Asian Research Journal of Agriculture

10(4): 1-13, 2018; Article no.ARJA.44741
ISSN: 2456-561X

Impacts of Cooking Times (Steaming and Cooking on Embers) on Some Physico-Functional Parameters of Yam (*Dioscorea bulbifera*) Flours Cv *Dougon-won* Consumed in Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. Author JYA collected the data and wrote the first draft of the manuscript. Author GSEE performed the manuscript writing. Author MTK designed the study, performed the statistical analysis and wrote the protocol. Author BJF managed the analyses of the study. Author LPK managed the literature searches and supervised the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARJA/2018/v10i430041
Editor(s):
(1) Dr. Moreira Martine Ramon Felipe, Universidade de Santiago de Compostela, Spain.
(2) Dr. Jean Béguinot, Biogeosciences Department, University of Burgundy, France.
Reviewers:
(1) Adriana Pavelková, Slovak University of Agriculture in Nitra, Slovakia.
(2) Rosendo Balois Morales, Universidad Autonoma de Nayarit, Mexico.
(3) Okpo, O. Ngozi, Federal College of Agric Produce Technology Kano, Nigeria.
Complete Peer review History: http://www.sdiarticle3.com/review-history/44741

Original Research Article

Received 17 November 2018
Accepted 25 February 2019
Published 12 March 2019

ABSTRACT

Impacts of cooking times (steaming and cooking on embers) on some physico-functional parameters of yam (*D. bulbifera)* flours cv *Dougou-won* were determined during 10, 20 and 30 min. Results showed that steaming and cooking on embers increased significantly (*P* <0.05) the dispersibility (D), water absorption capacity (WAC), paste clarity (PC), water solubility index (WSI), swelling power (SP), least gelation capacity (LGC) and solubility (S) but decreased significantly (*P* <0.05) foam capacity (FC), wettability (W) and foam stability (FS) of flours (*D. bulbifera) cv Dougou-won*. Steaming increased significantly (*P* <0.05) oils absorption capacity (OAC) and bulk density

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(BD). However, cooking on embers decreased significantly (*P* <0.05) oils absorption capacity (OAC) but not affected significantly (*P* <0.05) bulk density (BD). The steaming time (30 min) is recommended to considerably influence the physico-functional parameters of the yam (*D. bulbifera*) flours cv *Dougou-won.*

Keywords: Cooking on embers; Dioscorea bulbifera; flours; physico-functional parameters; steaming.

1. INTRODUCTION

Yams with different species of the genus *Dioscorea*, are edible tubers and important staple foods of many tropical countries including Côte d'Ivoire, Togo, Ghana, Nigeria and Burkina-Faso [1,2]. It is a major contributor to food security in west Africa, but out of the over 600 known yam species, only seven are mostly consumed [3]. According to FAO statistics, 48.7 million tonnes of yam were produced on five million hectares in about 47 countries worldwide in 2005, and 97 % of this was in sub-Saharan Africa [4]. West and central Africa account for 94 % of world production. Nigeria is the leading producer with 34 million tonnes followed by Côte d'Ivoire (5 million tonnes), Ghana (3.9 million tonnes) and Benin (2.1 million tonnes). Among yams cultivated in the tropics, is *Dioscorea bulbifera* also know as potato yam or air potatoes. It is an aerial yam which is cultivated in the Southeast Asia, West Africa, South and Central America. This yam specie produced aerial starchy bulbils. Bulbils weighing up one kilogram are not exceptional but those of 200-300 g are usual [5]. 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.

In Côte d'Ivoire, two cultivars are used for plantation, one with a greater size bulbils and a yellow flesh (local name is *Dougou-won*) and second named *Won-kpia* has small bulbils with mauve colored flesh [6]. The yam *Dioscorea bulbifera* is a good source of iron, phosphorus and calcium [7,8]. Before eating the yam *Dioscorea bulbifera* must be cooked. Sevral cooking process are used for it. There are boiling, steaming, baking, roating, frying and cooking on embers. It is reported that cooking caused loss to nutrients. However, the effect of cooking on the technological parameters of yam (*Dioscorea bulbifera)* flour remains to be evaluated. This study was conducted to assess impacts and times of steaming and cooking on embers from physico-functional parameters of *Dioscorea bulbifera* flour in order to choice the best time of the cooking process which can ameliorate the functional properties.

