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EFFECT OF BOILING AND ROASTING ON THE NUTRIENTS, PHYTOCHEMICAL AND FUNCTIONAL PROPERTIES OF RED AND GREEN CULTIVARS OF *D. BULBIFERA* FLOURS

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ABSTRACT

Two cultivars (green and red) of *Dioscorea bulbifera* were processed individually by boiling (100ºC, 25 min) or roasting (175ºC, 60 min) into flour. The processed and unprocessed samples were evaluated for nutrients, phytochemical and functional properties. The results revealed that the raw green cultivar had higher values (12.94, 8.19 and 3.06%) of moisture, protein, and ash, respectively than the red cultivar with 12.94, 8.19 and 3.06%, respectively. The red cultivar contains more fat (3.92%) and carbohydrate (75.05%) compared to the green cultivar with 3.20 and 69.16% values, respectively. The green cultivar contains more Mg and Zn contents (362.30 mg/100g and 1476.27 µg/100g, respectively) than the values (344.43 mg/100g and 1288.50 µg/100g, respectively) of the red cultivar. The phytochemicals; alkaloid, flavonoid, tannin, and diosgenin (3.27, 1.91, 0.29 and 176.42 mg/100g, respectively) were more in red cultivar than the green cultivar (3.06, 1.74, 0.26 and 162.24 mg/100g) while higher content of saponins (10.07 mg/100g) was observed in red cultivar than green cultivar (7.43 mg/100g). Boiling and roasting led to a reduction in Mg, Zn, vitamin C contents and all the proximate parameters in both cultivars except carbohydrates. The water absorption capacity, bulk density, swelling capacity of both treated cultivars increased, but roasting had a lower effect than boiling. Boiling and roasting reduced the alkaloid, tannin, flavonoid, saponin contents except diosgenin content of the two cultivars, with boiling inducing a greater effect than roasting.

Contribution/Originality: This study documents the most suitable processing method for *Dioscorea bulbifera flour* as related to maximizing nutrients and functionality. The potentials of *Dioscorea bulbifera cultivars* as a functional food ingredient which would encourage its increase in production and further utilization in diverse ways were also highlights.

1. INTRODUCTION

Dioscorea bulbifera also known as aerial yam is a semi-wild food crop that grows on vines climbing onto poles and trees in farmlands. It is cultivated in the West Africa, consumed by a small number of communities in some parts of Nigeria, South East Asia, and South and Central America. The wild form also occurs in both Asia and Africa (Ojinnaka, Odimegwu, & Ilechukwu, 2016). This aerial yam is classified in India as wild yam and medicinal plant (Shanthakumari, Mohan, & De Britto, 2008; Subhash, Sarla, & Jaybardhan, 2012). This yam has been known to be an unpopular yam among the edible yam species because it is not well known to all communities. The ever-increasing population and to address the food insecurity problem necessitates research into under-utilized and almost extinct crops like *D. bulbifera* which are less preferred compared to other yam species. In Asia, the tubers have been highly recommended for treating diabetes disorder and have been used traditionally into a reduction of blood sugar, for the provision of more sustainable energy form and enhance protection against obesity and diabetes (Ahmed et al., 2009; Chandra, Saklani, Mishra, & Bamrara, 2012).

Traditionally, aerial yams are claimed to possess therapeutic, purgative, analgesic and anti-inflammatory properties among others. Dried and powdered tubers have been used in the treatment of ulcers, hemorrhoids, syphilis, dysentery, breast lump, carbuncles and lung abscess (Ming-Hua & Sen-Rong, 2010). Some bioactive components in *Dioscorea bulbifera* such as flavonoids can be used to solve the problem of hyperglycaemia and hyperlipidemia; conditions associated with diabetes. Such properties are due to the presence of phytochemicals. However, *D. bulbifera* contains rich amount of saponins and oxalate. Saponins lower blood cholesterol thus reducing heart disease. Although, saponins also functions as antioxidants and antifungal, they are also known to impair protein digestion, vitamins and minerals assimilation in the gut, and leads to hypoglycaemia among others. Tannins, alkaloids and hydrogen cyanide are also found in *Dioscorea bulbifera* (Celestine & David, 2015). Tannins are found in plant foods and strongly inhibit iron absorption by forming insoluble chelates (Roos et al., 2013). (Dioscorine is an important alkaloid found in Dioscorea species which is naturally toxic but can be removed by washing and cooking (Eka, 1998).

