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Research Article

Effects of Boiling and Frying on Nutritional and Antioxidant Properties of Three Sweet Potato Cultivars (*Ipomoea batatas* L (Lam)) in North-Western Nigeria

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ABSTRACT

Sweet potato (*Ipomoea batatas*), is a creeper of *Convolvulaceae* morning glory family. It is widely cultivated as an essential staple food in most parts of the world. Nutrition has a significant role in preventing many chronic diseases, such as cardiovascular diseases, cancers, and degenerative brain diseases. This study determined the effects of boiling and frying on the nutritional constituents of three *I. batatas* cultivar (red, white and purple skinned-cultivars). The samples were analyzed for antiradical activity, total phenolic content, ascorbic acid, β-carotene and proximate compositions. The results showed that, the β-carotene, ascorbic acid, total phenolic contents and the mineral compositions of the raw samples were generally higher than those of the treated samples. On the other hand, the anti-radical scavenging activity of the treated samples is higher than the raw samples. The results of the nutritional composition analysis show that all the three cultivars have no significant differences ($p<0.05$) in total ash, crude fiber and carbohydrate content with the processing methods. These findings are invaluable in the choice of cooking procedures of potatoes.

Keywords: *Ipomoea batatas, Cultivars, Cooking methods, Effects, Proximate constituent*

INTRODUCTION

Ipomoea batatas (sweet potato), a creeper of Convolvulaceae family/morning glory family, originated from Central America and is widely cultivated as important stable food in most part of the world. The plant is perennial; the roots are edible fleshly, storage underground stem node. The leaves are single heart-shaped and the flowers are monocots the roots are the edible part. This is a character shown by only this species within the *Ipomoea* family. Furthermore, it is one of the world most important food crops due to its high nutritional and antioxidant properties (Islam *et al*., 2003). *Ipomoea batatas* is a crop with easy adaptability to a wide range of agro-economic conditions (e.g. temperature, drought, low soil fertility). Recent studies have shown that *I. batatas* contains such functional components as anthocyanins and dietary fibers which are essential for humans (Teow *et al*., 2007). It is also rich in nutrients, vitamins and anti-oxidants such as Total Phenolic Contents (TPC) and ascorbic acid (vitamin C, and carotenoids). Again, it has been showed that *I. batatas* contain all the above mentioned anti-oxidants, minerals and vitamins (Islam *et al*., 2003). The two most familiar ways of consuming *I. batatas* in Katsina State are boiling and frying. These methods of processing *I. batatas* for consumption make it palatable; however, they could have attendant adverse effects on the proximate compositions of the potatoes (Wang and Kays, 2001). Although, processing could result in the loss of some nutrients, it can also convert other nutrients into a form that would otherwise not be used by human body. Yet again, processing yields desired texture, flavor and palatability in food (Xu *et al*., 2016). *I. batatas* cultivars have abundant secondary metabolites like anthocyanins, carotenoids and phenolic acid and also rich in vitamin C, vitamin B6, carbohydrates and dietary fibers. According to F.A.O. (Oke *et al*., 1990), the leaves and roots are good sources of vitamin A, C and B2 (riboflavin) and lutein. Among the different cultivars of *I. batatas* species the dark orange flesh is reported to have the highest contents of beta-carotene compared to the white cultivars, this reason has witness an increase in the production of colored cultivar in Africa where there is vitamin A deficiency relative to other parts of the world (van Jaarsveld *et al*., 2005). Some studies have shown that *I. batatas* contains such functional components as polyphenols, anthocyanins and dietary fibers which are important for human health (Islam *et al*., 2003). Cooking can be detrimental and beneficial to the nutrient contents of food (Chukwu, 2009). The common methods of frying include shallow frying, sautéing, stir frying and deep-fat frying in vegetable oil or melted animal fats. Food industries use these methods of frying in enhancing the texture, quality and flavor of foods like French fries, doughnuts and poultry products (Xu *et al*., 2016). Frying involves the immersion of food products in hot oil (about 175˚C) and continuous cooking until the desired property of the product is obtained. The duration of cooking, type of oil and food product surface greatly affects the texture, flavor and quality attributes of the food (Tareke *et al*., 2002).