2. MATERIALS AND METHODS

2.1 Materials

Bulbils of *Dioscorea bulbifera* (cultivar *Dougou-won*) yam 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) in September 2016. 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 steamed and grilled on embers bulbils of *D. bulbifera* (cv *Dougou-won*). All chemicals reagent used were of analytical grade and purchased from Sigma Chemical Company (USA).

2.2 Production of Raw, Steamed and Cooking on Embers Flours

Bulbils (5 kg) 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 500 g each. Three parts of the sliced were steamed at 100°C for 10 (FV_{10}), 20 (FV_{20}) and (FV_{30}) minutes. Three parts of the sliced were grilled on embers for 10 (FB_{10}), 20 (FB_{20}) and (FB_{30}) minutes. The remaining one part (FNT_0) 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 powdere samples were packed into airtight sealed plastic bags and stored in the refrigerator for later analysis.

2.3 Physico-Functional Parameters of Flours

2.3.1 Oil Absorption Capacity (AOC)

The oil capacity of flours from *Dioscorea bulbifera* cv *Dougou-won* bulbils was evaluated according to [9] method. 1 g of sample (M_o) was mixed with 10 ml in a weighed 20 ml centrifuge tube. The slurry was agitated on a vortex mixer for 2 min, allowed to stand at 28°C for 30 min and then centrifuged at 4500 rpm for 30 min. 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 (%) = (MO – M1 / Mo) × 100

2.3.2 Water Absorption Capacity (WAC) and Water Solubility Index (WSI)

The water absorption capacity and solubility index of flours from *Dioscorea bulbifera*, cv *Dougou-won* were evaluated according to [10,11] methods respectively. 1 g of flour samples (M_o) was each weighed into a centifuge tube and 10 ml distilled water added. The content of the centrifuge tube was shaken for 30 min in a KS 10 agitator. The mixture was kept in a water bath (MEMMERT) (37 °C) for 30 min and centrifuged (ALDRESA, DITACEN II) at 5000 rpm for 15 min. 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:

$$WAC\ (\%) = (M_2 - M_1 / M_1) \times 100$$
$$WSI\ (\%) = (M_2 - M_1 / M_1) \times 100$$

2.3.3 Foam capacity (FC) and Foam Stability (FS)

The foam capacity (FC) and stability (FS) of flours from *Dioscorea bulbifera* cv *Dougou-won* were studied by the method of [12]. 3 g of flour was transferrred 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:

$$FC\ (\%) = (V_1 - V_2 / V_o) \times 100$$
$$FS\ (\%) = (FC / FC_o) \times 100$$

2.3.4 Bulk density (BD)

The method described by [13] was used for the determination of bulk density. 50 g of *D. bulbifera* flour was put into 100 ml measuring cylinder. The measuring cylinder was then tapped continuous. It on a laboratory table until a constant volume was obtained. BD (g/cm^3) was calculated using following the formula:

DB (g/cm3) = (Weight of sample / Volume of sample after taping)

2.3.5 Flour dispersibility (D)

The flour dispersibility was detemined by the method described by [14]. Ten (10) g of flour were weighed into 100 ml measuring cilynder and distilled water added to make a volume of 100 ml. The set up was stirred vigorously for 1 min. The volume of the settled particles was registered after regular time step of 30 min. The volume of settled particles was subtracted from 100. The difference was reported as percentage of dispersibility.

2.3.6 Wettability (W)

The method of [15] was used. Into a 25 ml graduated cylinder with a diameter of 1 cm, 1 g of sample was introduced. A finger was placed over the open end of the cylinder which was invested and clamped at a height of 10 cm from the surface of a 600 ml beaker containing 500 ml of distilled water. The finger was removed and the rest material allowed to be dumped. The wettability is the time required for the sample to become completely wet.

2.3.7 Iodine affinity of starch

The iodine affinity of flours from *Dioscorea bulbifera* cv *Dougou-won* was assayed using guidelines of [16]. 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 0.1 N 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):

$$IAS\ (ppm) = (VD \times Vt \times Na / VA \times Ms \times 100) \times 10^6$$

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.