Dioscorea bulbifera bulbs need to be processed to an edible form, as they cannot be used in the raw state. The tubers often have a bitter taste which can be removed either by soaking or boiling for detoxication (Kay, 1987) before eating. In Asia detoxication and roasting of the grated tuber are used for processing bitter cultivars of this yam while Celestine and David (2015) reported that boiling and roasting are the common methods of preparing *D. bulbifera* for consumption by the South Eastern Nigeria and it is subsequently eaten with vegetable sauce or palm oil. The bulb is eaten on peeling off the hardback after cooking. The boiled tubers are also sliced and sun-dried to form echa, which can be stored for long and used at periods of food scarcity and the bitter taste of *D. bulbifera* disappears after proper boiling or roasting in traditional processing (Celestine & David, 2015). These processing methods may also affect other bioactive ingredients contained in *Dioscorea bulbifera*. Hence, a processing method that will not drastically deplete the bioactive components below the level required for the functionality has to be established. Also the correct processing techniques need to be employed to achieve the maximal nutrient composition of the crop (Princewill-Ogbonna & Ibeji, 2015). It is envisaged that the result of this study will be able to highlight the most suitable processing method for *Dioscorea bulbifera* as related to maximizing the bioactive ingredients and also individual potentials of each cultivar; this would encourage an increase in its production and encourage further utilization in diverse ways.

2. MATERIALS AND METHODS

2.1. Materials

Two cultivars of *D. bulbifera* (red and green) were purchased from the Orba market, Enugu State. The yam cultivars were identified and authenticated by the Department of Plant Science and Biotechnology, University of Nigeria, Nsukka, Nigeria. Chemicals and reagents used were procured from accredited chemical dealers.

2.2. Methods

Bulbs from two different cultivars (green and red) of *Dioscorea bulbifera* were divided into three portions (3000 g) per cultivar, washed in tap water and processed as in Figure 1. One portion (1000 g) was peeled, boiled (100 °C, 25 min) and sliced into chips of 5±1 mm thickness; the second portion (1000 g) was roasted (100 °C, 60 min). The third portion (1000 g) which was not processed, served as control. The chips were oven-dried at 65 °C for 12 h, cooled for 30 min in a desiccator, milled using a Kenwood blender (1.5l-BL440a) and sieved through 0.25 mm mesh and then packaged in polyethylene bags until used.

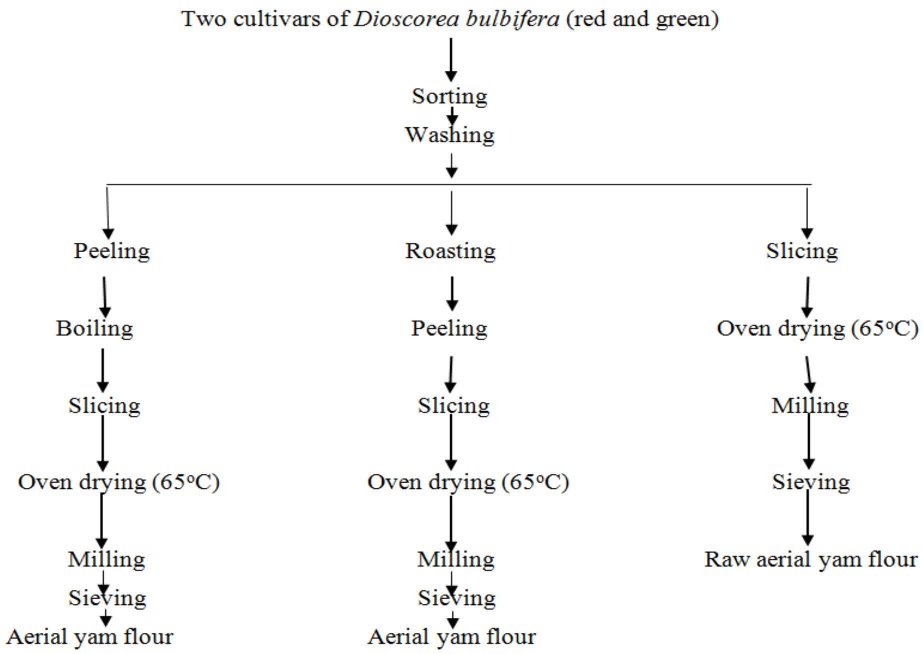

Figure-1. Production of *Dioscorea bulbifera* flours

2.3. Determination of Nutrient Composition

The moisture, protein, fat, fibre and ash contents of the red and green cultivars and control were determined by AOAC (2010) methods. The sample's carbohydrate was determined by difference: % carbohydrate = 100 – (% moisture + protein + % ash + crude fibre + fat). The calorific content was calculated as: Calorie (Kcal/100g) = (4 x % carbohydrate) + (4 x protein) + (9 x % fat). The method of Olokodona (2005) was used to analyze vitamin C content while magnesium and zinc contents were analyzed according to Shahidi, Chavan, Bal, and McKenzie (1999) methods.

