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Research Article

EFFECT OF PROCESSING ON THE CHEMICAL COMPOSITION, PHYTOCHEMICAL CONTENTS AND FUNCTIONAL PROPERTIES OF YELLOW FLESHED AERIAL YAM (*DIOSCOREA BULBIFERA*) FLOUR

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ABSTRACT

Objective: The broad objective of this work was to evaluate the chemical composition and functional properties of *Dioscorea bulbifera* flour as affected by blanching and sulfiting.

Methods: Yellow fleshed *D. bulbifera* bulbs were processed by sulfiting (1.0%) for 30 minutes and steam blanching (10 minutes). The unprocessed sample served as control. The slices were oven dried at 40°C to constant weight, milled in an attrition mill and then sieved through a 200 µm sieve. Standard analytical methods were used to evaluate the chemical and functional properties of the flours.

Results: Steam blanching significantly increased crude fiber, protein, ash, and carbohydrate when compared with the raw and sulfited samples. Alkaloid, flavonoid, and saponin contents ranged from 2.04-3.63, 8.84-12.34, and 0.46-0.73, respectively, in the steam blanched samples. Sulfiting significantly increased the phytate and carotenoid contents from 0.24-0.82 and 0.08-4.83, respectively. Steam blanching significantly ($p<0.05$) increased the water absorption capacity, swelling capacity and least gelation capacity compared to the raw and sulfited sample.

Conclusion: This study shows that steam blanching is preferable for use in the control of enzymatic browning in *D. bulbifera* compared to sulfiting since it significantly increased most of the chemical and functional properties of the flour.

Keywords: *Dioscorea bulbifera*, Steam blanching, Sulfiting, Functional properties.

INTRODUCTION

Yam (*Dioscorea* spp.) is a food crop that plays a key role in food security and sustenance for the majority of the population in Nigeria. Aerial yam (*Dioscorea bulbifera*) belongs to Dioscoreaceae family and has common names such as air yam, air potato, potato yam, and *edu* or *adu* in the Eastern part of Nigeria. Aerial yam is available in two varieties, as the edible and non-edible [1]. Two varieties of the edible *D. bulbifera* are mainly cultivated. One variety being yellow fleshed with large sized bulbil, whereas another variety has a mauve colored flesh with smaller sized bulbil [2]. *D. bulbifera* is rich in phytonutrients and has being shown to possess the physiological functions to certain diseases other than its nutritional functions [3,4]. *D. bulbifera* are cultivated for their bulbils and are eaten same way like other types of yam. It is regarded as food for the poor and eaten mainly during food scarcity. *D. bulbifera* is less preferred probably due to its distinctive taste and variable size of the bulbils when compared to other yam types.

With the growing emphasis on food insecurity and malnutrition in Africa, it becomes imperative to develop the functionality of locally available underutilized food crops such as *D. bulbifera*. This would go a long way in reducing post-harvest losses and adding value to this food crop thereby generating income for the farmers and Nigeria as a whole. *D. bulbifera* is highly susceptible to enzymatic browning which is caused by the oxidation of phenolic compounds by polyphenol oxidases in the presence of oxygen. Blanching and sulfiting have a long been used in food industries to inhibit both enzymatic and non-enzymatic browning in food. The objective of this work was to determine the chemical and phytochemical composition and functional properties of *D. bulbifera* as affected by blanching and sulfiting.

METHODS

Procurement of raw materials

D. bulbifera bulbs were purchased from Eke market, in Obollo Eke, Udenu Local Government Area, Enugu State, Nigeria. Laboratory grade sodium metabisulfite was purchased from a local store in Ogige market, Nsukka, Enugu State, Nigeria.

Preparation of flour samples

D. bulbifera bulbs were divided into three portions, and each portion was washed, peeled, and sliced to 2 mm thickness. The first portion was immersed in sodium metabisulfite solution (1.0%) for 30 minutes [5]. The second portion was steam blanched in a metal sieve over boiling water at 100°C for 10 minutes, while the third portion which was untreated served as control. The slices were oven dried at 40°C to constant weight, milled in an attrition mill and then sieved through a 200 µm sieve. The flours were then packed in air tight containers. The flow chart for the preparation of *D. bulbifera* flour is shown in Fig. 1.

Chemical analysis

Crude fiber, crude protein, ash, and fat were carried out using the methods described by AOAC [6], and carbohydrate content was calculated by difference.

