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Effect of boiling and baking times on the functional properties of aerial yam (*Dioscorea bulbifera)* flours cv *Dugu-won* harvested in Côte d'Ivoire

Jacques Y. Achy, Gbocho Serge Elvis Ekissi*, Pamphile Kouadio Bony Koffi, Fankroma Martial Thierry Koné, Lucien Patrice Kouamé

Department of Food Science and Technology, University Nangui Abrogoua (ex University Abobo, Adjame), Laboratory of Biocatalysis and Bioprocessing, Abidjan, Côte d'Ivoire

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Abstract

The study examined the effect of boiling and baking times on the functional properties of aerial yam (*Dioscorea bulbifera)* flours in order to assess which one can ameliore better their functional properties. Boiling and baking times affected significantly ($P<0.05$) the functional properties of *D. bulbifera* cv *Dugu-won* flours. They increased the water absorption capacity (WAC), water solubility index (WSI), bulk density (BD) dispersibility (D), least gelation concentration (LGC), paste clarity (PC), swelling power (SP) and solubility of aerial yamflours cv *Dugu-won*. But they decreased iodine affinity of starch, foam capacity and foam stability. The boiling increased the absorption capacity of olive oil, maize oil, red oil, dinor oil and sunflower oil from *Dioscorea bulbifera* cv *Dugu-won* bulbils flours. The baking decreased the absorption capacity of the same oils. Boiling and baking have been found to give good functional properties which can be high importance in food manufacturing industries. However boiling ameliored better functional properties of aerial yam *flours* cv *Dugu-won* than baking.

* **Corresponding Author:** Gbocho Serge Elvis Ekissi ✉ ekiss_esg@yahoo.com

Introduction

Yams, the edible tubers of various species of the genus *Dioscorea*, are important staple foods and a potential source of ingredients for fabricated foods in many tropical countries because of their high starch content (Survey, 2012). It is a major staple food for an estimated 60 million people in the region stretching from Côte d'Ivoire to Cameroon, an area commonly referred to as "Yam Zone" of West Africa (Akissoe *et al*., 2003; Jimoh and Olatidoye, 2009). They are the most preferred of all roots and tubers by millions of people in the yam zones of Africa (FAO, 1985).

Yams are cultivated mainly in three areas of the world: West-Africa and parts of East, Central and Southern Africa (FAO, 1999) are the primary cultivation areas, producing about 95 % of the world yam production followed by Southeast Asia including China, Japan and Oceania. Only a few species of yams are cultivated as food crops. Yams are an excellent source of starch, which provides caloric energy (Coursey, 1973). Yams are widely grown and consumed amongst various communities in the tropics, amongst them is the *Dioscorea bulbifera* also known as potato yam or air potatoes. It is an aerial yam wich is cultivated in the Southeast Asia, West Africa, South and Central America.

Dioscorea bulbifera is available in two varieties, the edible and non-edible. The edible varieties are cultivated and widely distributed in West Africa, West Indies, South Pacific, and South East Asia (FAO, 1985; Survey, 2012). *Dioscorea bulbifera* is among the most important tuber crops in West Africa. It is included in the roots and tubers which are widely distributed throughout the tropics with only a few in the temperate regions of the world (Coursey, 1967; FAO, 1996). Together with cereals they constitute the main source of energy in the tropics. This yam specie produced aerial starchy bulbils. Bulbils weighing up one kilogram are not exceptional but those of 200-300 g are usual (Degras, 1986).

In Côte d'Ivoire, two cultivars of *D. bulbifera* are used for plantation. The first one is a cultivar with a greater size bulbils and a yellow flesh. Its local name is *Dugu-won*. The second named *Won-kpia* has small bulbils with mauve colored flesh (Libra *et al*., 2011).

In Bété's country (forest population in western Côte d'Ivoire), *Dioscorea bulbifera* is cultivated for their bulbils which are consumed once cooked like potatoes in water with oil and local ingredients. *Dioscorea bulbifera* is a good source of iron, phosphorus and calcium (Tandall, 1983; Abara *et al*., 2000, Achy *et al*., 2016). Before eating, the yam *Dioscorea bulbifera* must be cooked. Sevral cooking process are used for it. There are boiling, steaming, baking and grilling on embers. Cooking has been reported to either be beneficial or detrimental to the nutritional content of food (Chukwu *et al*., 2010).