2.4. Determination of Phytochemicals

Tannin was determined using the method of Price and Butler (1997). Alkaloid was analyzed by the Harborne (1976) methods. The analysis of flavonoid, Saponin and diosgenin contents were carried out by Boham and Kocipai (1994); Obadoni and Ochuko (2001) and TLC method of Harborne (1976) as modified by Shah and Lele (2012) respectively.

2.5. Functional Properties Determination

The method described by Okaka and Potter (1977) was used to analyze the bulk density, methods described by Sathe and Salunkhe (1981) for water absorption capacity, Coffman and Garcia (1977) for least gelation capacity while swelling capacity was carried out according to Takahashi and Seib (1988) method

2.6. Experimental Design and Statistical Analysis

The Completely Randomized Design (CRD) was used to design experiments. One way Analysis of Variance (ANOVA) was used to analyze all data obtained and statistical significance was accepted at $p < 0.05$. Means separation was carried out with Duncan's new multiple range tests.

3. RESULTS AND DISCUSSION

3.1. Proximate Composition of Red and Green Cultivars of D. Bulbifera

The proximate composition of two cultivars of *D.bulbifera* (aerial yam) is presented in Table 1. The samples showed moisture values between 4.44 and 12.94%. The raw green aerial yam (RGAY) had higher moisture content (12.94%) than the raw red aerial yam (RRAY) (9.59%). More moisture reduction was observed in samples processed by roasting. These findings agree with Ayo, Ojo, and Obike (2018) who reported moisture contents of 10.37% and 9.50% for green aerial yam and roasted green aerial yam, respectively. Rapid heating and high temperature of roasting which causes complex changes in the components of the food may be the reason (Fellows, 2005). The moisture contents of the raw cultivars were higher than the values (7.41 and 7.16%) reported by Princewill-Ogbonna and Ibeji (2015) for red and green cultivars, respectively. This slight difference could be associated with the level of maturity, environmental factors and experimental method of analysis (Okonkwo & Opara, 2010; Shanthakumari et al., 2008). The moisture content reflects the quantity of solid matter present in the sample and the rate of spoilage is also related to the volume of moisture existing in foods (Sanful, Oduro, & Ellis, 2013). The level of moisture in this study shows that the boiled and roasted aerial yam flour may have low spoilage capacity owing to their low moisture level.

The protein content of the samples varied from 3.14-8.19%. The raw green aerial yam (RGAY) contains more protein (8.19%) than the raw red aerial yam (RRAY) flour (5.29%). Princewill-Ogbonna and Ibeji (2015) reported protein values of 6.82 and 7.27% for red and green cultivar, respectively while Ayo et al. (2018) reported protein value of 7.59% for green aerial yam flour. These values are similar 7.11 and 5.34% for boiled and roasted green aerial yam flour, respectively observed in this work and comparably higher than values of 5.15% for white yam and 4.88% for water yam flour reported by Alaise and Llinden (1999). However, the protein content of the boiled (4.08%) and roasted (3.14%) red aerial yam (BRAY and RoRAY) observed in the present study are quite lower than the value of 15.75% reported by Shanthakumari et al. (2008) for wild aerial yam flour. The reduction in protein content of the boiled aerial yam flour may be attributable to the loss of free amino acids due to leaching (Ezeocha, Ojimelukwe, & Onwuka, 2012) while the susceptibility of proteins to heat, as well as evaporation, may be accountable for the reduction in the protein content of the roasted aerial yam flour. The variations among the protein content of the cultivars could be attributed to the variations in factors such as climate, maturity at harvest and length of storage time (Princewill-Ogbonna & Ibeji, 2015).

Table-1. Proximate composition (%) of red and green cultivars of *D.bulbifera* (aerial yam) flour processed by boiling and roasting.

Sample	Moisture	Protein	fat	Fibre	Ash	Carbohydrate
RGAY	$12.94^{a}\pm0.03$	$8.19^{a}\pm0.04$	$3.20^{d}\pm0.00$	$3.45^{a}\pm0.05$	$3.06^{a}\pm0.04$	$69.16^{f}\pm0.08$
BGAY	$11.31^{b}\pm0.03$	$7.11^{b}\pm0.03$	$2.10^{f}\pm0.01$	$2.91^{d}\pm0.02$	$2.87^{e}\pm0.13$	$73.70^{e}\pm0.10$
RoGAY	$7.27^{e}\pm0.04$	$5.34^{c}\pm0.01$	$2.84^{e}\pm0.01$	$3.24^{c}\pm0.04$	$2.27^{d}\pm0.01$	$79.04^{b}\pm0.07$
RRAY	$9.59^{c}\pm0.04$	$5.29^{d}\pm0.01$	$3.92^{a}\pm0.02$	$3.47^{a}\pm0.03$	$2.68^{b}\pm0.04$	$75.05^{d}\pm0.08$
BRAY	$8.53^{d}\pm0.03$	$4.08^{e}\pm0.02$	$3.50^{c}\pm0.00$	$2.95^{d}\pm0.05$	$2.08^{f}\pm0.01$	$78.86^{c}\pm0.05$
RoRAY	$4.44^{f}\pm0.04$	$3.14^{f}\pm0.01$	$3.77^{b}\pm0.02$	$3.34^{b}\pm0.04$	$2.41^{c}\pm0.04$	$82.90^{a}\pm0.06$