2.3.8 Paste clarity (PC)

The paste clarity was determined according to the method of [17]. A 1 % aqueous suspension was made by suspending 0.2 g of flour in 20 ml of distilled water in a stoppered centrifuge tube and vortex mixed. The suspension was heated in a boiling water (100°C) bath for 30 min. After cooling, clarity of the flour was determined by measuring percent transmittance at 650 nm against water blank on a spectrophotometer JASCO V-530 (UV/VIS, Model TUDC 12 B4, Japan Servo CO, LTD Indonesia).

2.3.9 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 [12].

2.3.10 Swelling Power (SP) and Solubility

The effect of temperature on swelling and solubity was carried out according to the method of [18]. 0.5 g of the flour sample (W) was accurately weighed and quantitatively transferred into a clean dried test tube and weighed (W_1). The flour was then dispersed in 50 cm^3 of distilled water using stirrer. The slurry obtained was heated for 30 min at various temperatures from 50°C to 100°C. The mixture was cooled at room temperature and centrifuged for 15 min at 2600 rpm. The residue obtained after centifugation with the water was retained and the test tube was weighed (W_2). Aliquots (5 ml) 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 100 g of starch on dry weight basic. Swelling power was calculated using the formula:

$$\text{Swelling power (g/g)} = (W_2 - W_1) / W$$

2.4 Statistical Analysis

All analyses were carried out in triplicates. Results were expressed by means of ± SD. Statistical significance was established using one-way analysis of Variance (ANOVA) model to estimate the impacts of modification main impact on physico-functional parameters of flours from *Dioscorea bulbifera* cv *Dougou-won* at 5 % level. Means were separated according to Duncan's multiple range analysis (P <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).

3. RESULTS AND DISCUSSION

The OAC is the ability to absorb or retain oil. They are also important because of their storage stability and particulraty in the rancidity development [19]. The result of OAC is given in Table 1. The steaming after 30 min increased significantly (P <0.05) the absorption capacity of olive oil, maize oil, red oil (non refined palm oil), dinor oil (refined palm oil) and sunflower oil from *Dioscorea bulbifera* flours cv *Dougou-won*. The OAC range between 38.20±2.03 to 43±3 % for olive oil, 45±2 to 54±3 % for maize oil, 51±2.65 to 64±3 % for red oil, 53±2 to 65±5.58 % dinor oil and 50±2.65 to 58 ± 1.73 % for sunflower oil. The OAC for these different oils were higer than those obtained from yam *Dioscorea*. *alata* cv yellow (0.96 g/g) flour [20] and lower in potato flour (168± 10.95 %) [21] and Nigerian jackfruit seed flour (300 %) [22]. However, the cooking on embers decreased significantly (P <0.05) the absorption capacity of olive oil, maize oil, red oil, dinor oil and sunflower oil from *Dioscorea bulbifera flours* cv *Dougou-won*. The OAC range between 32±2 to 23±2.65 % for olive oil, 39±1 to 28±1.73 % for maize oil, 43±3 to 35±1.73 % for red oil, 45±1.73 to 29±2.65 % dinor oil and 40 ± 2 to 31±1 % for sunflower oil. The OAC increasing could be attributed to the proteins denaturation and dissociation. This may have ocurring steaming which unmasks the non-polar residues from protein molecular [13]. The OAC decrease with cooking on embers could be attributed to a decrease in protein in *Dioscorea bulbifera flours* cv *Dougou-won* which tend to reduce the hydrophobicity and thereby causing a low fat binding to protein. The flour in this present study is potentially useful in structural interaction in food especially in flavor retention, improvement of palatability and extension of shelf life particulary in bakery or meat products where oil absorption is desired [23].

Water absorption capacity is the property of a substance that determines the extent to which it can bind with water. This property determines to some extent the rate at which rancidity occurs in food [24]. [25] described water absorption

Table 1. Oil absorption capacity for olive oil, sunflower oil, maize oil, Dinor oil and red oil of flours from raw and cooked *D. bulbifera* cv *Dougou-won*

	Oil absorption capacity (%)				
Flours	**Olive oil**	**Sunflower oil**	**Maize oil**	**Dinor**	**Red oil**
		Steamed *D. bulbifera* flours cv Dougou-won			
FNT0	35±2DE	46±2.65DEF	42±5.57CDE	50±3CD	48±2.65EF
FV10	38.20±2.03EF	50±2.65EFG	45±2DEF	53±2DE	51±2.65CD
FV20	41±2FG	54±3.61GHI	48±1.73FG	58±2EF	62±3GH
FV30	43±3FG	58±1.73I	54±3HI	65±5.58GH	64±3IJ
		Cooking on embers *D. bulbifera* flours cv Dougou-won			
FNT0	35±2DE	46±2.65DEF	42±5.57CDE	50±3CD	48±2.65EF
FB10	32±2CD	4±2BCD	39±1BC	45±1.73C	43±3CD
FB20	26±3.46AB	36±1.73AB	35±1.73B	37±2.65B	38±1.73A
FB30	23±2.65A	31±1A	28±1.73A	29±2.65A	35±1.73AB

