

Effect of Pre-treatment and Drying on the Nutritional and Mineral Composition of *D. bulbifera* flour

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The effect of pre-treatment and drying methods on the nutritional and mineral composition of the aerial yam (*Dioscorea bulbifera*) was evaluated. Flours were obtained by subjecting the yam to different pre-treatment and processing methods (grating, steaming, boiling, solar and oven drying). They were dried, milled and sieved. The flours obtained were evaluated for their mineral and nutritional compositions. Between the different processing methods, the flour samples had mineral contents ranging from 34.2 to 42.3mg/100g phosphorus; 78.0 to 149.0mg/100g calcium; 8.2 to 10.2mg/100g iron; 51.7 to 89.1mg/100g sodium; 1026.6 to 1467.6mg/100g potassium and 53.33 to 138.67mg/100g ascorbic acid. The nutritional content ranged from 8.77% to 12.45% moisture, 0.84% to 1.91% protein, 0.49% to 1.77% fat, 2.97% to 3.88% ash, 0.94% to 2.17% fibre and 79.64% to 84.23% carbohydrates. The results in this study indicate that the grated and solar dried samples were able to maintain much more ascorbic acid than the other treatment methods. For both phosphorus and sodium the grated and oven dried samples maintained more minerals than the other methods. The drying methods affected the nutritional content of the yam flour. It was also observed that pre-treatment and processing enhanced nutrient availability in the flour samples. Overall boiling and solar drying did not significantly change the amount of minerals in *Dioscorea bulbifera*.

Key words: Minerals, nutrients, potato yam, processing, solar drying.

INTRODUCTION

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. *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 [1]. Together with cereals they constitute the main source of energy in the tropics. *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 [1,2]. In Ghana, the *Dioscorea bulbifera* is distributed throughout the ten regions and appear in both edible and non-edible varieties (Figures 1 and 2 respectively). The inedible grows wild whilst the edible are cultivated. Predominantly, they are grown on large scale in the North, Upper West and Upper East regions [2]. The yam *Dioscorea bulbifera* is used as food and is a good source of iron, phosphorous and calcium [3,4]. They are usually eaten boiled, charcoal roasted and rarely pounded as 'fufu'.

Even though they are endowed with the minerals essential for proper functioning of the human body, they are less preferred and are only utilised during the famine seasons thereby rendering it underutilised and causing

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Figure 1. Edible bulbifera from Central Region.



Figure 2. Non-edible bulbifera from Central Region.

post-harvest losses to the region and loss of income to the farmers. The aim of this research is to explore the effect of different processing methods on the nutritional and mineral composition of the aerial yam to provide information on the best methods to apply in its processing to ensure maximum retention of all the nutrients. This study will provide relevant information for product developers and in motivating farmers to cultivate the yam on large scale to enhance their income.

MATERIALS AND METHODS

Source of Materials

Dioscorea bulbifera were obtained from Tamale in the Northern Region of Ghana. The samples were collected

in January 2012. The samples were sent to the Crops Research Institute of the Council for Scientific and Industrial Research at Fumesua in the Ashanti region of Ghana for laboratory analysis.

Dioscorea bulbifera flour preparation

The flour was prepared by cutting the peeled aerial yam into 1cm thick slices and divided into eight parts. Six parts were randomly selected and subjected to three different treatments, (i) boiling; where the yam slices were placed into a rice cooker of boiling water and boiled at 100° C for 20 min. (ii) steaming; the slices were placed in a colander over boiling water and steamed at 100° C for 25min and (iii) grating; The slices were grated with a local grater into thin strips. One part of the treated and non-treated yam were oven dried at 60°C for three days,