Note: Values are means of triplicate determinations ± SD. Means in the same column with different superscripts are significantly ($p < 0.05$) different.
Keys: RGAY= raw green aerial yam flour; BGAY= boiled green aerial yam flour; RoGAY= roasted green aerial yam flour; RRAY= raw red aerial yam flour; BRAY= boiled red aerial yam flour; RoRAY= roasted red aerial yam flour.

The fat content of the green and red aerial yam flour varied from 2.10-3.92%. The raw green aerial yam flour (RGAY) fat content (3.20%) was lower than that of the raw red aerial yam flour (RRAY) (3.92%). Boiling had higher reduction effect on fat contents of both cultivars the boiled green aerial yam flour (BGAY) having fat content of 2.10% and the boiled red aerial yam flour (BRAY) fat content of 3.50% while the roasted samples had fat contents of 2.84% and 3.77%, respectively. The fat content observed in the present work varies from the reported values for the red cultivar (2.21%) and the green cultivar (0.37%) by Princewill-Ogbonna and Ibeji (2015). Ayo et al. (2018) reported a fat content of 3.86% for the green aerial yam flour which is higher than the value (3.20%) for green yam flour in this study but close to the value (3.92%) obtained for the raw red aerial yam flour (RRAY). Yams generally contain low levels of fat (Ngoddy, 1985). The fat contributes to the palatability of the crop.

The crude fibre content of the samples ranged between 2.91 and 3.47%. The raw red aerial yam flour had a comparable fibre value (3.47%) with the raw green aerial yam flour (3.45%) and the values were comparatively higher than the values of 1.88 and 1.64%, respectively reported by Princewill-Ogbonna and Ibeji (2015). Shanthakumari et al. (2008) reported fibre contents of 3.92% which is slightly higher than the values obtained for the raw cultivars of aerial yam flour. Boiling reduced the fibre content of the cultivars significantly ($p<0.05$) more than roasting as the boiled green aerial yam flour (BGAY) had a fibre content of 2.91% and boiled red aerial yam flour (BRAY) fiber content of 2.95% while the roasted samples had fiber contents of 3.24% and 3.34% for the roasted green aerial yam flour and roasted red aerial yam flour, respectively. An increase in the fibre content of roasted aerial yam flour was earlier reported by Ayo et al. (2018). The variation in fibre among the experimental samples was attributable to differences in experimental methods, geographical locations, and climate conditions. Fibre is essential in food; it absorbs water, provides roughage for the bowels and supports intestinal transit. Fibre causes lowering of total cholesterol and LDL cholesterol, regulation of blood pressure and causes water attraction and gel formation in digestion, which results in carbohydrate trapping and reduces glucose absorption, consequently lowering blood sugar levels (Dhingra, Michael, Rajput, & Patil, 2012).

The ash content of the samples ranged between 2.08 and 3.06% and that of raw green aerial yam flour (RGAY) (3.06%) was higher than that of raw red aerial yam flour (RRAY) (2.68%). The values obtained for the ash content of both cultivars in this work were comparably lower than the values of 3.77 and 3.97% reported by Princewill-Ogbonna and Ibeji (2015) for raw green and red aerial yam flour, respectively but comparatively higher than the values of ash between 2.16% and 2.37% reported by Ayo et al. (2018) for pre-heated aerial yam flour. Boiling and roasting significantly ($p<0.05$) reduced the ash content of the aerial yam cultivars flour. Upon boiling, a value of 2.17 and 2.08% were obtained for BGAY and BRAY, respectively while values of 2.27 and 2.41% were obtained for the roasted samples, respectively. The ash content reflected in this study suggests that *D.bulbifera* is rich in minerals.