Values are mean ± standard deviation of triplicate measurements and those bearing different letter within a columns are significantly different at P<0.05

capacity as an important processing parameter that has implications for viscosity. Furthermore, the water absorption capacity (WAC) is important in bulking and consistency of products as well as baking applications. The water absorption capacity (WAC) is showed in Table 2. The steaming and grilling on embers from *Dioscorea bulbifera* cv *Dougou-won* bulbils flours increased significantly (*P* <0.05) WAC after 30 min. Similar results were reported by [26] who showed increasing WAC values in flours from corm taro *Colocasia esculenta* cv *Yatan* (312.21±27.32 to 526.76±35.36 %). The WAC from *Dioscorea bulbifera* cv *Dougou-won* bulbils flours range between 161±4.58 to 227 ± 5.20 % for steaming after 30 min. The WAC from *Dioscorea bulbifera* cv *Dougou-won* bulbils flours range between 152±4.46 to 177±2.65 % for grilling on embers after 30 min. The WAC for the steaming and grilling on embers in ours study were lower than those obtained for cooked breadnut flours (290-310 %) [27] and pre-cooked cocoyam (247.5-562.5 %) [28].The ability of food to absorbe water may be sometimes attributed to its proteins content [29]. The denatured proteins in flours due to heat processing bind more water and hence could lead to flour higher water absorption [30]. The WAC is important in the development of ready to eat foods and a high absorption capacity may assure products cohesiveness [31].

The water solubility index (WSI) reflects the extent of starch degradation [32]. The WSI (17.31 ±0.80 %) observed (Table 2) for the flour of raw *Dioscorea bulbifera* cv *Dougou-won* bulbils is lower compared to that of flour from steaming (19.75±2.05-33±2.65 %) and grilling on embers (18.8±0.26 - 28±1.73 %) *Dioscorea bulbifera* cv *Dougou-won* bulbils after 30 min, indicating that steaming and cooking on embers have more profound effect on starch degradation. Similar obsevations were recorded by [33], when using yam *Dioscorea* spp flours (9.26±0.11 to 15.31±0.85 %).

Foams are used to improve texture, consistency and appearence of foods [34]. Foam is a colloïdal of many gas bubbles trapped in liquid or solid. Small air bubbles are surrounded by thin liquid films [35]. The foam capacity is showed in Table 2. The results showed that steaming and cooking on embers decreased the foam capacity (FC) of *Dioscorea bulbifera* flours cv *Dougou-won* during 30 min. Their values varied from 21.30±0.82 % to 14±2.65 % for flours steamed during 30 min and 24.82±1.28 % to 19.50±1.56 % for bulbils cooking on embers during the same time. The value obtained from raw flours (26.67±0.26 %) is higher that those of *Dioscorea alata* cv yellow (15.33±3.05 %) (Harijono et al., 2013) and brown tigernut (11.07 %) [36].

The foaming stability of steamed and cooking on embers bulbils flours are presented in Figs. 1 and 2. The foam stability (FS) of *D. bulbifera* flours cv *Dougou-won* decreased significantly (*P* <0.05) with steaming and cooking on embers time. The foam obtained from steamed bulbils flours stabilized faster (6 h) than those obtained by cooking on embers flours (7 h) after 30 min. The reducing of foaming properties was related to protein denaturation. These results agreed with the finding of [37] 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 [26].

There was an inverse relationships between foams capacity and foam stability. Flours with high foaming ability could form large air bubbles surrounded by thinner less flexible protein film. This air bubble might be easier to collapse and consequently lowered the foaming stability [38]. This results suggest that bulbil of *Dioscorea bulbifera* cv *Dougou-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 [39].