Frying technique affects the proximate structures of roots and tubers and each bit of food fried in it. The decision of sautéing fat relies upon numerous elements, for example, accessibility, cost, searing execution, flavor and soundness of item during capacity. As profound fat browning is ordinarily done at high temperatures (somewhere in the range of 160°C and 180°C) and within the sight of air and dampness, these searing oils and fats will go through physical and substance weakening which will influence their broiling execution and the capacity steadiness of the sautéed items (Fauziah *et al*., 2000). Furthermore, highly oxidized oils may also produce polyaromatic hydrocarbons that are thought to have a carcinogenic effect (Rahman *et al*., 2007).

Few reports have been published about the influence of cooking methods on different cultivars of *I. batatas* with respect to functional and nutritional compounds. However, to the best of our knowledge there is no information available about the influence of boiling and frying on the nutritional composition of three cultivars of *I. batatas* (red, white and purple) grown in Nigeria. Boiling and frying are the most common cooking approaches in Nigeria. This study is therefore, aimed at investigating the effect(s) of boiling and frying on the nutritional composition of three cultivars of *I. batatas*.

MATERIALS AND METHODS

Materials

Collection of potatoes

Ten (10) kg each of *I. batatas* cultivars (red, white and purple) where harvested in September 2018 at three different Sites (Figure 1). The white one were cultivate at Wagini, Batsari Local Government, Katsina state, Nigeria. The Red one was cultivated at Zangon Kataf Local Government, Kaduna State, Nigeria and the purple one from Gboko Benue State, Nigeria. Some part of the *I. batatas* portion was used for the preliminary test and the remaining parts were used for boiling, frying and as fresh *I. batatas* samples.

Cooking procedures

Boiling

The sorted tubers of white, red and purple cultivars of 2.0 kg were boiled by submerging them in boiling water (95–100^{0}C) in a stainless steel pot for 20, 25, and 30 min, respectively. The boiling was maintained using a hot plate. Boiling time for the tubers of each cultivar was again determined by preliminary tests with modification as describe in the methods of Dincer *et al*. (2011).

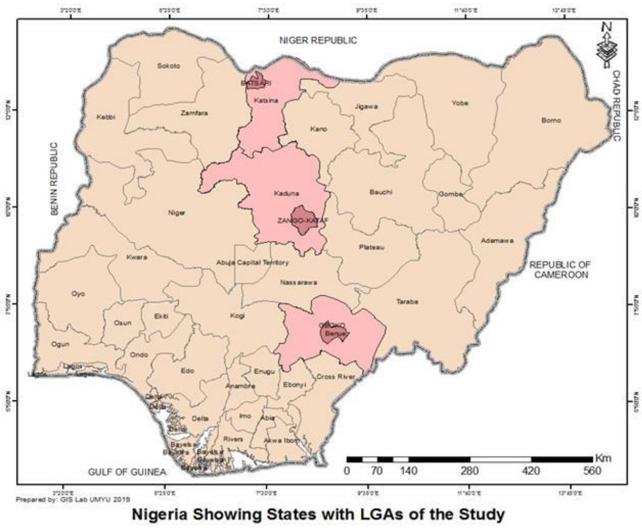

Figure 1: Map of sites where *Ipomoea batatas* L. was collected

Frying

For the frying, 1.5 kg part of the different cultivars were washed with running tap water and peeled with a *I. batatas* pillar and cut in to slice of 2 cm thickness. The sliced potatoes were fried under a regulated temperature of 80ºC using Sunola Oil (Sunola Palm Oil Nig Ltd brand). The time taken for the frying was 10 min, 12 min and 13 min, respectively (Fetuga *et al*., 2014).