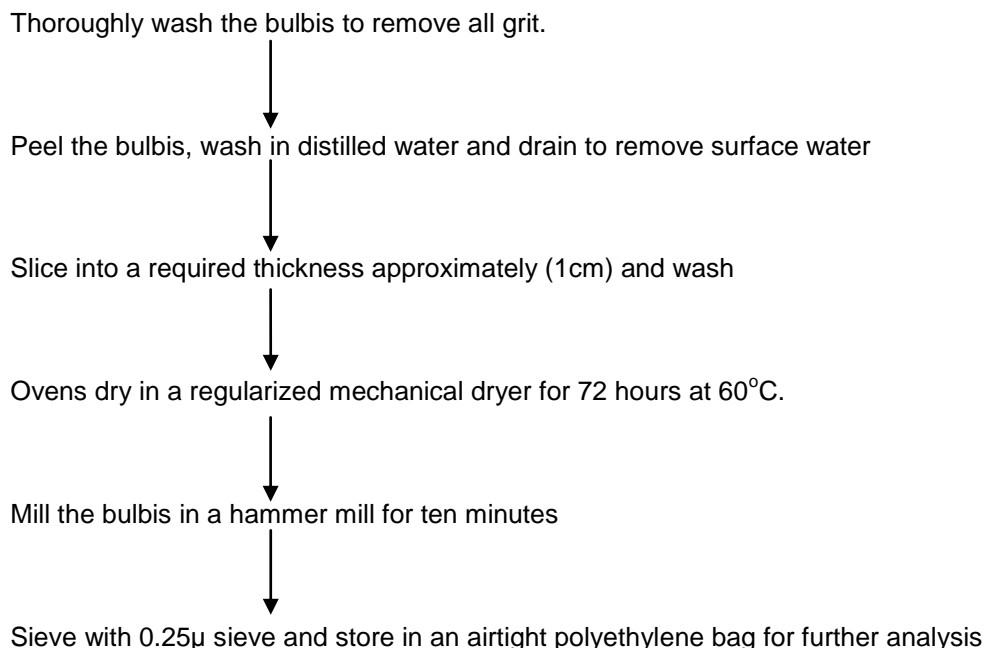


Figure 3. Flow chart for the *Dioscorea bulbifera* yam flour preparation.

milled and sieved with a 0.25 μ sieve and stored in a polyethylene bag for further analysis. The remaining tuber part was solar dried for 4 to 5 days. They were milled with a hammer mill Retsch (Adda Antriebstechnik, GMBH 63322 Rodermark), sieved and stored in a polyethylene bag for further analysis (Figure 3).

Proximate Analysis

Proximate analysis of samples were determined according to AOAC [5,6] the samples were analysed for moisture, ash, protein, fat, and carbohydrate (By difference).

Mineral and Vitamin C Analysis

Mineral analysis was done with the methods described by Hunter *et al.* [7] and Benton *et al.* [8]. The flour sample (0.48–0.52 g) was weighed into a clean ceramic crucible. The crucible was placed in a muffle furnace and heated to 500 °C over a period of 2 hours. The sample was allowed to ash for another 2 hours and cooled. The ash sample was transferred into 50 ml centrifuge tube and the crucible was subsequently rinsed with 5 ml distilled water and 5 ml (3 times) of *aqua 62 regia* making a total added volume of 20 ml. The sample was vortexed to mix the contents thoroughly and centrifuged at 3000 rpm for 10 min. The supernatant was decanted into micro-vials.

Mineral Determination: Ca, K, Na, P and Fe were determined using flame atomic absorption spectrophotometer (model Buck 205 from Buck Scientific,

USA). Aqua regia was prepared as follows; In a 2 L volumetric flask was poured 1.2 L distilled water, 400 ml conc. HCL and 133 ml of 70% nitric acid were carefully added and the volume was made to 2 L. Ascorbic acid was determined by the method [9].

Statistical Analysis

Data was analysed using stat graphics (Centurion version) and Minitab (14th version). Analysis of variance (ANOVA) was used to test for significant differences between the means. Duncan multiple range test was used to determine significant differences among the various samples.

RESULTS AND DISCUSSION

Effect of three pre-treatments and drying on the proximate composition of *Dioscorea bulbifera* flour

The results of the effect of pre-treatment and drying on the quality of *D. bulbifera* flour were produced using grating, steaming, boiling, solar and oven drying methods in their percentage composition as presented in Table 1. Proteins contribute 4 Kcal/g of energy and are important to human health. The protein content of the solar dried samples ranged between 1.17% and 1.91%. The protein content was recorded highest for the steamed whilst lowest for the boiled sample. There was significant difference ($p < 0.05$) between the steamed and boiled samples, and also between the control and the boiled

Table 1. Effect of pre-treatment and drying on nutritional composition of *D. Bulbifera* (%).