But we dont know if cooking ameliored functional properties of yam *Dioscorea bulbifera*. Most of the yams are consumed after being cooked or processed. In general, yams are prepared at home on the basis of convenience and taste preference rather than retention of nutrient and health-promoting compounds (Masrizal *et al*., 1997). Moreover, yams are always cooked before being eaten. Yams nutrients and functional properties appear to be influenced by cooking methods. However, there is no consistent information on the effects of thermal treatments on the properties of its constituents

The objective of this study was to assessment the effect of cooking (baking and boiling) times on functional properties of bulbils flours (*Dioscorea bulbifera*) in order to choice the best cooking process which can ameliore the functional properties.

Materials and methods

Materials

Bulbils (aerial yam) of *Dioscorea bulbifera* (cultivar *Dugu-won*) used for this work were randomly harvested at maturity (6 months after planting) from a farm in Agou, South-East portion of Côte d'Ivoire (West Africa). They were immediately transported to Laboratory and stored under prevailing tropical ambient conditions (19-28°C, 60-85%) for 24 hours befor the preparation of flours from raw and boiled and baked bulbils of *Dioscorea bulbifera* (cv *Dugu-won*).

Flours Processing

Bulbils (5kg) were washed with clean tap water, peeled and sliced into cubes then rinsed with distilled and deionized water. The slices were divided into seven parts of 500g each. Three parts of the sliced were boiled at 100°C for 10 (FE10), 20 (FE20) and (FE30) minutes. Three parts of the sliced were baked at 100°C for 10 (FF10), 20 (FF20) and (FF30) minutes. The remaining one part (FNT0) and the cooked six parts were put into an oven and dried at 45°C for 2 days. The dried samples were ground into fine powder to pass through a 250 µm sieve. Dried powder samples were packed into airtight sealed plastic bags and stored in the refrigerator for later analysis.

Functional properties evaluation

Iodine affinity of starch (IAS)

The iodine affinity of starch of flours from bulbils (*Dioscorea bulbifera*, cv *Dugu-won*) was assayed using guidelines of Kawabata *et al.* (1984). Three (3) g of flour were introduced into 50 ml beakers and made up to 30 ml dispersios using distilled water. The dispersion was stirred occasionally within the first 30 min and then filtered through Whatman no.42 filter paper. A 10 ml aliquot of the filtrate was pipetted into a conical flash, phenolphtalein was added and the filtate titrated with 0.1N I_2 solution to a bluish back end-point. The starc cell damage (free starch content) was calculated using the titre value and expressed as iodine affinity of starch. IAS (ppm):

$$\text{IAS (ppm)} = \frac{VD \times Vt \times Na}{VA \times Ms \times 100} \times 10^6$$

Where VD = Total volume of dispersion; VA = Volume of aliquot used titration,
Vt = Titre value, Ms = Mass (db) of flour used, Na = Normality of iodine solution used

Flour dispersibility (D)

The flour dispersibility was detemined by the method described by Kulkani *et al.*, (1991). 10g of flour were weighed into 100ml measuring cilynder and distilled water added to make a volume of 100ml. The set up was stirred vigorously for 1min. The volume of the settled particles was registered after regular time step of 30min. The volume of settled particles was subtracted from 100. The difference was reported as percentage of dispensability.

Paste clarity (PC)

The paste clarity was determined according to the method of Craig *et al.* (1989). A 1% aqueous suspension was made by suspending 0.2g of flour in 20ml of distilled water in a stoppered centrifuge tube and vortex mixed. The suspension was heated in a boiling water (100°C) bath for 30min. After cooling, clarity of the flour was determined by measuring percent transmittance at 650nm against water blank on a spectrophotometer JASCO V-530 (UV/VIS, Model TUDC 12 B4, Japan Servo CO, LTD Indonesia).

Least Gelation Concentration (LGC)

Appropriate sample suspension of 2, 4, 6, 8, 10, 12, 14, 16 and 20% w/v were prepared in 5 ml distilled water. The test tubes containing these suspensions were heated for 1 hour. The tubes are quickly cooled at 4°C. The least gelation concentration was determined as concentration when the sample from the invested test tube did not fall down the slip (Coffman and Garcia, 1977).