Extraction

After the treatments, the samples were placed on a bench at room temperature to cool down. The fresh and treated samples were cut into small pieces. They were divided into two parts, the first part was used for proximate analysis and the other was dried using hot air ovum (Genlab Limited, Model MINO/100/F) at 60ºC until the final moisture content was less than 4%. All *I. batatas* samples from different processing methods and raw tissue were homogenized and packed in plastic plates covered with aluminum foil and stored at −20 °C untill analyses.

Analyses

Proximate analysis

The moisture content, fat, ash, protein, fiber, fat, lipids and carbohydrate were determined using method adopted by the Association of Analytical Chemists (AOAC) (Horwitz and Latimer, 2005) and reported as the percentage composition of the constituents (w/w).

Determination of total phenolic content:

Total phenolic content was determined according to the method described by Siddhuraju and Becker (2003), Ten microliter aliquots of the extract (2 mg/2 ml) was taken in test tube and made up to the volume of 1 ml with distilled water. A half (0.5) ml of Folin-Ciocalteu phenol reagent and 2.5 ml of sodium carbonate were added and allowed to stand for 40 min at room temperature and the absorbance was recorded at 725 nm against the reagent blank. The analysis was performed in triplicate and the result was expressed as garlic acid equivalents.

Determination of beta carotene:

All-trans-b-carotene (Sigma Chemical Co., USA) was used as the standard. Total carotenoid content in the potato tubers sample were determined by acetone–petroleum-ether extraction followed by spectrophotometric measurement (Islam *et al*., 2003). Extraction of carotenoid was performed by grinding of processed *Ipomoea batatas* sample in mortar and pestle, filtration through sintered glass filter under vacuum and separation from acetone to petroleum ether. The petroleum eluent adjusted to specific volume was read at 450 nm in a spectrophotometer (UV-2550, UV–Visible, Shimadzu, Tokyo, Japan) for concentration of total carotenoids.

Determination of ascorbic acid

Ascorbic acid analysis of the samples was carried out by the method used by Dincer *et al*. (2011). The sample (500 mg) was extracted with 10 ml of 1% metaphosphoric acid solution in centrifuge tubes by shaking (200 rpm) at room temperature for about 30 min. This was followed by centrifuging the slurry at 3,000 g and 4 °C for 15 min. One milliliter of supernatant was added into 9 ml of dye solution (15 mg 2.6-dichlorophenol indophenol/l) and its absorbance was measured at 515 nm within 20 s after shaking. Standard curve were prepared by appropriate dilutions of L-ascorbic acid from which the ascorbic acid content of the samples were determined. The results were expressed as milligrams of ascorbic acid/100 g.

Anti-radicals activity analysis

Free radicals scavenging activity of different extract of *I. batatas* were measured by α, α-diphenyl-β-picrylhydrazyl (DPPH) method as modified by Koleva *et al*. (2002). The DPPH solution (1 ml) was added to 3 ml of different extract in ethanol at different extract concentrations (5, 10, 15, 20, 25 ug/ml). The mixture was shaken vigorously and allowed to stand at room temperature for 30 min. Then absorbance was measured at 517 nm by using ascorbic acid as a reference (spectrometer standard compound) and experiment was conducted in three replicate. The IC_{50} value of the sample was calculated using a log dose inhibition curve. Lower absorbance of the reaction mixture indicated higher free radical activity (Koleva *et al.,* 2002). The DPPH scavenging effect (%) inhibition = A0-A1/A0×100. Where A0 is the absorbance of control reaction and A1 is the absorbance of test sample.

Statistical analysis

Analysis of data was performed using the Statistical Analysis System software (Graphad Prism, version 8.2) to determine the effects of the dependent variables. Mean values were compared using Turkey’s multiple comparison test at the 5% level. Statistical analyses of the treatments were replicated and analyses were carried out using three replicates.