The method of Casterline *et al.* [7] was used to determine the starch content of the flour. 25 g of the sample was weighed into a beaker. 15 ml of water was added to make a stiff dough which was allowed to stand in the beaker. It was removed, squeezed in between the fingers and gently kneaded under a stream of running water until all the starch was washed into the collection beaker through a 100 µm mesh. The supernatant was allowed to sediment; excess water was decanted off. The starch extract was evaporated to dryness in a hot air oven. Crispy dried starch was weighed and calculated as percentage as:

$$\% \text{ Starch} = \frac{\text{Weight of starch}}{\text{Weight of sample}} \times 100$$

Amylose content of the samples was determined using the method of Williams *et al.* [8]. About 0.1 g of starch was weighed into a 100 ml

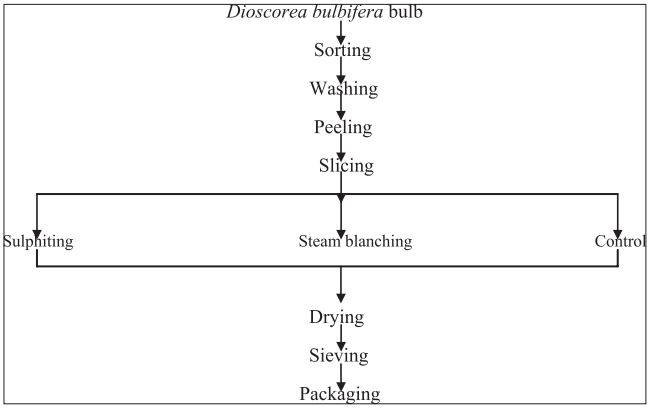

Fig. 1: Production of *Dioscorea bulbifera* flour

volumetric flask. 1 ml of 99.7-100% (v/v) ethanol and 9 ml 1N NaOH was carefully added, and the mouth of the flask was covered with foil and the content was allowed to homogenize. The sample was heated for 10 minutes in boiling water bath to gelatinize the starch (timing started when boiling begins). The samples were removed from the water bath and allowed to cool very well. It was made up to mark with distilled water. Absorbance (A) was read using a spectrophotometer at 620 nm wavelength. The blank which contained 1 ml of ethanol and 9 ml of NaOH was then boiled and made up to mark with distilled water. 5 ml was pipetted into a 100 ml volumetric flask. 1 ml of 1N acetic acid and 2 ml of iodine solution was added and then made up to mark. This was used to standardize the spectrophotometer at 620 nm.

The amylopectin content of the samples was calculated by difference as follows:

Amylopectin=% Starch content−% Amylose content.

Phytochemical analysis

The alkaloid content was determined using the method described by Harborne [9]. 5 g of the sample was weighed into a 250 ml beaker and 200 ml 20% acetic acid in ethanol was added and covered to stand for 4 hrs. This was filtered and the extract was concentrated using a water bath to one-quarter of the original volume. Concentrated ammonium hydroxide was added drop-wise to the extract until the precipitation was complete. The whole solution was allowed to settle, and the precipitate was collected by filtration and weighed. Alkaloid content was calculated as:

$$\% \text{ Alkaloid } = \frac{\text{Weight of alkaloid + Paper} - \text{Weight of paper}}{\text{Sample size}} \times 100$$

Carotenoid content of the samples was determined according to the method described by Harborne [9]. Each sample (5 g) was homogenized in methanol (1 ml) using a laboratory blender. The homogenate was filtered to obtain the initial crude extract. 20 ml of ether was added to the filtrate to take up the carotenoid. It was mixed and then treated with 20 ml of distilled water in a separating funnel. The ether layer was recovered and evaporated to dryness at low temperature (35-50°C) in a vacuum dessicator. The dry extract was then saponified with 20 ml of ethanolic potassium hydroxide and left overnight in a dark cupboard. The next day, the carotenoid was taken up in 20 ml of ether and then washed with two portions of 20 ml distilled water. The carotenoid extract (ether layer) was dried in a desiccator and then treated with light petroleum and allowed to stand overnight in a freezer (−10°C). The next day, the precipitated steroid was removed by centrifugation and the carotenoid extract was evaporated to dryness in a weighed evaporation dish, cooled in a desiccator and weighed. The weight of carotenoid was determined and expressed as a percentage of the sample weight.

$$\% \text{ Carotenoid } = \frac{\text{Weight of carotenoid + Dish} - \text{Weight of empty dish}}{\text{Sample size}} \times 100$$