Bulk density (BD)

The method described by Oladele and Ainaby (2007) was used for the determination of bulk density. 50 g of *D. bulbifera* bulbils flour was put into 100 ml measuring cylinder. The measuring cylinder was then tapped continuously on a laboratory table until a constant volume was obtained. BD (g/cm³) was calculated using following the formula:

$$\text{BD (g/cm}^3) = \frac{\text{Weight of sample}}{\text{Volume of sample after taping}}$$

Water absorption capacity (WAC) and Water solubility index (WSI)

The water absorption capacity and solubility index of flours from bulbils of *Dioscorea bulbifera*, cv *Dugu-won* were evaluated according to Phillips *et al.* (1988) and Anderson *et al.* (1969) methods respectively. 1g of flour samples (M_0) was each weighed into a centifuge tube and 10ml distilled water added. The content of the centrifuge tube was shaken for 30min in a KS 10 agitator.

The mixture was kept in a water bath (MEMMERT) (37°C) for 30min and centrifuged (ALDRESA, DITACEN II) at 5000rpm for 15min.

The resulting sediment (M_2) was weighed and then dried at 105°C to constant weight (M_1). The WAC and WSI were then calculated as follows:

$$WAC\,(\%) = \frac{M_2 - M_1}{M_1} \times 100$$

$$WSI\,(\%) = \frac{M_2 - M_1}{M_1} \times 100$$

Oil absorption capacity (OAC)

The oil capacity of flours from *Dioscorea bulbifera* cv *Dugu-won* bulbils was evaluated according to Eke and Akobundu (1993) methods. 1 g of sample (M_o) was mixed with 10ml in a weighed 20ml centrifuge tube. The slurry was agitated on a vortex mixer for 2min, allowed to stand at 28°C for 30min and then centrifuged at 4500rpm for 30min. The clear supernatant was decanted and discarted. The adhering drops of oil were removed and the tube was weighted (M_1). The AOC was calculated as follows:

$$OAC\,(\%) = \frac{M_O - M_1}{M_O} \times 100$$

Foam capacity (FC) and foam stability (FS)

The foam capacity (FC) and stability (FS) of flour from *Dioscorea bulbifera* cv *Dugu-won* bulbils were studied by the method of Coffman and Garcia (1977). 3g of flour was transferred into clean, dry and graduated (50 ml) cylinders. The flour samples were gently level and the volumes noted. Distilled water (30 ml) was added to each sample; the cylinder was swirled and allowed to stand for 120 min while the change in volume was recorded every 10 min. The FC (%) and FS (%) values were calculated as follows:

$$FC\,(\%) = \frac{V_t - V_O}{V_O} \times 100$$

$$FS\,(\%) = \frac{FC}{FC_O} \times 100$$

Where V_o (ml) is the original volume of sample, V_t is the total volume after different times (ml) and. FC_O is the foam capacity at 0 min.

Swelling Power (SP) and Solubility

The effect of temperature on swelling and solubity was carried out according to the method of Adebooye and Singh (2008). 0.5g of the flour saùmple (W) was accurately weighed and quantitatively transferred into a clean dried test tube and weighed (W_1). The flour was then dispersed in 50cm^3 of distilled water using stirrer. The slurry obtained was heated for 30min at various temperatures from 50°C to 100°C. The mixture was cooled at room temperature and centrifuged for 15min at 2600rpm. The residue obtained after centifugation with the water was retained and the test tube was weighed (W_2). Aliquots (5ml) of the supernatant were dried to a constant weight at 110°C. The residue obtained after drying solubilized in water. Solubility was calculateed as g per 100g of starch on dry weight basic. Swelling power was calculated using the formula:

$$SP\,(g/g) = \frac{W_2 - W_1}{W}$$

Statistical analysis

All analyses were carried out in triplicates. Statistical significance was established using one-way analysis of Variance (ANOVA) models to estimate the effect of treatment on functional properties of flours from aerial yam (D.bulbifera) at 5% level. Means were separated according Tukey's (HSD) test at $P<0.05$, with the help of the software.

Results and discussion

Functional properties of food are defined as physicochemical properties reflecting complex interactions between the composition, structure, conformation and physicochemical properties components (Kohnhorst *et al.*, 1990). The aerial yam flours functional properties could be influenced by cooking times. There could have significant differences ($P<0.05$) between raw and cooked breadfruit pulp flours functional properties.

The water absorption capacity (WAC) is presented in Table 1. The WAC is the ability to absorb or retain water. It is a functional property used in determining the suitability of utilising a material in baked foods such as bread where high WAC is needed (Onuegbu *et al.*, 2001).