The carbohydrate content ranged between 69.16 and 82.90% which fell within the values (50-84.9%) of most root crops (Bukola, 2018). The raw red aerial yam flour (RRAY) contained more carbohydrates (75.04%) than the green raw aerial yam flour (GRAY) (69.16%). The carbohydrate content of the roasted red aerial yam flour was more than that of the other processed aerial yam flours. Carbohydrate content of 75.81% reported by Ayo et al. (2018) for raw aerial yam was comparable to the values obtained in this current study for the raw aerial yams. Princewill-Ogbonna and Ibeji (2015) reported comparable carbohydrate values of 77.41% and 77.16% for red and green cultivars, respectively. The carbohydrate content of yams is affected by age of the tuber, species and cultivar differences (Martin, 1979). These factors may be responsible for the observed variation in the carbohydrate content of *D. bulbifera* flour.

3.2. Vitamin C and Mineral Contents of Flours of Boiled and Roasted Red and Green Cultivars of D. Bulbifera

Table 2 shows the vitamin C contents of the green and the red aerial yam flours. Both cultivars had the same vitamin C content (0.28 mg/100g). Boiling produced marginal reduction on the vitamin C content of the green aerial yam flour (BGAY) and significant reduction on that of the boiled red aerial yam flour (BRAY) (0.27 and 0.25 mg/100g, respectively). The loss may be due to leaching into the water during boiling and /or loss due to application of heat as vitamin C is soluble in water and heat sensitive. Roasting caused higher loss of vitamin C in both *D. bulbifera* flours of RoRAY and RoGAY (0.21 and 0.22 mg/100g, respectively). This further decrease due to roasting could be attributed to the heat-labile nature of vitamin C through the use of dry heat. The values obtained for the raw red and raw green aerial yam flour were slightly close to the values obtained for the yellow cultivar (0.26 mg/100g) and higher than the values obtained for the green cultivar (0.13 mg/100g) and red cultivar (0.04

mg/100g) by Princewill-Ogbonna and Ibeji (2015). The yam samples are not good sources of vitamin C. Low vitamin C has been said to be associated with an increased risk of developing diabetes. Vitamin C is a powerful antioxidant and oxidative stress can upset glucose metabolism and hyperglycaemia (Opara, 2004). Antioxidants are beneficial in the preventing and/or management of diabetes (Christie, Girgis, & Gunton, 2014). Vitamin C also favors the absorption of iron in the intestines, protects against infections and intervenes in the healing of wounds (Roger, 1999).

Table 2 also shows the results of the mineral contents of the green and red aerial yam flours processed by boiling and roasting. Raw green aerial yam flour (RGAY) had a significantly ($p<0.05$) higher magnesium (362.30 mg/100g) content than raw red aerial yam flour (RRAY) (344.43 mg/100g). Both boiling and roasting reduce the magnesium content of the green and red cultivars by 5.9-6.9 and 1.7-4.7%, respectively. More reduction of magnesium contents was observed in boiled flours than in roasted flour samples. Higher magnesium content for aerial bulbs (758.94 mg/100 and 440.17 mg/100g) than the values in the present work has been reported earlier by Celestine and David (2015) and Shanthakumari et al. (2008). Pham, Pham, Pham, Miller, and Pham (2007) reported that hypomagnesemia occurs at an increased frequency in patients with type 2 diabetes and is connected to poor glycemic control, coronary artery diseases as well as diabetic retinopathy. Diabetes may induce hypomagnesemia, however, high consumption of magnesium may result in a lower risk for type 2 diabetes (Kao et al., 1999; Lopez et al., 2004; Song, Manson, Buring, & Liu, 2004; Van, Hu, Rosenberg, Krishnan, & Palmer, 2006). Consumption of processed *D.bulbifera* yam flour may confer an advantage.

Table-2. Vitamin C and mineral contents of red and green cultivars of *D.bulbifera* (aerial yam) flour processed by boiling and roasting.

Sample	Vitamin C (mg/100g)	Mg (mg/100g)	Zn (µg/100g)
RGAY	$0.28^{a}\pm0.02$	$362.30^{a}\pm0.36$	$1476.27^{a}\pm0.47$
BGAY	$0.27^{ab}\pm0.02$	$340.88^{c}\pm0.60$	$1284.61^{b}\pm0.53$
RoGAY	$0.22^{c}\pm0.01$	$345.30^{b}\pm0.08$	$1109.47^{c}\pm12.04$
RRAY	$0.28^{a}\pm0.01$	$344.43^{b}\pm0.38$	$1288.50^{b}\pm0.79$
BRAY	$0.25^{b}\pm0.01$	$320.64^{e}\pm0.21$	$1078.62^{d}\pm15.06$
RoRAY	$0.21^{c}\pm0.01$	$338.48^{d}\pm1.29$	$831.87^{e}\pm7.35$

Note: Values are means of triplicate replications ± SD. Means in the same column with different superscripts are significantly ($p < 0.05$) different.
Keys: RGAY= raw green aerial yam flour, BGAY= boiled green aerial yam flour, RoGAY= roasted green aerial yam flour, RRAY= raw red aerial yam flour, BRAY= boiled red aerial yam flour, RoRAY= roasted red aerial yam flour.