Tannin content of the samples was done using the method of Price and Butler [10]. 2 g of the sample was weighed into a 250 ml flask followed by addition of 200 ml of 0.004M $K_3Fe(CN)_6$ and 10 ml of 0.008M $FeCl_3$ in 0.008M HCl. The flask was allowed to stand for 20 minutes but stirred occasionally at 10 minutes interval, and 1 ml aliquot was removed. To this aliquot, 2 ml of 0.008M $FeCl_3$ in 0.008M HCl and 10 ml of 0.0015M $K_3Fe(CN)_6$ was added. After adding the final reagent, the absorbance was read at 720 nm after 30 seconds against a blank. The tannin content was calculated as:

$$\text{Tannin mg} / 100\,\text{g} = \frac{\text{Concentration of standard} \times \text{absorbance of standard}}{\text{Absorbance of standard} \times \text{sample size}} \times \text{df}$$

Where, df: Dilution factor

Phytate content was determined using the method described by Oberleas [11]. The sample was first extracted with 0.2 HCl. The extract (1 ml) was poured into a test tube fitted with a ground glass stopper together with 1 ml of ferric solution (prepared by dissolving 0.2 g ammonium (iii) sulfate in 10 ml of NaCl). The solution was made up to 100 ml with distilled water. The tube was heated in a boiling water bath for 30 minutes cooled in ice for 15 minutes and then allowed to reach ambient temperature. The content of the tube was centrifuged for 30 minutes at 300 rpm. After centrifugation, the supernatant (1 ml) was mixed with 1.5 ml of 2, 2 bipyridine solution and absorbance measured at 519 nm against distilled water using Agilent spectrophotometer (Model 5805, Agilent Spectrophotometer England). The phytic acid content was calculated as:

$$\% \text{ Phytic acid } = \frac{100 \times \text{Vf} \times \text{C}}{\text{W} \times \text{Va} \times 100}$$

Where, C: Concentration of curve, Va: Total volume of extract analyzed, Vf: Total volume of extract, W: Weight of sample.

Flavonoid content was determined using the method as described by Boham and Kocipai [12]. Exactly 10 g of the sample was extracted repeatedly with 100 ml of 80% aqueous methanol at room temperature. The whole solution was filtered through Whatman filter paper No. 1. The filtrate was later transferred into a crucible and evaporated to dryness over a water bath and weighed. Flavonoid content was calculated as:

$$\% \text{ flavonoid } = \frac{W_1 - W_2}{W} \times 100$$

Where, W_1=Weight of flavonoid+Evaporation dish

W_2=Weight of empty evaporation dish

W=Sample size

Saponin content was determined by the method described by Obadoni and Ochuko [13]. The sample (5 g) was mixed with 50 ml of 20% aqueous ethanol. The sample was heated with continuous stirring over a hot water bath for four hours at about 55°C. The mixture was filtered and the residue reextracted with another 50 ml of 20% ethanol. The combined extracts were reduced to 10 ml over water bath at 90°C. The concentrate was transferred into a separating funnel, and 20 ml of diethyl ether was added and shaken vigorously. The aqueous layer was recovered while the ether layer was discarded. The purification process was repeated. 15 ml of n-butanol was added, and the combined n-butanol extracts were washed twice with 10 ml of 5% aqueous sodium chloride. The remaining solution was heated over water bath. The samples were dried in the oven to a constant weight and the saponin content was calculated as a percentage.

$$\% \text{ Saponin } = \frac{\text{Weight of saponin} + \text{Dish} - \text{Weight of empty dish}}{\text{Sample size}} \times 100$$

Functional Properties

The bulk density was determined according to the method described by Okaka and Potter [14]. The sample (50 g) was put into a 100 ml graduated cylinder and tapped 20-30 times. The bulk density was calculated as weight per unit volume of sample:

$$\text{Bulk density } = \frac{\text{Weight of sample}}{\text{Volume of sample after tapping}}$$

Water absorption capacity was determined using the method of Sathe and Salunkhe [15] with slight modifications. 10 ml of distilled water was added to 1 g of the sample in a beaker. The suspension was stirred using a magnetic stirrer for 5 minutes. The suspension obtained was centrifuged at 3000 rpm for 30 minutes, and the supernatant measured in a 10 ml graduated cylinder. The density of water was taken as 1.0 g/cm^3. Water absorbed was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant.