The bulk density is a measure of the heaviness of a flours simple. It is important for determining pakaging requierements, material handing and application in wet processing in the food industry [40]. The bulk density of bulbils flours are given in Table 2. The result showed that BD of flours increased in steaming and cooking on embers after 30 min. They values ranged respectivly from 0.74±0.02 to 0.82±0.02 g/cm^3 and 0.73±0.04 to 0.77±0.03 g/cm^3. The raw flour of *D. bulbifera* cv *Dougou-won* (0.72±0.02 g/cm^3) is higher from flours of winged bean seed (0.34±1.41 g/ml, [41] and jackfruit seed (0.298 g/ml, [22] but low than soybean flour (1.85±0.05 g/ml, [42]. 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 [43]. Low BD is advantagereous for the infants as both calorie and nutrients density in enhanced per feed of the child [44]. The high BD of flours showns that they would be useful in puddings and serve as thickners in food products.

The dispersibility is a measure of reconstitution of flour or starch in water. The dispersibility determines the tendency of flour to move apart from water molecules and reveals its hydrophobic action [45]. [14] reported that the higher the dispersibility, the better the starch reconstitues in water to give a fine and consistent paste. In this study, the result in Table 2 showed that steaming increased significantly (P <0.05) bulbils flours after 30 min. Their values ranged from 23±1.73 to 34±3 %. But the grilling on embers of bulbils flours after 30 min did not vary significantly (P <0.05). These results were lower than those reported by [46] who reported the respective values 55-66 % and 50-70 % for local rice of Nigeria and Caprice rice. The increasing dispersibility of flour from *D. bulbifera* cv *Dougou-won* could may be caused by starch gelatinisation which increases the water-binding capacities [47].

The wettability (W) is the time required for the sample to become completely wet [15]. In this study, the result showed that steaming and cooking on embers decreased significantly (P <0.05) flours after 30 min. Their values (Table 3) ranged from 311±3.46 to 220±4.36 sec and 157±2.65 to 43±2.65 sec respectivly. The decreasing of wettability of flours result to low interfacial tension between the particules and the liquid [48]. The wettability of raw flours (410±2.65 sec) is higher than those of yams *Dioscorea alata* (6.15 sec) and *Dioscorea rotundata* (6.54 sec) [49].

Table 2. Some physico-functional parameters of *D. bulbifera* flours cv *Dougou-won*

Flours	WAC (%)	WSI (%)	FC (%)	D (%)	BD (g/cm3)	W (sec)
Steamed *D. bulbifera* cv flours Dougou-won						
FNT0	149.42±4,50A	17.31±0.80A	26.67±0.26I	16±1.73A	0.72±0.02A	410±2.65F
FV10	161±4.58B	19.75±2.05AB	21.30 ±0.82FG	23±1.73BC	0.73±0.03AB	311±3.46O
FV20	182±4C	25±2CDE	17.02±1.15DE	29±1.15CDE	0.75±0.03AB	260±3M
FV30	227±5.20E	33±2.65F	14±2.65C	34±3GH	0.79±0.04CD	220±4.36J
Cooking on embers *D. bulbifera* flours cv Dougou-won						
FNT0	149.42±4.50A	17.31±0.80A	26.67±0.26I	16 ±1.73A	0.72±0.02A	410±2.65F
FB10	152±4.46A	18.8±0.26AB	24.82±1.28HI	19±2A	0.73±0.04A	157±2.65F
FB20	166±2.65B	24±1.73CD	22.28±1.14FGH	26±3.46B	0.75±0.03AB	101±1.73E
FB30	177±2.65C	28±1.73E	19.50±1.56EF	32 ±1.73DEF	0.77±0.03AB	43±2.65A

Values are mean ± standard deviation of triplicate measurements and those bearing different letter within a columns are significantly different at P<0.05. WAC: Water absorption capacity; WSI: Water solubility index; FC: Foam capacity; D: Disperibility; BD: Bulk density; W: Weattability