The zinc content of the flour samples ranged between 831.87 and 1476.27 µg/100g. The raw green aerial yam flour (RGAY) had higher magnesium content (1476.27 µg/100g) than the raw red aerial yam (1288.50 µg/100g). A decrease in zinc contents was observed in roasted green and red aerial yam flours (RoGAY) and (RoRAY) and the reduction was significant ($p<0.05$). Both boiling and roasting reduced the zinc contents in both cultivars by 12.98 - 16.29% and 24.85-35.44%, respectively The values obtained in this work vary from the values (0.17-0.36 mg/100g) reported by Celestine and David (2015). Shanthakumari et al. (2008) reported the zinc content of aerial bulbs to be 1.30 mg/100g which is similar to the values obtained in this study. The aerial yam samples are good sources of zinc. Hegazi, Ahmed, Mekkawy, Mortagy, and Abdelkadder (1992) noted insulin secretions were improved in patients with type-2-diabetes when zinc was supplemented. Also, hypoglycemic properties, as well as insulin-mimetic properties, have been shown by zinc complexes (Yoshikawa, Ueda, Miyake, Sakurai, & Kojima, 2001).

3.3. Functional Properties of Red and Green Cultivars D.Bulbifera

Table 3 presents the result of the functional properties of green and red *D. bulbifera* cultivar flours. The water absorption capacity of the samples ranged between 56.44 and 75.98%. The raw green aerial yam flour (RGAY) had water absorption capacity of 65.40% and the raw red aerial yam flour (RRAY) water absorption capacity of 56.44%. Upon boiling, the water absorption capacity of the samples increased which was more in green aerial yam flour than the red variety (75.98% and 72.59%, respectively). Roasting increased the water absorption capacity of the samples as seen in the observed values for roasted green aerial yam (68.87%) and roasted red aerial yam flour (59.52%) but not as much as boiling. Princewill-Ogbonna. and Ezembaukwu (2015) also reported an increase in the water absorption capacity of boiled aerial yam flour. Products with more hydrophilic constituents give rise to higher water absorption capacity (Akubor & Eze, 2012). Flour with high water absorption capacity is suitable for baking (Kohnhorst, Uebersax, & Zabik, 1990) hence, the samples will find applications in bakery industry.

Table-3. Functional properties of red and green cultivars of D.Bulbifera (Aerial Yam) flour processed by boiling and roasting.

Sample	Water Absorption Capacity (%)	Bulk density (g/ml)	Swelling Capacity (%)	Gelation Capacity (%)
RGAY	$65.40^{d}\pm0.62$	$0.71^{c}\pm0.02$	$70.25^{c}\pm0.04$	$15.00^{b}\pm0.00$
BGAY	$75.98^{a}\pm1.01$	$0.82^{a}\pm0.03$	$82.68^{a}\pm1.06$	$4.00^{f}\pm0.00$
RoGAY	$68.87^{c}\pm0.23$	$0.75^{bc}\pm0.01$	$73.64^{b}\pm0.29$	$8.00^{d}\pm0.00$
RRAY	$56.44^{f}\pm0.52$	$0.66^{d}\pm0.03$	$65.88^{e}\pm0.20$	$16.00^{a}\pm0.00$
BRAY	$72.59^{b}\pm0.73$	$0.79^{ab}\pm0.02$	$70.15^{c}\pm0.14$	$6.00^{e}\pm0.00$
RoRAY	$59.52^{e}\pm0.56$	$0.71^{c}\pm0.04$	$68.53^{d}\pm0.70$	$10.00^{c}\pm0.00$

Note: Values are means of triplicate relications ± SD. Means in the same column with different superscripts are significantly ($p<0.05$) different.
Keys: RGAY= raw green aerial yam, BGAY= boiled green aerial yam, RoGAY= roast green aerial yam, RRAY= raw red aerial yam, BRAY= boiled red aerial yam, RoRAY= roast red aerial yam.

