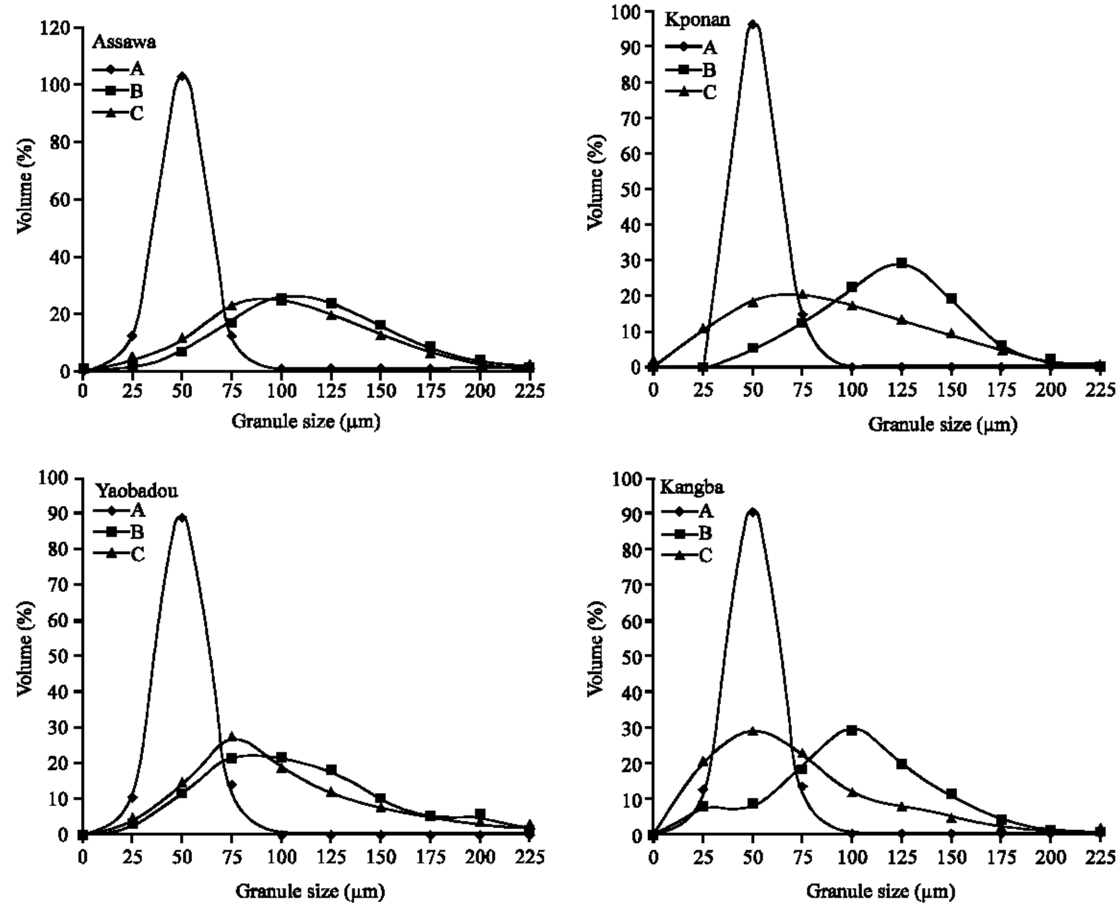

Fig. 3: Granule size distribution of starch content in yam flours, A: Raw yam flour; B: Baked yam flour and C: Boiled yam flour

sweet potato. In general, after cooking, minerals levels decreased and boiling decreased significantly minerals in yam ($p \le 0.05$) than baking whatever the method of cooking and the variety of yam. The decrease of minerals in boiling than baking is due to their great solubility in water during hydrothermal treatment, similarly to those reported by Akin-Idowu *et al*. (2009). Also, the results of alcohol-soluble sugars composition in raw yam showed that alcohol-soluble sugars levels are lower and sucrose is the major component (Table 2). These results corroborated previous studies where sucrose content is considerable and range from 0.3-2.6 mg/100 g (Agbor-Egbe and Treche, 1995) in *Dioscorea cayanensis-rotundata*. The levels of glucose and fructose were similar to those marked by researchers Agbor-Egbe and Treche (1995). After cooking, the values obtained fall in boiling due to the hydrolysis of sugars during cooking as mentioned by Bornet.