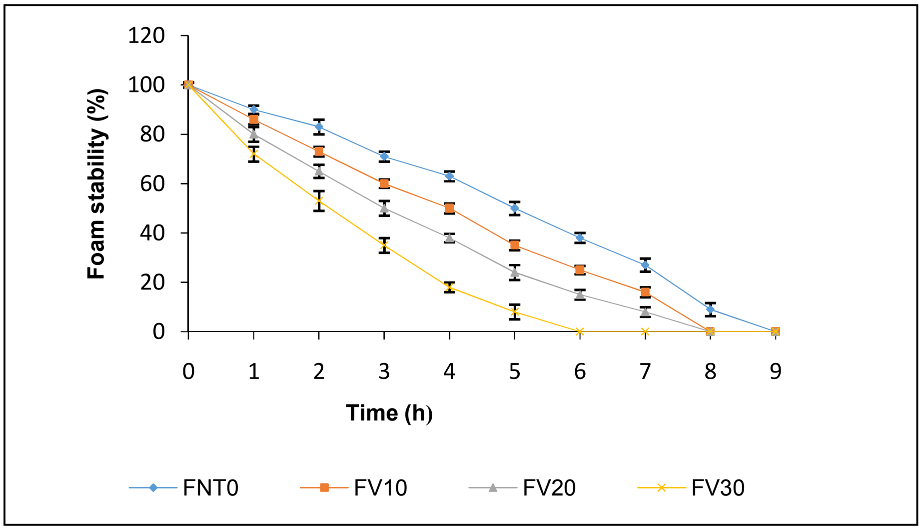

Fig. 1. Foam stability of raw and steaming *D. bulbifera* flours cv Dougou-won at different temperature

The iodine affinity of starch from raw flour (*D. bulbifera)* cv *Dougou-won* (53±4.36 ppm) is lower than those for flours from steamed (31±4.58 to 48±4.36 ppm) and cooking on embers (37±3.61 to 48±4.36 ppm). The result (Table 3) showed that the steamed and cooking on embers flours contained starch granules with the high affinity for iodine or in consonnance with reports by [50] contains more amylose. [51] reported that amylose aggregation has a strong impact on the texture of the pastes.

The paste clarity is an important that governs different applications of flours and starches for food processing. Light transmittance of *D. bulbifera flours* cv *Dougou-won* obtained by steaming and cooking on embers (Table 3) ranged respectivly from 45 ± 1.73 to 63±2 %T and 45±1.73 to 52±2 %T. The low clarity 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 [52]. Consequently, pastes were turbid or opaque as described in the literature [17]. Pastes obtained after steaming and cooking on embers are more transparente than native starch suspension in the raw flour [52]. The increasing of starch pastes clarity could be du to light refraction reduction by the granules remnant [52].

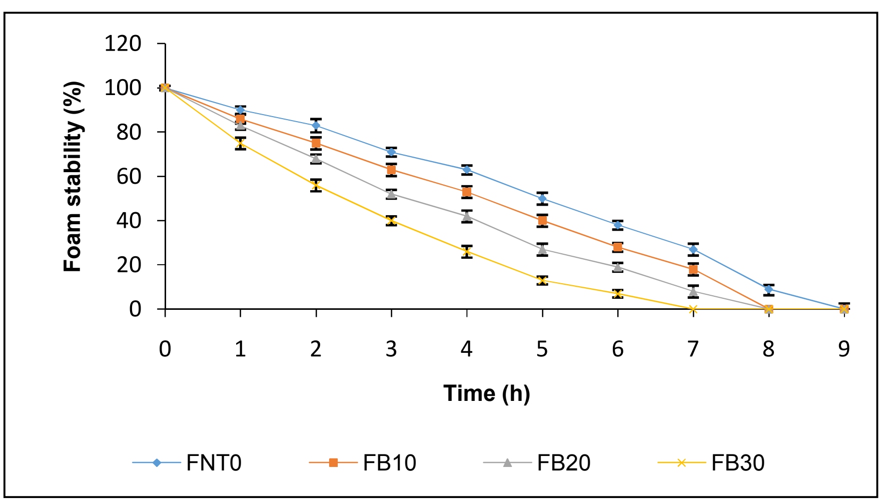

Fig. 2. Foam stability of raw and cooking on embers *D. bulbifera* flours cv Dougou-won at different temperature

Table 3. Some physico-functional parameters of *D. bulbifera* flours cv *Dougou-won*

Flours	IAS (ppm)	PC (% T)	LGC (%)
Steamed *D. bulbifera* cv Dougou-won flours			
FNT0	53±4.36J	43±1.73A	2
FV10	48±4.36HIJ	45±1.73ABC	4
FV20	39 ± 3.61EFG	61±2.65E	8
FV30	31±4.58CD	63±2EF	12
Cooking on embers *D. bulbifera* cv Dougou-won flours			
FNT0	53±4.36J	43±1.73A	2
FB10	48±4.36HIJ	45±1.73ABC	4
FB20	42±4.36FGH	48±2.65BC	6
FB30	37±3.61FG	52±2D	10