RESULTS AND DISCUSSION

Results

Proximate composition of the *I. batatas*

The effects of different cooking methods on the proximate compositions of purple, red and white skinned *I. batatas* cultivar are represented in Table 1. The ash contents of the samples were in the range of 2.1% - 2.87%. Highest ash content was observed in white (Fried) cultivar (2.87%) and lowest in Red (raw) cultivars (2.10%). The crude fibers contents are in the range of were 2.06 -3.00%.

The result shows that the protein content of the raw and treated samples of three *I. batatas* cultivars ranged between

3.72 - 5.05%. The highest protein content of the *I. batatas* was found in Red (raw) cultivars (5.05±0.03%) and the lowest was in purple (Fried) cultivar (3.30±0.15%).

The result in the Table shows that fat contents have significant differences between cultivar and the treatments, which ranged from 3.67 - 6.54%. The fried sample, indicate more fat contents than other treatment and the white have high fat content with 6.54%, followed by the purple cultivar with 6.14% and then the red cultivar with 5.76%.

Beta-carotene content

Table 2 shows the result of estimated beta-carotene contents of the three *I. batatas* cultivars and the cooking methods. From the results, the highest beta-carotene content was present in raw purple cultivar followed by raw white then raw red potato cultivars. The beta-carotene content of the purple, white and red *I. batatas* cultivar were in the ranges of 1.42-5.76, 2.16-5.25 and 1.44-4.07 mg/100 gm respectively.

Total ascorbic acid

Table 2 shows the result of estimated ascorbic acid contents of the three *I. batatas* cultivars and the cooking methods. The results show that raw red cultivar has the highest content of vitamin C with 0.37 mg/100 g followed by the raw purple cultivar with 0.36 mg/100 g and then the raw white cultivar with 0.28 mg/100 g.

Table 1. Effects of Different Cooking Methods on the Proximate Compositions of Purple, red and White Skinned *I. Batatas* Cultivar

	Cultivar	Proximate Compositions					
Cultivars	Cooking	Total Ash (%)	Crude Protein (%)	Moisture (%)	Crude Fibre (%)	Crude Lipid (%)	Total Carbohydrate
Red	Raw	2.12 ± 0.03^{a}	5.05 ± 0.03^{a}	10.02 ± 0.13^{a}	2.22 ± 0.19^{a}	4.68 ± 0.28^{a}	75.91 ± 0.41^{a}
	Boiled	2.22 ± 0.24^{a}	5.02 ± 0.01^{ab}	11.12 ± 0.8^{ab}	2.37 ± 0.23^{a}	3.58 ± 0.28^{b}	76.03 ± 1.7^{ab}
	Fried	2.42 ± 0.03^{a}	3.75 ± 0.03^{c}	5.36 ± 0.4^{a}	2.06 ± 0.05^{a}	5.73 ± 0.49^{c}	80.67 ± 0.69^{c}
Purple	Raw	2.14 ± 0.02^{a}	4.26 ± 0.01^{a}	8.35 ± 0.28^{a}	2.63 ± 0.18^{a}	5.42 ± 0.26^{a}	78.13 ± 1.29^{a}
	Boiled	2.16 ± 0.02^{a}	4.34 ± 0.03^{ab}	9.28 ± 0.37^{b}	2.25 ± 0.39^{a}	4.35 ± 0.31^{b}	77.62 ± 0.34^{a}
	Fried	2.23 ± 0.06^{a}	3.30 ± 0.15^{e}	6.10 ± 0.26^{c}	2.35 ± 0.55^{a}	6.14 ± 0.12^{c}	79.88 ± 0.58^{a}
White	Raw	2.61 ± 0.02^{a}	4.64 ± 0.02^{a}	6.23 ± 0.24^{a}	3.00 ± 0.92^{a}	3.57 ± 0.24^{a}	79.76 ± 1.00^{a}
	Boiled	2.56 ± 0.29^{a}	4.74 ± 0.03^{b}	5.30 ± 0.33^{b}	2.68 ± 0.12^{a}	3.67 ± 0.24^{ab}	81.11 ± 0.66^{a}
	Fried	2.87 ± 0.04^{a}	3.72 ± 0.04^{c}	4.57 ± 0.28^{c}	2.38 ± 0.13^{a}	6.54 ± 0.22^{c}	80.06 ± 0.26^{a}