The boiling water and baking from *Dioscorea bulbifera* cv *Dugu-won* bulbils flours increased significantly (P<0.05) WAC after 30min. Similar results were reported by Koné *et al.* (2014) who showed increasing WAC values in flours from yam *kponan* (*D. cayenesi-rotundata*). The WAC from *Dioscorea bulbifera* cv *Dugu-won* bulbils flours range between 175±5.20 to 236±3.46% for boiling water after 30min. The WAC from *Dioscorea bulbifera* cv *Dugu-won* bulbils flours range between 150±3.46 to 167±2% for baking after 30 min. The WAC for the boiling water and baking in ours study were lower than those obtained for cooked breadnut flours (290-310%) (Nwabueze *et al.*, 2008) and pre-cooked cocoyam (247.5-562.5%) (Fagbemi *et al.*, 2006). The ability of food to absorbe water may be sometimes attributed to its proteins content (Kinsella, 1976). The denatured proteins in flours due to heat processing bind more water and hence could lead to flour higher water absorption (Otis and Akobundu, 2007). According to Aryee (Aryee *et al.*, 2006), water absorption capacity depends on the associative forces among starch components where weak inter associative forces result into high water binding capacity. Water absorption capacity is the ability of flour particles to entrap large amounts of water, such that exudation is prevented (Chen and Lin, 2002).

The water solubility index (WSI) reflects the extent of starch degradation (Diosady *et al.*, 1985). The WSI (17.31±0.80%) observed for the flour of raw *Dioscorea bulbifera* cv *Dugu-won* bulbils is lower compared to that of flour from boiled (20.25±1.98 to 36.85±2.66 %) and baking (18.20±0.17 to 26±1.73%) *Dioscorea bulbifera* cv *Dugu-won* bulbils (Table 1), indicating that boiling and baking have more profound effect on starch degradation. Similar obsevations were recorded by Hsu *et al.* (2003), when using yam *Dioscorea* spp flours (9.26±0.11 to 15.31±0.85%).

Table 1. Functional properties of aerial yam (*Dioscorea bulbifera) flours* cv *Dugu-won*during boiling and baking times.

	Functional properties (%)							
	WAC	WSI	FC	D	BD (g/cm3)	IAS (ppm)	PC	LGC
	Aerial yam Flours and boiling times							
FNT0	149.42 ± 4.50^{A}	17.31 ± 0.80^{A}	26.67 ± 0.26^{I}	16± 1.73^{A}	0.72 ± 0.02^{A}	53± 4.36^{J}	43 ± 1.73^{A}	2
FE10	175 ± 5,20^{C}	20,25 ± 1,98^{AB}	20,88 ±1,06^{FG}	25± 1,73^{BC}	0,74 ± 0.02^{AB}	45± 4.58^{GHI}	46 ± 2.65^{ABC}	4
FE20	197 ± 3,46^{A}	27,10 ± 2,76^{DE}	15,82 ± 0,39^{CD}	29± 1,15^{CDE}	0,76 ± 0.01^{AB}	36± 3.46^{CDE}	62 ± 2.65^{E}	8
FE30	236 ± 3,46^{F}	36,85 ± 2,66^{G}	13 ± 1,73^{BC}	36± 1^{GH}	0,82 ± 0.02^{CD}	27± 2.65^{BC}	66 ± 2^{F}	14
	Aerial yam Flours and baking times							
FNT0	149,42 ± 4,50^{A}	17,31 ± 0,80^{A}	26,67 ± 0,26^{I}	16± 1.73^{A}	0,72 ± 0.02^{A}	53± 4.36^{J}	43 ± 1.73^{A}	2
FF10	150 ± 3,46^{A}	18,20 ± 0,17^{AB}	25,12 ±2,34^{HI}	18± 2.65^{A}	0,73 ± 0.03^{A}	50± 5.20^{IJ}	44 ± 2.65^{AB}	4
FF20	160 ± 4,36^{B}	22 ± 1,73^{BC}	23,70±2,34^{GH}	24± 2.65^{BCD}	0,74 ± 0.03^{AB}	44± 5.20^{FGHI}	46 ± 1.73^{ABC}	6
FF30	167 ± 2^{B}	26 ± 1,73^{DE}	21,16 ± 1,04^{FG}	30± 2.65^{EFG}	0,76 ± 0.03^{AB}	40± 3.46^{EFG}	49 ± 1.73^{CD}	8

Values are means of triplicate determination Means with different superscript in the same column are significantly different from each other at (P>0.05) WAC=Water Absorption Capacity; WSI=Water Solubility Index; FC=Foam Capacity; D= Flour Dispersibility; BD=Bulk Density; IAS=Iodine Affinity of Starch; PC=Paste Clarity; LGC=Least Gelation Concentration