Values are mean ± standard deviation of triplicate measurements and those bearing different letter within a columns are significantly different at P<0.05. IAS: Iodine affinity starch; PC: Paste clarity; LGC: Least gelation concentration

The least gelation concentration (LGC) can be described as a measure of the minimum amount of starch/flour or their blends that is needed to form gel in a given volume of water. The higher the LGC, the higher the starch/flour needed to form gel [53]. The least gelation concentration of raw flour (2 %) was lower from that of steamed (12 %) and cooking on embers flour (10 %) after 30 min. This result (Table 3) showned that steaming and cooking on embers increased the least gelation concentration in flours. But the least gelation from steamed flours was more increased than that of cooking on embers 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 [23]. The gelling capacity of flour has been attributed to denaturation and thermal degradation of starch [54]. [55] 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 [56, 57].

Swelling power (SP) is a measure of swollen starch granule, food eating quality is connected with retention of water swollen starch granules [58]. The swelling power of starch granules is showed in Figs. 3 and 4. The result showed that steaming and grilling on embers increased significantly (P <0.05) the value of swelling power after 30 min. Their value ranged respectivly between 2.9±0.01 to 12.80±0.02 g H20/g DM and 2.7±0.32 to 10.80±0.22 g H20/g DM. This result could be due to its fat content. The swelling power of raw flours (2.5±0.2–8.7±0.17 g H_20/g DM) is lower than those of flour from *Artocarpus altilis* (1.3–13.6 g H_2O/g DM) [59] and higher than those of *Dioscorea rotundata* flour (2.70±0.01) [60]. The changes in the swelling power indicates the degree of exposure of the internal structure of the starch present in flour to the action of water [61].

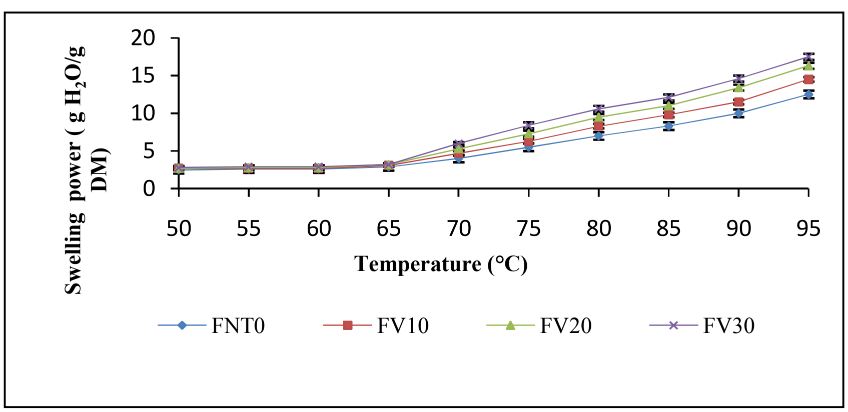

Fig. 3. Swelling power of raw and steaming *D. bulbifera* flours cv Dougou-won at different temperature

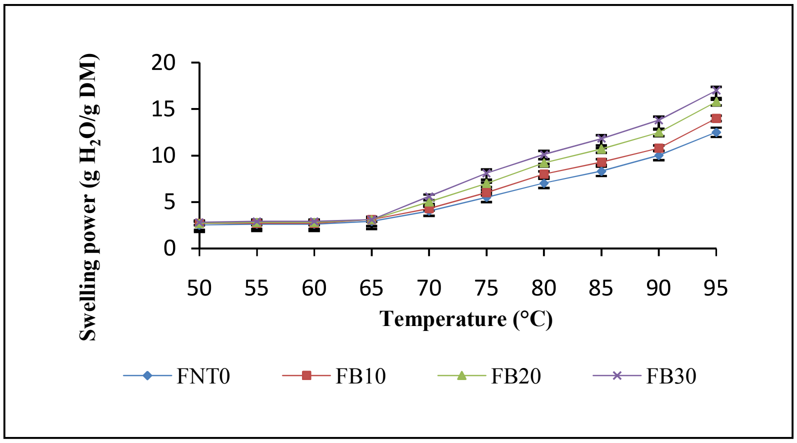

Fig. 4. Swelling power of raw and cooking on embers *D. bulbifera* flours cv Dougou-won at different temperature