The raw green aerial yam flour (RGAY) and the raw red aerial yam flour (RRAY) had bulk densities of 0.71 and 0.66 g/ml, respectively. Boiling and roasting significantly ($p<0.05$) increased the sample bulk density and the increase was more in boiled flour samples compared to the roasted flour samples. The findings of this result corroborate that of Princewill-Ogbonna. and Ezembaukwu (2015) who earlier reported an increase in bulk density of roasted aerial yam flour. Bulk density measures how heavy the flour sample is. Low bulk density confers an advantage in food products digestion particularly for infants and also in transportation cost while products high bulk density may confer advantages particularly as thickeners for food products with high dispensability (Udensi & Eke, 2000). Bulk density is essential for packaging requirements determination, material handling and use of wet processing in the food industry (Ocloo, Bansa, Boatin, Adom, & Agbemavor, 2010). The aerial yam flour samples may find applications in production of infant foods and food for diabetic patients due to their low bulk density (Jimoh, Olurin, & Aina, 2009) as both calorie and nutrient density is enhanced per feed of the child.

The raw green aerial yam flour (RGAY) and raw red aerial yam flour (RRAY) had a swelling capacity of 70.25 and 65.88%, respectively. The values observed in the present study indicate that boiling and roasting increased swelling capacities significantly ($p<0.05$). Boiled green aerial yam flour (BGAY) and boiled red aerial yam flour (BRAY) had swelling capacities of 82.68 and 70.15%, respectively which were higher than those of the roasted samples (73.64 and 68.53%, respectively). Higher swelling index in boiled aerial yam flour than in roasted sample was in agreement with the findings of other researchers (Princewill-Ogbonna. & Ezembaukwu, 2015). Swelling capacity indicates the index of water absorption capacity of the flour granules during heating (Loos, Hood, & Graham, 1981). The high swelling capacity of flour could be an advantage in dough development in baked foods (Ayo et al., 2018). The gelation capacity of the samples varied from 4-16%. Raw red aerial yam flour (RRAY) had a higher gelation capacity than raw green aerial yam flour (RGAY). Gelation capacity was reduced more in both cultivars by boiling. The basic function of the gel is to bind or solidify the free water in food (Onimawo & Akubor, 2012). Gelation capacity is linked to water absorption capacity; this could explain the high values for the swelling capacity observed in the boiled samples.

3.4. Phytochemical Components of Green and Red Cultivar Flours of D.Bulbifera as Affected by Processing Methods

The results of the effect of boiling and roasting on the phytochemical contents of red and green *D.bulbifera* (aerial yam flour) are presented in Table 4. The alkaloid content of the flour samples ranged between 2.06 and 3.27 mg/100g. The raw green aerial yam flour.

Table-4. Phytochemical content (mg/100g) of red and green cultivars of *D.bulbifera* (aerial yam) flour processed by boiling and roasting.

Samples	Alkaloid	Flavonoids	Tannins	Saponins	Diosgenin
RGAY	$3.06^{b}\pm0.06$	$1.74^{b}\pm0.10$	$0.26^{ab}\pm0.03$	$10.07^{a}\pm0.04$	$162.47^{b}\pm0.86$
BGAY	$2.06^{f}\pm0.03$	$0.79^{f}\pm0.04$	$0.15^{cd}\pm0.01$	$8.68^{c}\pm0.04$	$124.13^{d}\pm0.87$
RoGAY	$2.19^{e}\pm0.01$	$1.05^{e}\pm0.05$	$0.18^{cd}\pm0.05$	$9.49^{b}\pm0.03$	$108.26^{f}\pm0.95$
RRAY	$3.27^{a}\pm0.06$	$1.91^{a}\pm0.03$	$0.29^{a}\pm0.04$	$7.43^{d}\pm0.51$	$176.42^{a}\pm1.08$
BRAY	$2.57^{d}\pm0.12$	$1.26^{d}\pm0.04$	$0.13^{d}\pm0.05$	$5.26^{f}\pm0.02$	$137.34^{c}\pm0.50$
RoRAY	$2.87^{c}\pm0.07$	$1.53^{c}\pm0.14$	$0.21^{bc}\pm0.01$	$6.21^{e}\pm0.02$	$118.89^{e}\pm0.65$

Note: Values are means of triplicate determinations ± SD. Means in the same column with different superscripts are significantly ($p < 0.05$) different.
Keys: RGAY= raw green aerial yam, BGAY= boiled green aerial yam, RoGAY= roast green aerial yam, RRAY= raw red aerial yam, BRAY= boiled red aerial yam, RoRAY= roast red aerial yam.

(RGAY) had a lower (3.06 mg/100g) alkaloid value than the raw red aerial yam flour (RRAY) (3.27 mg/100g) indicating that red cultivars contain more alkaloids than the green cultivars. Ayo et al. (2018) reported alkaloid value of 0.19 mg/g for green aerial yam flour while Okwu and Ndu (2006) reported value of 0.88mg/100g in a *D. bulbifera* cultivar which are comparably lesser than the values seen in this work. Boiling and roasting had a significant ($p<0.05$) effect on the alkaloid contents of both cultivars with boiling reduced it to lower levels (2.06% in green cultivar and 2.57% in the red cultivar) compared to roasting (2.19% and 2.87%, respectively). Alkaloids have a bitter taste which can be removed by washing and cooking (Eka, 1998) and also many pharmacological activities such as antihypertensive and anticancer effects and antimalarial activity (quinine) (Wink, Schmeller, & Latz-Brüning, 1998).