The least gelation concentration was determined using the method of Coffman and Garcia [16]. The flour dispersions of 2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18%, and 20% (w/v) prepared in 5 ml distilled water were heated at 90°C for 1 hr in a water bath. The contents were cooled under tap water and kept for 2 hrs at 10±2°C. The least gelation concentration was determined as that concentration when the sample from inverted tube did not slip.

Swelling power was determined by the Takashi and Sieb [17] method. The sample (1 g) was weighed into 50 ml centrifuge tube. 50 ml of distilled water was added and mixed gently. The slurry was heated in a water bath at 60, 70, 80, 90, 100°C, respectively for 15 minutes. During heating, the slurry was stirred gently to prevent clumping of the starch. On completion of 15 minutes, the tubes containing the paste were centrifuged at 3000 rpm for 10 minutes using a centrifuge. The supernatant was decanted immediately after centrifuging. The weight of the sediment was taken and recorded. The moisture content of the gel was thereafter determined to get the dry matter content of the gel.

$$\text{Swelling power } = \frac{\text{Weight of wet sediment}}{\text{Weight of dry matter in the gel}}$$

Statistical analysis

Experiments were based on completely randomized design. All data were subjected to analysis of variance using Statistical Package for the Social Sciences version 17 computer software, and means were separated using Duncan's Multiple Range Test. Significance was accepted at $p<0.05$.

RESULTS AND DISCUSSION

Chemical composition of *D. bulbifera*

The chemical composition of *D. bulbifera* flour samples as affected by processing methods (sulfiting and steam blanching) is presented in Table 1. Steam blanching had a significant ($p<0.05$) effect on the chemical composition of *D. bulbifera* on the moisture, protein, crude fiber, ash, carbohydrate, and amylose when compared to the sulfited and untreated samples. Steam blanching significantly ($p<0.05$) increased the moisture of the flour from 5.4% to 6.56% probably due to steam blanching time which may have allowed for more absorption of water. Fat content of the flour was significantly ($p<0.05$) decreased by steam blanching. This could be attributed to the leaching effect. The crude fiber content obtained in this work (Table 1) was relatively higher than 2.35%, 2.89% and 1.20% reported by Afoakwa *et al.* [18], Abara [19] and Ogbuagu [20], respectively. The wide variation could be due to varietal differences and stage of maturity of the bulbs used. Starch and amylopectin were significantly ($p<0.05$) increased by sulfiting but decreased by steam blanching. The decrease in starch content as a result of steam blanching could be due to leaching and extraction of starch into blanching water, hence, the reduction in starch. A similar decrease in starch content as a result of blanching was reported by Harijono *et al.* [21] in *D. alata* (water yam) and Wireko-Manu *et al.* [22].

Phytochemical components of *D. bulbifera* flour

Table 2 shows the effect of sulfiting and steam blanching on the phytochemical composition of *D. bulbifera.* Sulfiting and steam blanching significantly ($p<0.05$) increased the alkaloid, flavonoid, phytate, and carotenoid contents. The increment recorded in these phytochemicals as a result of steam blanching could be due to the type of blanching and steam blanching time which activated these antinutrients but was not enough to extract them out into the steam blanching water. Egbe and Akinyele [23] had earlier reported that blanching had little or no effect on the reduction of antinutrients as the time lag was too short for them to have hydrated and induce leaching.

Tannin and saponin contents were significantly ($p<0.05$) reduced by sulfiting and steam blanching. Reduction in tannin content of *D. bulbifera* during the steam blanching and sulfiting might be attributed to the fact that tannins are polyphenols, and all polyphenolic compounds are water soluble in nature [24]. Akin-Idowu *et al.* [25] and Ezeocha *et al.* [26] also reported a decrease in tannin content of cooked *D. cayensis* and cooked *D. dumetorum*.

Functional properties of *D. bulbifera* flour

Table 3 shows the effect of sulfiting and steam blanching on the functional properties of *D. bulbifera* flour. The bulk density of the flours ranged between 0.734 and 0.817 g/cm^3. Steam blanching significantly ($p>0.05$) increased the bulk density. This result contradicted a decrease in bulk density reported by Arisa *et al.* [27] in steam blanched plantain but agreed with the reports of Tagogoe [28] and Fagbemi [29] that bulk density increased as a result of blanching in taro and plantain flours,