The dispersibility is an useful functional parameter which give information to flours ability to reconstitute in water to have a fine and consistence paste and give an indication of good water-absorption capacity (Kulkarni *et al.*, 1991). In our wolk, the result in Table 1 showed that boiling and baking increased bulbils flours after 30 min. Their values ranged respectivly from 25±1.73% to 36±1% and 18±2.65% to 30±2.65%. These results were lower than those reported by Eke-Ejiofor *et al.* (2011) who reported the respective values 55-66% and 50-70% for local rice of Nigeria and Caprice rice. The increasing dispersibility of flour from *Dioscorea bulbifera* cv *Dugu-won* bulbils could may be caused by starch gelatinisation which increases the water-binding capacities (Dengate, 1984).

The bulk density (BD) of bulbils flours are presented into Table 1. The result showed that BD of bulbils decreased in boiling and baking after 30min. They values ranged respectivly from 0.74±0.02g/cm³ to 0.82±0.02g/cm³ and 0.73±0.03g/cm³ to 0.76±0.0.g/cm³.

The raw flour of *Dioscorea bulbifera* cv *Dugu-won* bulbils (0.72±0.02 g/cm3) is similar to that from wheat flours (0.71g/cm3) (Akubor, 2007) but low than those of raw and fermented wheat flours with respective value 0.80 and 0.86g/cm3 (Ijarotomi, 2007). BD gives an indication of the relative volume of packaging material required. Generally, higher BD is desirable for greater ease of dispersibility and reduction of paste thikness (Padmashree *et al.,* 1987; Udensi and Eke, 2000). Low BD of flours are good physical attributes when determining transportation and storability since the products could be easily transported and distributed to required locations (Agunbiade and Sanni, 2003). Low BD is advantageous for the infants as both calorie and nutrients density in enhanced per feed of the child (Onimawo and Egbekun, 1998). High bulk density is a good physical attribute when determining mixing quality of particulate matter (Lewis, 1990).

The iodine affinity of starch from raw bulbils *Dioscorea bulbifera* cv *Dugu-won* flour (53±4.36ppm) is lower than those for flour from boiled bulbils (27±2.36ppm to 45±4.58 ppm and baked bulbils (40±3.46ppm to 50±5.20ppm). The result (Table 3) showed that the boiled and baked bulbils flours contained starch granules with the high affinity for iodine or in consonnance with reports by Raja (1992) contains more amylose. Brunnschweiler *et al.* (2006) reported that amylose aggregation has a strong impact on the texture of the pastes.

The paste clarity (PC) is an important that governs different applications of flours and starches for food processing. Light transmittance of *Dioscorea bulbifera* cv *Dugu-won* bulbils flours obtained by boiling and baking (Table 1) ranged respectively from 43±1.73 to 66±2% and 43±1.73 to 49±1.73%. The low PC of the raw flour would be explained by the fact that the not swollen starch granules remaned dense reflecting the maximum of light entering the medium (Tetchi *et al.*, 2007). Consequently, pastes were turbid or opaque as described in the literature (Craig *et al.,* 1989).

Pastes obtained after boiling and baking are more transparent than native starch suspension in the raw flour (Tetchi *et al.*, 2007). The increasing of starch PC could be do to light refraction reduction by the granules remnant (Tetchi *et al.*, 2007).

According to Gossette *et al.* (1984) gelation is an aggregation of denatured molecule. The least gelation concentration of raw flour (2%) was lower from that of boiled (14%) and baked bulbils flour (8%) after 30 min. This result (Table 1) showed that boiling and baking increased the least gelation concentration in bulbils flours. But the least gelation from boiled bulbils flours was more increased than that of baked bulbils flours. The ability of protein to form gels and provide structural matrix for holding water flavors, sugars and food ingredients is useful in food application in new product developpment (Aremu *et al.*, 2006). Boiling and baking may have denatured the bulbils proteins and thus, caused more aggregation than in the raw bulbils flour. Udensi*et al.* (2001) indicated that gelation is a quality indicator influencing the texture of food such as soup. Flours with least gelation concentration are not suitable for infant formulation since they require more dilution and would result in reduced energy density in relation to volume (Ezeji and Ojmelukwe, 1993; Onwulezo and Nwabuyu, 2009).