The determinations of titratable acidity, pH and oxalic acid were of interest because of their alleged adverse effect on mineral bioavailability. Also, alkaloids, linamarin and diosgenin make tubers of some species inedible or poisonous (Coursey, 1967). Data showed that titratable acidity was low in raw yam. After cooking, pH increased and titratable decreased. The value of pH in cooked-yams is similar to the values of 5.90-6.13 reported for yams by Kamenan *et al.* (1987) and it's consistent with previous study where Omonigho and Ikenebomeh (2000) had found pH = 6 in yam after cooking. But the titratable acidity is lower than 1.10 meq.g/100 g db estimated by Omonigbo and Ikenebomeh (2000).

The oxalic acid content of raw tubers was lower than those reported by Bradbury (1998) estimated to 17.6 and 12.7 mg/100 g db, respectively in *D. alata* and *D. esculenta* and those of Sahore *et al*. (2006) in wild yams (5.4-12.9 mg/100 g db). In addition, the results showed that boiling reduced significantly oxalic acid in yams than baking. The results agree with those of Sahore *et al.* (2006) that had found that boiling reduced oxalic acid in wild yam about 20% due to their solubility in water and their thermal sensitivity. So, results demonstrated that boiling decreased acidity in yams than baking. Published data on anti-nutritional contents in edible yams are limited. In this study, diosgenin values in raw samples are lower than those reported by previous studies estimated to 0.06-1.38% in wild yams (Sahore *et al*., 2006). Also, the alkaloids levels are lower than those observed by Sahore et *al*., 2006 (107.6-246.2 mg/100 g db) in wild yams. No comparable data on linamarin content of yams are available but results showed that linamarin content in the samples are very weak and decreased with cooking. The decrease of anti-nutritional factors in boiling than baking is probably due to their water solubility as reported by Bevan and Hirst (1958). This party of study demonstrated that varieties of *Dioscorea cayenensis-rotundata* tubers have weak quantities of anti-nutritional components and decrease with cooking. The results are consistent with previous studies where apart from cassava, the most cultivated varieties of tubers and edible roots do not contained any dangerous toxins after cooking (Coursey, 1967).

Previous studies showed that the major component of yams (*Dioscorea cayenensis-rotundata*) is starch with 80% of the dry matter and miners' nutritional components such as protein, lipid and fibre (Kouassi *et al*., 2009). These findings confirmed the fact that yams are important staple foods in many tropical countries because of the starch noted by (Chien-Chun). Before eating, yams are generally processed. Thus, in order to elucidate the possible changes in starch due to processing which might explains the difference observed in starch digestion, we examined swelling power, solubility, granules size distribution and least gelatinisation concentration of different sample flours. Data showed that cooked yam flours do not absorb water and do not swell well as temperature rises. In fact, in cooked-yams flours, damaged starch are present in greater proportion and absorb large quantities of water but do not retain it when heated, resulting in slow swelling values when the cooked-yams flours is heated as reported by Betancur-Ancona *et al.* (2003). This is also due to a tight correlation between starch granule diameter, gelatinization temperature and amylopectin chair length distribution and a negative relation with amylose content (Sasaki and Matsuki, 1998). That is why amylose proportion was high in raw yam flour and this proportion decreased with cooking (Table 5). In fact according to Ndouyang, a weak value of least gelatinisation concentration in food is associated with great amylose content. Thus, the increase of least gelatinisation concentration in cooked yam flours is due to the loss of amylose during cooking because of starch degradation or starch gelatinization. The results confirmed the hypothesis reported by Betancur-Ancona *et al.* (2003) which said that these phenomena could result from exuding of amylose when the starch granules of flours are gelatinized and since amylose content is lower in the raw flour its solubility percentage decreases. So, the decrease of swelling power and increased of solubility in boiled yam flours rather than baked yam flours while temperature rises is due to the grandly gelatinization provoked by boiling during cooking process. During boiling, the association of high temperature and high humidity alter easily the physical and chemical state of raw starch granules by taking up water and swelling (i.e., gelatinization) which irreversibly disrupts the crystalline structure of the starch, making it able to be readily hydrolyzed as reported by Englyst and Cummings (1987). And, the high swelling and weak solubility of baked yam flours rather than boiled yam flour in heating is due to its weak gelatinization of its starch because there was no external water added during sample cooking. This observation is confirmed by granule size distribution where raw starch granules and damaged starch granules are observed (Fig. 3). In fact, the higher diameter distribution (irregular and heterogeneous forms of the majority of granule starch population) in boiling than in baking shows that during cooking, starch gelatinized is so much in boiling than in baking. This great gelatinization accelerated solubility in boiling flour than in baking and could provoke a rapid digestion of yams. This observation is corroborated by Bornet when he reported that starch stays in food is an important way under a few more resistant and slowly digestible shapes. Very recently, Arvidsson-Lenner *et al.* (2004) reported that when starch in food gelatinized during heat treatment, higher is glycaemic response and glycaemic index. Similary, Brouns *et al.* (2005) showed that the rate of glucose entry into blood and the duration of elevated blood glucose are known to induce many hormonal and metabolic changes that may affect health and disease parameters. In this respect, low GI foods that we could obtain with baking could be benefit to health.