Table 1: Chemical composition of raw and processed *D. bulbifera* flour

Parameters	Sulfited flour	Steam blanched flour	Untreated flour
Moisture (%)	5.95^{b}±0.26	6.56^{a}±1.00	5.40^{c}±0.32
Protein (%)	9.17^{b}±0.16	9.89^{a}±0.03	7.76^{c}±0.13
Fat (%)	0.75^{a}±0.03	0.40^{b}±0.05	0.68^{a}±0.03
Crude fiber (%)	25.07^{c}±1.00	36.37^{a}±0.26	28.45^{b}±0.24
Ash (%)	2.86^{b}±0.03	3.09^{a}±0.02	2.67^{c}±0.03
Carbohydrate (%)	43.83^{b}±0.46	56.31^{a}±0.25	44.89^{c}±0.20
Starch (%)	78.95^{a}±2.76	16.40^{c}±0.63	64.22^{b}±0.67
Amylose (mg/100 g)	77.07^{c}±1.52	235.16^{a}±2.56	113.49^{b}±26.16
Amylopectin (%)	78.87^{a}±2.76	16.16^{c}±0.63	64.22^{b}±0.67

Means±standard deviation of 3 replications. Means within a row with the same superscript letters were not significantly ($p>0.05$) different.
D. bulbifera: Dioscorea bulbifera

Table 2: Phytochemical composition of raw and processed *D. bulbifera* flour

Parameters	Sulfited flour	Steam blanched flour	Untreated flour
Alkaloid (%)	2.06^{b}±0.34	3.63^{a}±0.99	2.04^{b}±0.31
Flavonoid (%)	11.23^{b}±0.14	12.87^{a}±0.61	8.84^{c}±0.36
Tannin (mg/100 g)	75.7^{b}±10.58	53.3^{c}±0.79	112.9^{a}±3.78
Phytate (%)	0.82^{a}±0.48	0.40^{b}±0.01	0.24^{c}±0.05
Carotenoid (%)	4.83^{a}±0.50	0.38^{b}±0.16	0.08^{b}±0.02
Saponin (%)	0.53^{a}±0.01	0.46^{a}±0.09	0.73^{a}±0.05

Means±standard deviation of 3 replications. Means within a column with the same superscript letters were not significantly ($p>0.05$) different.
D. bulbifera: Dioscorea bulbifera

Table 3: Functional properties of raw and processed *D. bulbifera* flour

Parameter	Sulfited flour	Steam blanched flour	Untreated flour
Bulk density (%)	0.734^{c}±0.02	0.817^{a}±0.02	0.776^{b}±0.02
WAC (%)	234.05^{b}±12.07	262.05^{a}±0.89	202.55^{c}±10.09
SC (%)	272.94^{b}±6.94	305.79^{a}±76.96	220.82^{c}±0.33
LGC (%)	15^{a}	2^{c}	10^{b}

Means±standard deviation of 3 replications. Means within a column with the same superscript letters were not significantly (p>0.05) different. WAC: Water absorption capacity, SC: Swelling capacity, LGC: Least gelation capacity, *D. bulbifera: Dioscorea bulbifera*

respectively. Bulk density is a function of particle size, and particle size is inversely proportional to bulk density. The high bulk density of *D. bulbifera* flours shows that they would be useful in puddings and serve as thickners in food products.

Steam blanching significantly (p>0.05) increased the swelling capacity of *D. bulbifera*. High swelling power for steam blanched samples could be attributed to low levels of fat. This is because high levels of fat lead to the formation of amylose-lipid complexes that restrict swelling. Abiodun and Akinoso [30] reported higher swelling power in trifoliate yam flour parboiled at 60°C which was attributed to amylose leaching into the cooking medium during processing. Several studies have shown that swelling capacity is well correlated to amylose and its properties; flour with high amylose content tends to have high swelling capacity [31].

The steam blanched sample had significantly (p<0.05) lower (2%) least gelation concentration than the other flours (10% and 15%). This could be because of the high amylose content of steam blanched sample. Amylose plays a key role in the gelation process as a result of the formation of amylose double helices. Sarko and Woo [32] proposed that amylose gelation may occur due to chain cross-linking by double helical "gel junction" zones forming between molecules. The gelation properties are related to water absorption capacity hence the high water absorption capacity of the steam blanched flour sample could explain the high gel formation capacity. Gelation takes place more readily at higher protein concentration because of greater intermolecular contact during heating [33]. This is true for steam blanched samples which had higher protein content and hence, higher gelation property among the other samples.

CONCLUSION

Steam blanching is preferable for use in the control of enzymatic browning in *D. bulbifera* compared to sulfiting since it significantly increased most of the chemical and functional properties of the flour. This shows that thermal treatment increases nutrient availability compared to sulfiting.

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