The result of OAC is showed in Table 2. The OAC is an important property in food formulation because fats improve the flavour and mouth feel of foods (Kinsella, 1976). They are also important because of their storage stability and particulraty in the rancidity development (Siddiq *et al.,* 2010). The boiling water after 30min increased significantly ($P<0.05$) the absorption capacity of olive oil, maize oil, red oil, dinor oil and sunflower oil from *Dioscorea bulbifera* cv *Dugu-won* bulbils flours. The OAC range between 39±1.73 to 44±3.61% for olive oil, 42±5.57 to 55±2.65% for maize oil, 48±2.65 to 64±3% for red oil, 50±3 to 67±2.65% dinor oil and 46±2.65 to 60±6% for sunflower oil. The OAC for these different oils were higer than those obtained for yam D. *dumetorum* flour (15%) (Medoua, 2005) and lower in yam *D. rotundata* flours (137-228%) (Akubor and Badifu, 2004) and Ghanian breadfruit (150-250%) (Appiah *et al.,* 2011b). The baking decreased significantly (P<0.05) the absorption capacity of olive oil, maize oil, red oil, dinor oil and sunflower oil from *Dioscorea bulbifera* cv *Dugu-won* bulbils flours. The OAC range between 34±1.73 to 28±1.73% for olive oil, 40±2.65 to 30±2% for maize oil, 45±3.61 to 37±1.73% for red oil, 47±3 to 35±2.65% dinor oil and 44±2 to 38±2% for sunflower oil. The OAC increasing could be attributed to the proteins denaturation and dissociation. This may be ocurring boiling water which unmasks the non-polar residues from protein molecular (Narayana and Nearing, 1982). The OAC decreasing could be attributed to a decreasing in protein in *D. bulbifera* cv *Dugu-won*bulbils flours which tend to reduce the hydrophobicity, and thereby causing a low fat binding to protein.

The presence of good degree of OAC in *Dioscorea bulbifera* cv "*Dugu-won*" bulbils flours may be suggested the presence of good lipophilic components which could be adapted to the production of sausages, soups and cakes.A high oil absorption capacity is valuable in ground meat formulations, meat replacers and extenders, doughnuts, pancakes and soups (Onimawo *et al.,* 2003).

Foams are used to improve texture, consistency and appearence of foods (Akubor, 2007). Results showed that foam capacity (FC) of *Dioscorea bulbifera* cv *Dugu-won* bulbils flours varied from 26.67±0.26% in raw to 13±1.73% for bulbils boiled during 30min and to 21.16±1.04% for bulbils baked during the same time. The FC values obtained were higher than those reported by Amon *et al.* (2011) in flour from taro (*Colocasia esculenta*) cv *Yatan*.

Table 2. Oil absorption capacity for Olive oil, sunflower oil, maize oil, Dinor oil and red oil of aerial yam flours *(D. bulbifera).*

	Oil absorption (%)				
	Olive oil	Sunflower oil	Maize oil	Dinor oil	Red oil
	Aerial yam flours and boiling times				
FNT0	35 ± 2^{DE}	46 ± 2.65^{DEF}	42 ± 5.57^{CDE}	50 ± 3^{CD}	48 ± 2.65^{EF}
FE10	34 ± 1.73^{DE}	44 ± 2^{CDE}	40 ± 2.65^{BCD}	47 ± 3^{C}	52 ± 3^{FGH}
FE20	30 ± 1.73^{BCD}	41 ± 2.65^{BCD}	37 ± 3.61^{BC}	40 ± 2.65^{B}	56 ± 2.65^{H}
FE30	28 ± 1.73^{ABC}	38 ± 2^{BC}	30 ± 2^{A}	35 ± 2.65^{B}	64 ± 3^{IJ}
	Aerial yam flours and baking times				
FNT0	35 ± 2^{DE}	46 ± 2.65^{DEF}	42 ± 5.57^{CDE}	50 ± 3^{CD}	48 ± 2.65^{EF}
FF10	34 ± 1.73^{DE}	44 ± 2^{CDE}	40 ± 2.65^{BCD}	47 ± 3^{C}	45 ± 3.61^{DE}
FF20	30 ± 1.73^{BCD}	41 ± 2.65^{BCD}	37 ± 3.61^{BC}	40 ± 2.65^{B}	40 ± 1.73^{BC}
FF30	28 ± 1.73^{ABC}	38 ± 2^{BC}	30 ± 2^{A}	35 ± 2.65^{B}	37 ± 1.73^{AB}

The foaming stability of boiled and baked bulbils flours are presented in Fig. 1 and 2. The foam stability (FS) of *Dioscorea bulbifera* cv *Dugu-won* bulbils flours decresed significantly (P<0.05) with boiling and baking time. The foam obtained from boiled bulbils flours stabilized faster (6h) than that obtained from baked bulbils flours (7h) after 30min. The reducing of foaming properties was related to protein denaturation.