Sample	Moisture		Ash	Protein	Fat	Fibre	Carbohydrate
	Wet	Dry Basis					
DBGS	-	12.45±0.46 ^a	3.88±0.05 ^a	1.25±0.11 ^b	1.02±0.10 ^c	1.76±0.08 ^b	79.64±0.63 ^e
DBBS	-	10.94±0.16 ^b	3.23±0.04 ^c	1.17±0.12 ^{bc}	1.17±0.25 ^{bc}	2.17±0.14 ^a	81.31±0.23 ^d
DBFS	-	10.57±0.31 ^b	3.43±0.15 ^b	1.28±0.03 ^b	0.96±0.08 ^c	0.94±0.07 ^e	82.81±0.31 ^{bc}
DBSS	-	10.03±0.08 ^c	3.72±0.02 ^a	1.91±0.51 ^a	1.40±0.28 ^b	2.17±0.05 ^a	80.77±0.65 ^d
DBSO	68.79±0.89 ^b	9.90±0.06 ^c	3.23±0.09 ^c	1.31±0.25 ^b	1.77±0.24 ^a	1.49±0.12 ^c	82.30±0.65 ^c
DBGO	66.01±1.18 ^c	9.61±0.21 ^{cd}	3.74±0.18 ^a	0.84±0.25 ^c	1.18±0.19 ^{bc}	1.19±0.13 ^d	83.44±0.24 ^{ab}
DBBO	72.46±2.33 ^a	9.36±0.17 ^d	3.06±0.14 ^{cd}	1.17±0.02 ^{bc}	0.49±0.13 ^d	1.87±0.17 ^b	84.06±0.27 ^a
DBFO	68.92±0.74 ^b	8.77±0.51 ^e	2.97±0.04 ^d	1.33±0.04 ^b	1.45±0.18 ^{ab}	1.25±0.07 ^d	84.23±0.62 ^a

Samples with same letters are not significantly different ($p < 0.05$) Dbgs= Dioscorea Bulbifera grated solar dried, dbbs= boiled solar dried, dbss,= steamed solar dried, dbfs= fresh(control) solar dried, dbgo= grated oven dried, dbbo= boiled oven dried, dbso= steamed oven dried and dbfo= fresh oven (control) dried.

samples. The protein content in the steamed sample was higher than in the control whilst it was lower in the boiled sample compared to the control. The values obtained in this study were lower than those recorded by Anon *et al.* [10], for raw and boiled taro flours. They recorded 5.88% and 8.87% for raw and boiled taro flours respectively. The values did not compare favourably with the values of Anon *et al.* [10] which indicated that there was no significance difference ($p < 0.05$) between the protein values for the boiled and raw taro flours as was the case in this study.

Fats are very necessary to the structure and biological functions of cells and are used as alternative energy source. The fat ranged between 0.96% and 1.40% with the steamed sample having a significantly higher fat content ($p < 0.05$) than the control which recorded the lowest value. The values obtained in this study differed significantly from the control. Raw yams are generally known to be low in lipid compared to the processed ones. The ash content is the total minerals present in the samples. The values for the ash content of the investigated samples ranged between 3.23% and 3.88% with the grated sample having the highest value and the boiled sample having the lowest. This means that the method of grating was able to retain most of the minerals in the sample. The values obtained were all significantly ($p < 0.05$) different from the control. The experimental value obtained for raw *D. bulbifera* (0.96%) was comparable to the value recorded by Anon *et al.* [10] for raw taro flour. The method of grating resulted in high ash contents implying that grating was able to retain most of the minerals in the sample. Moisture content of the pre-treated *D. bulbifera* on dry basis ranged between 12.45% and 10.03% with the grated sample recording the highest value and the steamed sample recording the lowest. Moisture content of the steamed sample of 10.03% is below 11% giving it a better shelf life compared to the control which recorded 10.57%. This observation was not in agreement with the values recorded by Adepoju [11]