Mean ± Standard deviation
The same Letters within a column of each cultivar indicate no significant differences between the treatments for each cultivar at ($p<0.05$).
Different letters in the same column of each cultivar indicate a significant different between the treatments for each cultivar at ($p<0.05$).

Total Phenolic Contents (TPC)

Significant difference ($p<0.05$) was observed (Table 2) between the TPC of raw, boiled and fried potato. Based on the treatments, only in fried purple that the value raised (with 1.60 mg/GAe/ml) which is higher than the fried samples of other cultivars, followed by boiled purple (with 0.59 mg/GAe/ml) and lastly the boiled red (with 0.52 mg/GAe/ml). Furthermore, significant differences ($P<0.05$) in total phenolic contents with the different cooking methods were found in all the three (3) *I. batatas* cultivars (red, purple and white).

Anti-Radical Activity

Table 2 shows the anti-radical activity of the three *I. batatas* cultivars. Results showed that much of the DPPH radical scavenging activity of the treated concentrations were more potential in the raw samples than in the cooked samples. The anti-radical activities of the samples were evaluated in DPPH radical scavenging activity using IC_{50} values of the sample. The IC_{50} value of the boiled white sample was found to be the lowest, which means they have highest anti-radical activity while IC_{50} of raw red had highest value which means they have lowest anti-radical activity. Significant differences ($P<0.05$) in DPPH scavenging activity with the different cooking methods were observed.

Table 2. Effect of Different Cooking Methods on Antioxidant Activity of Three *I. Batatas* Cultivars.

Cultivar	Cooking method	Beta-Carotene (mg/100g)	Ascorbic Acids (mg/100 g)	TPC (mg/GAe/ml)	DPPH IC_{50}
Red	Raw	4.07 ± 0.05^a	0.37 ± 0.01^a	6.55 ± 0.00^a	91.22 ± 0.10^a
	Boiled	3.14 ± 0.01^b	0.32 ± 0.02^b	0.52 ± 0.00^b	91.40 ± 0.21^a
	Fried	1.44 ± 0.03^c	0.31 ± 0.02^b	0.25 ± 0.01^c	88.78 ± 0.18^b
Purple	Raw	5.76 ± 0.02^a	0.36 ± 0.05^a	6.09 ± 0.01^a	89.75 ± 0.23^a
	Boiled	4.51 ± 0.59^b	0.16 ± 0.01^b	0.51 ± 0.01^b	89.42 ± 0.13^a
	Fried	1.42 ± 0.02^c	0.28 ± 0.01^c	1.60 ± 0.01^c	89.78 ± 0.05^a
White	Raw	5.25 ± 0.05^a	0.28 ± 0.01^a	6.18 ± 0.01^a	90.59 ± 0.07^a
	Boiled	2.16 ± 0.01^b	0.26 ± 0.00^b	0.33 ± 0.00^b	89.36 ± 0.09^b
	Fried	2.76 ± 0.03^c	0.25 ± 0.01^b	0.05 ± 0.00^c	88.50 ± 0.07^c

Mean ± Standard deviation.
The same Letters within a column of each cultivar indicate no significant differences between the treatments for each cultivar at ($p<0.05$)

DISCUSSION

Depending on the nature of processing, many nutrients can be reduced or removed during food processing. From this study, different cooking procedures caused variations in nutritional compositions between the cooked and unprocessed potatoes and between the potatoes processed using different cooking procedures (Tables 1 and 2). These findings are in agreement with the study of Dincer *et al.* (2011) on different *I. batatas* cultivars, which showed that the ash and crude fiber content were in the range of 2.13-2.62% and 2.11-2.76% respectively. However, the additional oil used during the frying probably caused the increased fat content (Bolade *et al.*, 2017). The differences in the fat contents among the *I. batatas* cultivar could again, be attributed to the difference in genetic composition, land of cultivation and/or agricultural practices.