CONCLUSION

On the basis of results obtained from the present experimental stage, it can be found that anti-nutritional and nutritional factors in yam *Dioscorea cayenensis-rotundata* is low and decreased with cooking notably by boiling. Furthermore, a strict dependence exists between swelling and solubility of yam as a consequence of gelatinization due to the starch degradation during cooking. From the technological point of view, boiling considerably affects structure of starch and provokes more gelatinization which is associated to the increased of rate of glucose during consumption than baking.

Although, boiling decreased the nutritional components in yams to minimize the rate of glucose into digestion and prevent metabolic diseases, we wish people could integrate baking yam in their habit because it could be dietary health food than boiling yam.

ACKNOWLEDGEMENT

The researchers wish to thank Professors Allassane Ouattara and Yves Jean Békro (University of Abobo-Adjame) for their collaboration and for their technical assistance.

REFERENCES

AOAC, 1984. Official Method of Analysis. 14th Edn., Association of Official Analytical Chemist, Washington, DC., USA.

Agbor-Egbe, T. and S. Treche, 1995. Evaluation of the chemical composition of Cameroonian yam gerplasm. J. Food Composition Anal., 8: 274-283.

Akin-Idowu, P.E., R. Asiedu, B. Maziya-Dixon, A. Odunola and A. Uwaifo, 2009. Effects of two processing methods on some nutrients and anti-nutritional factors in yellow yam (*Dioscorea cayenensis*). Afr. J. Food Sci., 3: 022-025.

Amani, N.G., K.G. Aka, Y.D. N'Dri, K.C. Degbeu and A. Sako, 2008. Evolution of functional properties of precocious yam starch (*Dioscorrea cayenensis-rotundata*) during tuberization. Int. J. Biol. Chem. Sci., 2: 324-330.

Amani, N.G.G., P. Colonna, A. Kamenan and A. Buleon, 2004. Variability in starch physicochemical and functional properties of yam (*Dioscorea* sp.) cultivated in Ivory Coast. J. Sci. Food Agric., 84: 2085-2096.

Arvidsson-Lenner, R., A. Nils-Georg, M. Axelsen, S. Bryngelsson and E. Haapa., 2004. Glyceamic index: Relevance for health, dietary recommendations and food labelling. Scand. J. Nutr., 48: 84-94.

Betancur-Ancona, D., J. Lopez-Luna and L. Chel-Guerrero, 2003. Comparison of the chemical composition and functional properties of *Phaseolus lanatus* prime and tailing starches. Food Chem., 82: 217-225.

Bevan, C.W.L. and J. Hirst, 1958. A convulsant alkaloid of *Dioscorea dumetorum*. Chem. Ind., 25: 103-103.