for *Dioscorea rotundata*. In his study, raw *D. bulbifera* flour recorded 58.8% and 62.3% for the boiled samples. The differences in the values obtained could be attributed to the duration of cooking time and variety. The values obtained for the control and steamed samples were higher than the raw taro flour (6.92%) [10], and lower than cocoyam flour (75.00%) [12]. The moisture level is essential for storage of flour, values higher than 12% facilitate microbial growth. Low levels are favourable and give a relatively longer shelf life [13]. Pierre [14] reported that, the lower the moisture content of a sample the better the efficiency of the drying method as shown in Table 1. Much of the water contained in the boiled and raw samples were removed during drying. The boiled sample had a value of 10.94% which is higher than boiled taro flour (8.33%) [10]. However there was no significant difference ($p < 0.05$) between the control and the boiled sample. This observation did not agree with studies by Adepoju [11] which reported that boiled *D. rotundata* flour was significantly higher in moisture content than in raw *D. rotundata* flour (62.3%, 58.8%). All the samples with the exception of the grated sample had low moisture content which is a very excellent attribute for storage. This implies that they may have longer shelf life if packaged well for storage.

In this study it was observed that the moisture content of the grated flour samples was the highest amongst the experimental samples and agrees with the observation made by Lamptey *et al.* [15]. It was expected, as grating exposes larger surface area for the faster loss of moisture in samples. In general, the moisture content of all the experimental samples was low. Fibre represents the portion of food not used up by the body but mainly made up of cellulose which together with lignin is reported to increase bulk stool [16]. The fibre content ranged between 0.94% and 2.17% with the boiled and steamed samples recording the highest and the control the lowest. There was a significant difference between the control and all the other samples, whilst there was no

significant difference recorded between the boiled and steamed samples. The values obtained for the steamed and boiled samples were found to be higher than those recorded for raw and boiled taro flours (1.22%, 1.20%) [10]. Dry matter content relates to good cooking quality. Higher dry matter contents denote better cooking qualities and extended storage life. The carbohydrate ranged between 79.64% and 82.1% with the control recording the highest value and the grated sample the lowest. There was no significant difference ($p < 0.05$) between the control, the steamed and boiled samples. Raw taro flour recorded a value of 80.94% [10] which was lower than the value obtained for the control in this study. The carbohydrate values for the *D. bulbifera* are reasonable as the dry matter of most root crops is made up of about 60-90% carbohydrate [17,18].

The protein content in the oven dried samples ranged between 0.84% and 1.33% with the control recording the highest value and the grated sample with the lowest. There was no significant difference ($p < 0.05$) between the control and steamed sample. This observation agrees with earlier studies, where there was no significant difference ($p < 0.05$) between the protein content of raw taro flour and boiled taro flour [10]. However, this did not agree with Onu *et al.* [19] who reported that cooking breaks down tannin which is well known to form complexes with protein thereby hindering protein availability and increasing level of proteins after cooking.

The fat content ranged between 0.49% and 1.77% with the steamed sample recording the highest and the boiled sample the lowest. The value obtained did not compare favourably with the value reported by Anon *et al.* [10] where there was no significant ($p < 0.05$) difference between the raw taro flour and boiled taro flour (0.87%, 0.85%). However, in this study, there was statistically no significant difference between the control with a value of 1.45% and the steamed (1.77%) and also between the control and the grated sample with a value of 1.18%. The value obtained for the control was however, higher than that recorded for *D. rotundata* (0.60%) [12]. The values obtained in this study showed that grating and steaming did not affect the lipid content of the flour, however boiling decreased the lipid content of the flour. The ash content ranged between 2.97% and 3.74% with the grated having the highest value and the control with the lowest. The values were higher than the values for *D. rotundata* and cocoyam as recorded in literature (1.10%, 1.60%) [12]. The experimental values obtained however compared favourably with the value for cocoyam (2.47%) as reported by Ogunlakin *et al.* [20], statistically there was no significant ($p < 0.05$) difference between the control and boiled sample which recorded 3.06%. This could imply that boiling is able to retain the mineral content of the yam flour.