These results agreed with the finding of Lin *et al.* (1974) that the native protein gives higher foam stability than denatured one. It's well know that, for a protein to have good foaming properties, it has to be very soluble, because foam capacity requires rapid adsorption of protein at the air/water interface during whipping penetration into the surface layer and re-organisation at the interface (Amon *et al.*, 2011). There was an inverse relationships between foams capacity and foam stability. Flours with high foaming ability could form large air bubbles surrounded by thinnera less flexible protein film.

Ths air bubble might be easier to collapse and consequently lowered the foaming stability (Jitngarrmkusol *et al.*, 2008). This results sugest that bulbil of *Dioscorea bulbifera* cv *Dugu-won* flours may be useful in food system to improve textural and leavening characteristics such as ice-cream, cakes or topping and confectioering oroducts where foaming property is important similar to that reported by Lee *et al* (1993).

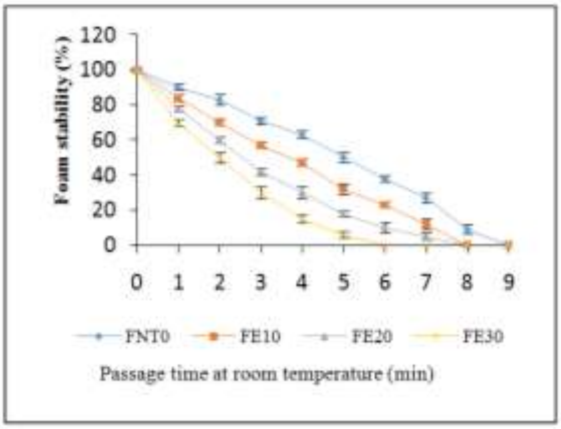

Fig. 1. Foam stability of raw and boiled *Dioscorea bulbifera* cv *Dugu-won* bulbils flours at different temperature.

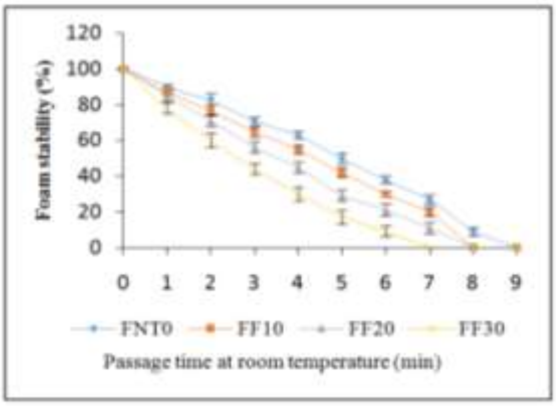

Fig. 2. Foam stability of raw and baked *Dioscorea bulbifera* cv *Dugu-won* bulbils flours at different temperature.

Swelling power of starch granules is an indication of the extent of associate forces within the granule (Moorthy and Ramanujan, 1986). The swelling power of starch granules is showed in Fig. 3 and 4. The result showed that boiling and baking increased significantly ($P<0.05$) the value of swelling power after 30min.

Their value ranged respectively between 2.6±0.01 to 14±0.03 gH_2o/g DM and 2.6±0.26 to 11.70±0.42 g H_2o/g DM. The results agreed with the finding of Oulaï *et al.* (2014) which indicated in their study that cooked pulp of breadfruit after 20 min between 50°C to 90°C increased the swelling power of pulp of breadfruit (1.4 to 17.09 gH_2o/g DM).

High swelling power is reported to constitute better thuckenening as well as a bulking agent (Iwoha and Nwankanma, 1998).

The flour solubility is water ability indicative to enter into starch granule. The solubility of raw flour from bulbils ranged between 10.20±0.06 to 13.60±1.73%. When bulbils were boiled or baked after 30 min their solubility of flour ranged respectively from 14.12±0.06 to 18.25±1.73% and 12.15 to 15.20±1.22% (Fig. 5 and 6). The result showed that boiling and baking after 30 min increased significantly ($P<0.05$) the solubility of flour from bulbils.