The flavonoids contents of the samples ranged between 0.79 and 1.91 mg/100g which are lower than the flavonoid content reported by Okwu and Ndu (2006) in *D. bulbifera* (8.04 mg/100g). Boiling and roasting had a reduction effect on the flavonoid contents of the *D. bulbifera* flours with higher reduction achieved with boiling (54.6% loss in BGAY and 34% loss in BRAY) compared to roasting (38.5% reduction in RoGAY and 20% reduction in RoRAY). The reduction in flavonoid contents of the red and green cultivars by boiling and roasting in this work also agrees with the work of McWilliams (1979) who reported that flavonoids are destroyed by heat processing methods like drying, roasting and boiling. Flavonoids are potent antioxidants that can prevent the negative effect of free radicals and reactive oxygen species on the human body (Mamta, Ghosh, & Pande, 2013).

The raw red aerial yam flour (RRAY) contains more tannin (0.29 mg/100g) than the raw green aerial yam flour (RGAY) (0.26 mg/100g). These values compared well with the values of 0.22 and 0.18 mg/100g for raw green and red cultivars, respectively reported by Princewill-Ogbonna and Ibeji (2015). Boiling caused higher reduction in the tannin contents of the yams than roasting as the boiled green aerial yam flour and the boiled red aerial yam flour contained less tannins (0.15 mg/100g and 0.13 mg/100g, respectively) compared to the roasted samples (0.18 and 0.21 mg/100g, respectively). Trace quantities of tannin in yam tubers act as an anti-rot agent. Tannins bind also with protein and minerals to form a soluble complex, thereby reducing protein and mineral bioavailability (Liener & Kakade, 1980). The thermal degradation and denaturation of the tannin during the cooking processes may have caused a reduction in tannin content (Kataria, Chauhan, & Sunita, 1989).

The raw green aerial yam flour (RGAY) contained more saponins (10.07 mg/100g) than the raw red aerial yam flour RRAY (7.43 mg/100g). A higher value (14.03 and 8.49 mg/100g) of saponins for green and red cultivar were reported by Princewill-Ogbonna and Ibeji (2015). A significant ($p<0.05$) reduction in the saponin contents of the green and red cultivars upon boiling (8.68 and 5.26 mg/100g, respectively) and roasting (9.49 and 6.21 mg/100g, respectively) were observed and the effects were higher in boiled samples than roasted samples. Saponins have a bitter taste which can be reduced by cooking. They also lower blood cholesterol thus reducing heart disease. Saponins exhibit hemolytic activity and properties of binding cholesterol (Sodipo, Akiniyi, & Ogunbameru, 2000). The observations in the present work were contrary to the report made by Ayo et al. (2018) that the saponins content of green aerial yam flour was 1.27 mg/g and the value for the roasted sample being 0.39 mg/g. The higher ability of the phytochemicals to be hydrolyzed during boiling may have contributed to the observed reduction in the present study (Ezeocha et al., 2012).

The values for the diosgenin contents ranged between 108.26 and 176.42 mg/100g. Diosgenin was more in the raw red aerial yam flour (RRAY) (176.42 mg/100g) than in the raw green aerial yam flour (RGAY) (162.47 mg/100g). Both boiling and roasting had a reduction effect on the diosgenin content of the green and red cultivars. However, roasting had a higher effect compared to boiling. Diosgenin has been said to be useful in the treatment of diabetes through the promotion of adipocyte differentiation and inhibition of inflammation of adipose tissues (Mafalda, Ana, Martins, & Samuel, 2016). The observation of this work suggests that diosgenin is heat-labile.

4. CONCLUSION

This study has shown that two cultivars of aerial yam can be processed by boiling and roasting and subsequently milled into flour. The green cultivar contains more protein and ash contents while the red cultivar had more fat, fibre and carbohydrate contents. Boiling improved the functional properties of the aerial yam flour than roasting in both cultivars. The green cultivar had a water absorption capacity of 65.40%, a bulk density of 0.71 g/ml, a swelling capacity of 70.25% and a gelation capacity of 15%. *Dioscorea bulbifera* flour showed the potentials of being used as a functional food ingredient based on its high functional properties. *Dioscorea bulbifera* was rich in phytochemicals, which were more in red aerial yam flour than the green cultivars. Boiling caused a higher reduction of phytochemicals in both cultivars than roasting.

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