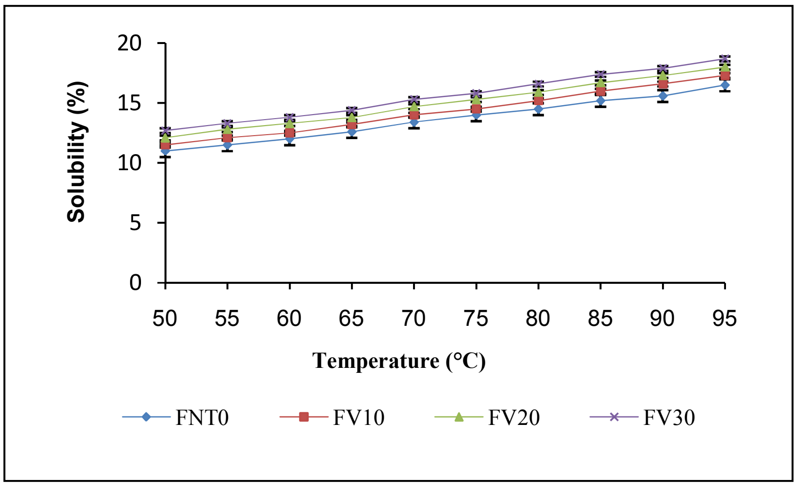

Fig. 5. Solubility of raw and steaming *D. bulbifera* flours cv *Dougou-won* at different temperature

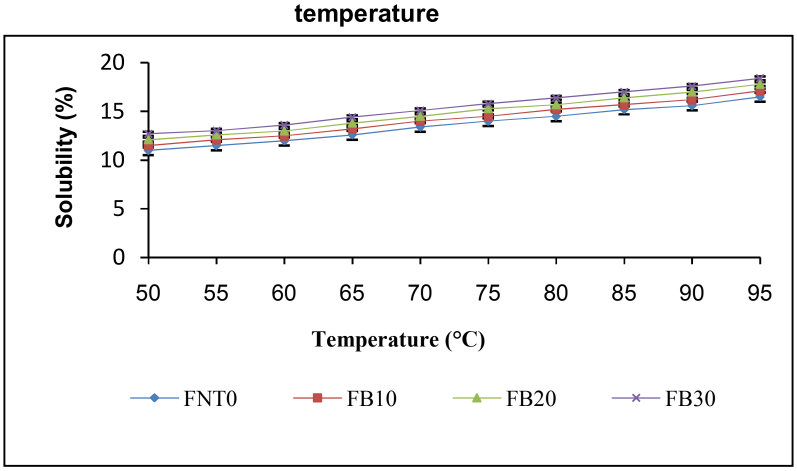

Fig. 6. Solubility of raw and cooking on embers *D. bulbifera* flours cv *Dougou-won* at different temperature

Solubility reflects the extents of intermolecular cross bonding with the granule [62]. The solubility of flour is showed in Fig. 5 and 6. The result showed that steaming and cooking on embers increased significantly (P <0.05) the value of solubility after 30 min. Their value ranged respectivly between 13.9±0.01 to 16.80±0.01 % and 11.92±0.12 to 14.82±0.25 %. The solubility of raw flour (10.20±0.06 to 13.60±1.73 %) is lower than those of jackfruit seed flour (13.20±0.98 %) (Eke-Ejiofor *et al.,* 2014) and *Dioscorea rotundata* flour (16.16±0.01 %) [60]. This high solubility of steaming (16.80±0.01 %) and cooking on embers (14.82±0.25 %) flour, suggests that it is digestible and could be suitable for infant food formulation.

4. CONCLUSION

The result of this study indicated that steaming and cooking on embers caused changes in the physico-functional parameters of *Dioscorea bulbifera* flours cv *Dougou-won*. They increased some physico-functional parameters of *D. bulbifera* flours cv *Dougou-won* but they decreased others. The presence of good degre of the absorption capacity of these oils can be suggested the presence of good lipophilic components which could be adapted to production of sauces, soup and cakes. The steaming and cooking on embers have been found to give good functional properties which can be high importance in food manufacturing industries. However steaming ameliored better physico-functional parameters of *Dioscorea bulbifera* flours cv *Dougou-won* than cooking on embers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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