This high solubility of boiling (18.28±1.73%) and baking (15.20±1.21%) bulbils flour, suggests that it is digestible and could be suitable for infant food formulation.

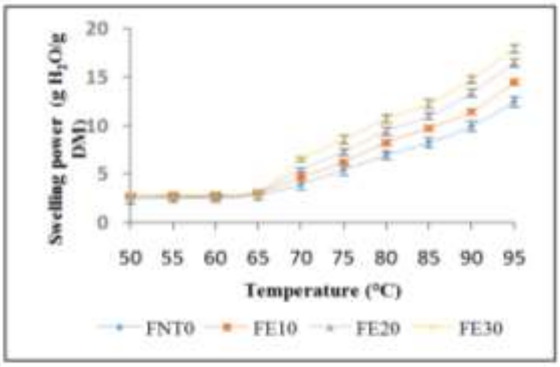

Fig. 3. Swelling power of raw and boiled *Dioscorea bulbifera* cv *Dugu-won* bulbils flours at different temperature.

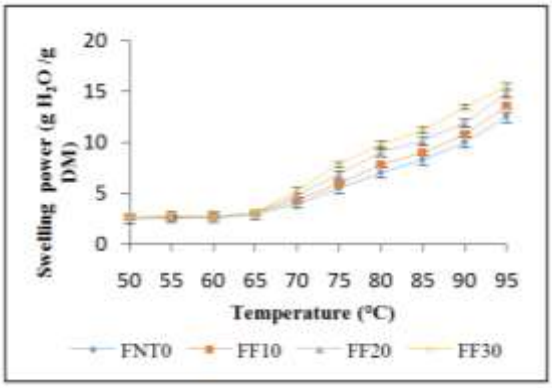

Fig. 4. Swelling power of raw and baked *Dioscorea bulbifera* cv *Dugu-won* bulbils flours at different temperature.

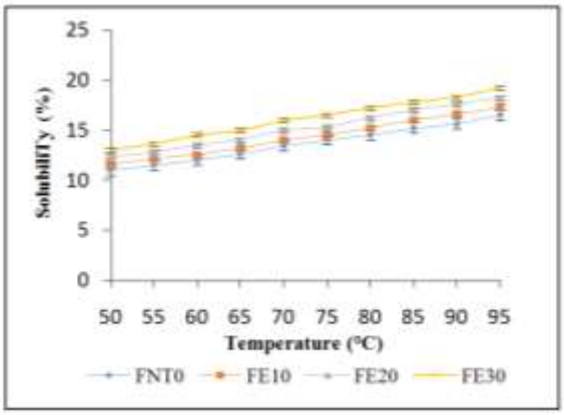

Fig. 5. Solubility of raw and boiled *Dioscorea bulbifera* cv *Dugu-won* bulbils flours at different temperature.

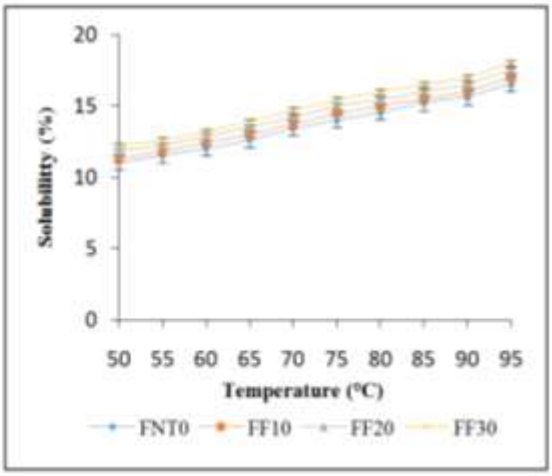

Fig. 6. Solubility of raw and baked *Dioscorea bulbifera* cv *Dugu-won* bulbils flours at different temperature.

Conclusion

The results of this study indicated that boiling and baking times affected significantly ($P<0.05$) the functional properties of aerial yam (*D. bulbifera) flours* cv *Dugu-won. Aerial yam (D. bulbifera) flours* from Côte d'Ivoire have a lot of potential in the food system. The high WAC of aerial yam flours was good providing agent and can thus be used as a thickener or gelling agent in various food products. The low bulk densities were as well as the high solubility. So, *aerial yam* flours would be useful in infant meals formulation.. However boiling ameliored better functional properties of aerial yam (*D. bulbifera)* flours cv *Dugu-won* than baking. They may find an application in sausage production where there is enough needing oil.

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