Other researchers (Dincer *et al.*, 2011) reported that the protein contents of different *I. batatas* cultivars ranged within 3.41% and 5.08%. Huang *et al.* (2006) reported that the protein content of *I. batatas* varieties ranged between 3.53% and 8.87%. Both boiling and frying treatment resulted in a significant reduction in beta-carotene content. In particular, the frying process caused the highest reduction in the beta-carotene contents of purple and red *I. batatas* cultivars. However, boiling caused a lower reduction in beta-carotene content of the same cultivars, only in white cultivar frying shows lower reduction. These findings agree with the findings of Dincer *et al*. (2011). In another study, similar reduction of beta carotene contents has been reported in different *I. batatas* cultivars with boiling treatments (Wu *et al.*, 2008).

Among the cooking procedures, the boiled red and boiled white cultivars have higher ascorbic acid contents, followed by the fried. Frying results to high beta-carotene content then boiling only in purple cultivar. The estimated ascorbic acids contents from our study is below the reported values of ascorbic acid by Dincer *et al*. (2011). In addition, Aywa *et al*. (2013) reported that boiling significantly reduce the vitamin C contents. Generally, various processing procedures including baking, frying and boiling are attributed to degradation of vitamins (Lee and Kader, 2000). In Table 2, significant differences in ascorbic acids contents with the different cooking methods were found in all the three (3) *I. batatas* cultivars. Gou *et al.* (2019) also reported similar decrease in the TPC of *I. batatas* cultivars. The decrease of TPC after frying/boiling could be attributed to leaching of the soluble form in the cooking oil or the water and breakdown of phenolic during cooking because of thermal destruction of compounds (Kourouma *et al.*, 2020).

Significant differences in IC_{50} with the different cooking methods were only found within the red and white *I. batatas* cultivars, but IC_{50} with the different cooking methods was only found in purple *I. batatas* cultivar. However, no significant difference in IC_{50} with the different cooking methods was found in the purple *I. batatas* cultivar. Studies by Dincer *et al.* (2011) reported no significant differences in IC_{50} of two *I. batatas* cultivar with processing methods.

The TPC were lost to different degrees according to the method of cooking, raw cultivars have higher TPC values; red *I. batatas* cultivar were found to have the highest mean value (with 6.6 mg/GAe/ml), followed by raw white (with 6.18mg/GAe/ml) and then raw purple (with 6.09 mg/GAe /ml). These results shows the richness of potato cultivars in TPC, which has also been demonstrated by different studies (Akrimi *et al.*, 2020; Gou *et al.*, 2019; Dincer *et al.*, 2011; Teow *et al.*, 2007). The results obtained show that the two modes of cooking cause a decrease in the TPC.

CONCLUSION

Interestingly, results showed that the beta-carotene, ascorbic acid acids, total phenolic content and the mineral composition of the raw samples were generally higher than those of the treated samples. The nutritional composition of all the three cultivars shows no significant differences in total ash and crude fiber content with the cooking methods, while the moisture and lipid contents of the samples shows significant differences between the raw cultivar and the treated ones. Conclusively, more of the nutritional contents retained in boiled sample then in the fried sample. Consequently, boiling rather than frying may be recommended.

AUTHORS' CONTRIBUTIONS

UL and AU designed the study, supervised the laboratory work and contributed in the interpretation of the study. KH participated in the collection and performing of the laboratory work, analysis of the data and the drafting of the manuscript. The final revised version was the collaborative effort of all the authors. All authors approved the final version and gave approval for its publication.

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CONFLICT OF INTEREST

Authors declare that there is no conflict of interest.

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