The moisture content on dry basis ranged between 8.77% and 9.0% with the steamed recording the highest and the control the lowest. There was however, no

significant ($p < 0.05$) difference between the grated, the boiled and steamed samples. The moisture content on wet basis ranged between 68.92% and 72.46% with the boiled sample recording the highest value and the control the lowest. This observation is understandable as the boiled samples imbibed water during the boiling process. Fiber content ranged between 1.19% and 1.87% with the boiled sample recording the highest value and the grated recording the lowest. This observation may be as a result of loss in fibre during the grating process. The control obtained 1.25% which was lower than the value for the boiled sample. The value obtained for the control however compared favourably with the value obtained for raw taro flour (1.22%) [10]. In the study of Anon *et al.* [10] there was no significant difference ($p < 0.05$) between the raw taro flour and the boiled taro flour (1.22%, 1.20%). Fibre content value of 3.10% was reported for raw *D. rotundata* flour, a value observed to be higher than that obtained for the control in this study. Observations made in this study indicate that *D. bulbifera* flour had higher fibre content than those of sweet potato flour (0.75%, red tubers, 0.50%) [21]. This observation is very important because crude fibre has useful role in providing roughage that aids digestion [22].

The carbohydrate content ranged between 82.30% and 84.23% with the control having the highest value and the steamed sample with the lowest. There was no significant difference ($p < 0.05$) between the control, boiled (84.06) and the grated sample with a value of 83.44%. The experimental values agree with the values obtained for *D. rotundata* [12]. The processing methods were able to maintain the carbohydrate content. The values obtained for crude protein, crude fat, ash and crude fibre of raw *D. bulbifera* sample was in close agreement with that recorded in literature [17,23]. Raw yam is low in crude lipid, fibre and protein, moderate in ash content, and high in moisture, carbohydrate and gross energy content. Pre-treatment and processing enhances nutrient availability in processed foods as compared to the raw.

The effect of pre-treatment and drying on the mineral and Vitamin C content of aerial yam flour

Mineral content is a measure of the amount of specific inorganic components present within a food material. The concentrations of minerals in tubers in general are influenced by several factors that include environmental, processing methods and genetic factors [24]. With respect to environmental factors the mineral content could be attributed to the availability of these minerals in the soil. It is estimated that humans require at least 22 mineral elements for a healthy life [24]. Studies have shown that over 60% of world's population are iron (Fe)-deficient and over 30% are zinc (Zn) deficient [24,25]. Deficiencies of calcium (Ca), magnesium (Mg) and copper (Cu) are also common in both developed and developing countries [24]. These deficiencies can be

Table 2. Effect of pre-treatment and drying on mineral and Ascorbic Acid Composition of *D. bulbifera* (mg/100g).

Sample Code	Ascorbic Acid	P	Ca	Fe	Na	K
DBGS	138.67±0.034 ^a	41.3±0.0058 ^a	78.0±0.016 ^f	8.2±0.002 ^d	68.4±0.005 ^b	1467.6±0.031 ^a
DBBS	79.33±0.012 ^e	34.2±0.0173 ^d	124.6±0.032 ^d	10.5±0.006 ^a	51.7±0.005 ^g	1270.8±0.030 ^f
DBSS	77.78±0.009 ^e	42.3±0.0040 ^a	100.1±0.020 ^e	8.3±0.003 ^d	54.4±0.005 ^f	1358.7±0.053 ^c
DBFS	93.55±0.010 ^d	39.4±0.0023 ^b	240.2±0.026 ^a	9.5±0.004 ^{bc}	66.9±0.002 ^c	1305.9.0±0.053 ^e
DBGO	122.44±0.024 ^b	42.2±0.0052 ^a	191.9±0.033 ^b	10.0±0.003 ^{ab}	89.1±0.005 ^a	1379.7±0.053 ^b
DBBO	105.78±0.008 ^c	37.10±0.0052 ^c	96.6±0.028 ^e	10.2±0.001 ^a	50.0±0.002 ^h	1314.7±0.031 ^d
DBSO	79.44±0.008 ^e	35.8±0.0075 ^d	149.0±0.028 ^c	10.2±0.005 ^a	55.7±0.005 ^e	1026.6±0.053 ^h
DBFO	53.33±0.010 ^f	35.7±0.0040 ^d	96.5±0.030 ^e	9.0±0.006 ^c	66.9±0.002 ^c	1255.0±0.030 ^g