Bradbury, J.H., 1998. The chemical composition of tropical root crops. Asean Food J., 4: 13-13.

Brouns, F., I. Bjorck, K.N. Frayn, A.L. Gibbs, V. Lang, G. Slama and T.M.S. Wolever, 2005. Glycaemic index methodology. Nutr. Res. Rev., 18: 145-171.

Brunnschweiler, J., D. Mang, Z. Farah, F. Escher and B. Conde-Petit, 2006. Structure-texture relationships of fresh pastes prepared from different yam (*Dioscorea* spp.) varieties. LWT-Food Sci. Technol., 39: 762-769.

Coffmann, C.W. and V.V. Garciaj, 1977. Functional properties and amino acid content of a protein isolate from mung bean flour. Int. J. Food Sci. Technol., 12: 473-484.

Coursey, D.G., 1967. Yams, an Account of the Nature, Origins, Cultivation and Utilization of the Useful Members of *Dioscoreaceas*. Tropical Agriculture Series, Tropical Products Institute, London, UK., pp: 230.

Degbeu, C.K., N.G. Amani, S.C. Aoussi and Y.D. N'dri, 2008. Longitudinal distribution and physico-chemical properties of yam (*Dioscorea* spp.) tuber starches. Food, 2: 52-56.

Englyst, H.N. and J.H Cummings, 1987. Digestion of polysaccharides of potato in the small intestine of man. Am. Soc. J. Clin. Nutr., 45: 423-431.

FAO/WHO, 1992. Codex alimentarius commission. Standard for Edible Cassava Flour- African Regional Standard. CODEX STAN 176-1991.

Huang, C.C., M.C. Lin and C.C.R. Wang, 2006. Changes in morphological, thermal and pasting properties of yam (*Dioscorea alata*) starch during growth. Carbohydrate Polymers, 64: 524-531.

Jacotot, B. and J.C. Leparco, 1992. Nutrition and alimentation. 2nd Edn., Masson, Paris, pp: 312.

Kamenan, A., L.R. Beuchat, M.S. Chinnan and E.K. Heaton, 1987. Composition and physico-chemical properties of yam *Dioscorea* species flour prepared using different processes. J. Food Process. Preserv., 11: 299-308.

Kouassi, B., J. Diopoh, Y. Leroy and B. Fournet, 1988. Total amino acids and fatty acids composition of yam (*Dioscorea*) tubers and their evolution during storage. J. Sci. Food Agric., 42: 273-285.

Kouassi, K.N., G.G. Tiahou, F.R.J. Abodo, M. Cisse-Camara and N.G. Amani, 2009. Influence of the variety and cooking method on glycemic index of yam. Pak. J. Nutr., 8: 993-999.

Leach, H.W., L.D. McCowen and T.J. Schoch, 1959. Structure of the starch granule. I. Swelling and solubility pattern of various starches. Cereal Chem., 36: 534-544.

Liu, H., N.A.M. Eskin and S.W. Cui, 2006. Effect of yellow mustard mucilage on functional and rheological properties of buckwheat and pea starches. Food Chem., 95: 83-93.

Omonigho, S.E. and M.J. Ikenebomeh, 2000. Effect of temperature treatment on the chemical composition of pounded white yam during storage. Food Chem., 71: 215-220.

Rolland-Sabate, A., N.G. Amani, D. Dufour, S. Guilois and P. Colonna, 2004. Macromolecular characteristics of ten yam *Dioscorea* sp. starches. J. Sci. Food Agric., 83: 927-936.

Sahore, D.A. and N.G. Amani, 2005. Composition of wild yams of Cote d Ivoire. Trop. Sci., 45: 110-113.

Sahore, D.A., N.G. Amani and A. Kamenan, 2006. Anitinutritional factors in wild yam tubers. Trop. Sci., 46: 113-115.

Sasaki, T. and J. Matsuki, 1998. Effect of starch structure on swelling power. Cereal Chem., 75: 525-529.

Wanasundera, J.P.D. and G. Ravindran, 1994. Nutritional assessment of yam (*Dioscorea alata*). Plant Foods Hum. Nutr., 46: 33-39.