Samples with same letters are not significantly different ($p < 0.05$) Dbgs= Dioscorea Bulbifera grated solar dried, dbbs= boiled solar dried, dbss,= steamed solar dried, dbfs= fresh(control) solar dried, dbgo= grated oven dried, dbbo= boiled oven dried, dbso= steamed oven dried and dbfo= fresh oven (control) dried.

attributed to the consumption of product from land with low mineral availability, and more refined foods. The data in Table 2 presents the mineral content for *D. bulbifera* which suggest it as a good source of such minerals as calcium, iron, sodium and potassium. However, there is no way to measure of its bioavailability which is dependent on several factors [24]. The variation in mineral content between the different samples gives a general sense of the mineral distribution in *D. Bulbifera* after processing.

The phosphorous (P) content of the solar dried samples was found to range from 34.2 to 42.3mg/100g with the steamed recording the highest value and the boiled recording the lowest value. The steaming and grating were able to maintain the phosphorus content in the yam flour. The values obtained in this study were lower than those obtained by Abara [26] for fresh tissue of bulbifera (64.40 and 150.00 mg/100 g) on wet and dry basis respectively and recorded in literature (37.00 and 62.15 mg/100g) [27-30]. Oven drying recorded a value of 35.7mg/100g for the control and 42.2mg/100g for the grated sample. The grating and boiled methods were also able to maintain the phosphorus content of the flour. Between the two drying methods, the P content recorded ranged from 34.2 to 42.3 with the solar (steamed) recording both the lowest and highest values. The values obtained in this study falls within the range of what is found in literature [11]. Calcium (Ca) content recorded ranged from 78.0 to 240.2mg/100g for solar drying with the control recording the highest value and grated the lowest. The significant differences ($p < 0.05$) observed indicated that steaming, boiling, solar drying and grating resulted in loss of calcium. The values observed in this study were found to be higher than those obtained by Abara [26] for *D. bulbifera* on wet and dry basis respectively (35.30 mg /100g and 205.60mg/100g). Barquar and Oke [31] and Abara [32] found 0.45% (450 mg/100 g) and 209.00 mg/100 g on dry weight basis. Oven drying recorded values between 96.5 and

191.9mg/100g with the control recording the lowest and the grated the highest value. The oven drying was able to maintain the calcium content of the yam flour. Between the oven and solar drying the range recorded was from 78.0 to 149.0mg/100g with the steamed oven dried obtaining the highest value and grated solar dried the lowest value. The differences observed between the calcium content in this study with other studies may be due to differences in species, composition of the soil in which it was grown, cultural practices, time of planting and water available [23]. Calcium is important for proper bone and teeth formation but as have been noted earlier on, its mere presence does not guarantee its availability as its absorption depends on the presence of vitamin D, oxalic and phytic acid [24].

Iron (Fe) content ranged from 8.2 to 9.5mg/100g with the control recording the highest and grated the lowest for solar drying. Boiling was able to maintain the iron in the flour whilst the other processing methods lost some iron. Oven drying recorded between 9.0 and 10.2mg/100g with the control recording the lowest value and both the boiled and steamed the highest. Between the oven and solar drying, the Fe content ranged from 8.2 to 10.2mg/100g with oven dried steamed and boiled both recording the highest and the boiled the lowest. Oven drying, steaming and boiling were able to maintain the iron content of the flour. The iron content of 8.2 to 10.2 mg/100 g obtained in this study for dry tissue is higher than any so far reported. FAO [27]; FAO [28]; Eka [29] and Egbe and Treche [30] reported 2.00, 1.68 and 1.30 mg/100 g respectively of iron in the tissue of *Dioscorea bulbifera* on fresh weight basis. Barquar and Oke [31] reported 3.46 ppm of iron on dry weight basis in the tissues of *Dioscorea bulbifera*. Oven drying in this study was able to maintain the iron content of the flour whilst solar drying and solar dried samples lost some amount of iron. From the values obtained in this study, it will be safe to conclude that *dioscorea bulbifera* may be a major source of dietary iron despite the presence of phytic acid

and in terms of processing oven drying will be recommended.

Sodium (Na) content recorded for solar drying ranged from 51.7 to 66.9mg/100g with the control obtaining the highest and boiled the lowest. Significant differences ($p < 0.05$) observed in all the treatments. Grating, steaming and boiling reduced the sodium content of the flour. This indication is good as hypertensive patients will be comfortable with foods low in sodium. Oven drying recorded a range from 50.0 to 89.1 with grated obtaining the highest and boiled the lowest. Between the two drying methods, Na content ranged from 51.7 to 89.1mg/100g with the highest value recorded by the oven drying. Oven dried grated sample increased in sodium indicating it will not be a good processing method for the yam. The values obtained in this study were lower than those recorded in literature. Abara [26] recorded a range of 220.00 and 550.00 mg/100 g on wet and dry weight basis respectively of the tissue, whilst Barquar and Oke [31] found 126.00 mg/100g. Available literature report indicates that the sodium content of yams including *Dioscorea bulbifera* is low therefore the values obtained in this study are acceptable. The differences observed in the various samples could be attributed to environmental and soil differences. This implies people who suffer from hypertension can safely consume the yam without fear of rising blood pressure.

Potassium (K) content ranged from 1270.8 to 1467.6mg/100g with the grated recording the highest and the boiled the lowest for solar drying. Oven drying recorded a range from 1026.6mg/100g for steamed sample and 1379.7mg/100g for grated sample. Between solar and oven drying the potassium content ranged from 1026.6 for oven drying and 1467.6 for solar drying. The values observed in this study were found to be higher than those reported in literature. Egbe and Treche [30] reported values of 337mg/100g whilst value of 440.00 mg/100 g found for the tissue on dry weight basis was recorded by Abara [26]. These values were found to be lower than the value of 1100mg/100g as reported by Barquar and Oke [31]. Grating, steaming and solar drying were able to maintain the potassium content of the flour whilst boiling reduced the potassium content. Meanwhile, grating, boiling and oven drying were able to maintain the potassium content whilst steaming solar dried lost some amount of potassium. From the results of this study, *D.bulbifera* is high in potassium and is not adversely affected by the treatments in this study which is good for maintaining normal blood pressure.

Ascorbic acid content observed for solar drying ranged between 77.78mg/100g for steamed and 138.67mg/100g for the grated sample. Oven drying recorded a low value of 53.33mg/100g for the control and a high value of 122.44mg/100g. Between the two drying methods the ascorbic acid content ranged from 53.33 for oven drying and 138.67mg/100g for solar drying. The study values were higher than the value of 1.67mg/100 recorded by

Okwu and Ndu [33] for *D. bulbifera*. The grated and solar dried samples were able to maintain much more vitamin C than the other treatment methods. For phosphorus, potassium and sodium the grated and oven dried samples maintained more minerals than the other methods. Overall the boiling and solar drying did not significantly change the amount of minerals in *D.bulbifera*.

Conclusions

The results of this study indicated that processing methods, oven drying, solar drying, grating, boiling and steaming has significant effect on the nutritional content. The variation in mineral content between the different samples gives a general sense of the mineral distribution in *D. Bulbifera* after processing. The grated and solar dried samples were able to maintain much more vitamin C than the other treatment methods. For both phosphorus and sodium the grated and oven dried samples maintained more minerals than the other methods. Overall boiling and solar drying did not significantly change the amount of minerals in *D. bulbifera*. Steamed and boiled oven drying methods have been found to be an efficient method to produce flour with good retention of nutritional properties.

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