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Evaluation of the Effects of Boiling on the Nutrient and Phytonutrient Composition of (Aduh) Aerial Yam Tubers

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ABSTRACT

This study investigates proximate, mineral and phytonutrient composition of raw and boiled yam (*Aduh*) flour samples. The aduh samples were divided into two equal portions. The tubers were sorted by removal of defected tubers and divided into two equal portions of one kilogram each for the pre-treatments One portion was processed raw and the second potion was subjected to boiling treatment. The proximate and mineral composition was analyzed using the method of AOAC, (2010) while the method described by Onwuka (2005) was employed in determining the phytonutrient content. The results of the proximate composition showed that the raw *aduh* sample had moisture content (6.37%), ash (2.33%), crude fibre (3.64%), crude protein content (9.81%), crude fat (3.86%), carbohydrate (77.21%) and energy value of 369.94%. The values of the raw sample were higher than that of the boiled sample due to the leaching away of nutrients into the boiling water. The mineral composition showed that the flours contained 205.60 – 316.31 µg/100g calcium, 139.00 – 161.00 µg/100g magnesium, 440 – 920.00 µg/100g potassium, 550.00 – 640.00 µg/100g sodium, 590.00 – 1735 µg/100g iron and 152.00 – 412.00 µg/100g zinc, respectively. The phytonutrient composition of the raw *aduh* flour were alkaloids (2.16%), flavonoids (1.75%), saponins (1.27%), tannin (0.21%) and phytate (1.88%) were significantly ($p<0.05$) reduced during boiling treatment process. Boiling treatment led to great reduction of the anti-nutritional factors. However, a slight reduction in the nutrient parameters was observed for the boiled sample but such reduction cannot be compared with the positive gains of removal of antinutrients. Thus, it is recommended that *Aduh* be properly cooked for at least 60 min before consumption.

Keywords: Aduh, aerial yam, proximate, mineral, boiling, phytonutrient composition.

Introduction

Yam is grown and cultivated for its energy-rich tuber. The yams are members of the genus Dioscorea in the section, *Enantiophyllum*. *Dioscorea* is the largest genus of the family Dioscoreaceae, containing between three and six hundred species (Ezeocha and Ojimelukwe,

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2012). Only a few species of yams are cultivated as food crops. The most important species of Dioscorea include *D. rotundata, D. alata, D. cayenensis, D. dumetorum, D. esculenta* and *D. bulbifera*. Yams (*Dioscorea* spp.) are important source of carbohydrate for many people of the Sub-Saharan region, especially in the yam zone of West Africa (Akissoe *et al*., 2003), and are the third most important tropical root crop after cassava and sweet potato (Onyeka *et al*., 2006). Aerial yam (*Dioscorea bulbifera*) also known as air potatoes is a member of the *Dioscoreaceae* family often considered as a wild species of yam native to Africa and Asia (Kayode *et al*., 2017). Ghana is leading in the production of aerial yam (Udensi *et al*., 2010). Aerial yam is among the most underutilized food crops in the world and Africa in particular where it grows and appears in both the wild and edible forms. It has a long vine and it produces tubers (bulbis) which grow at the base of its leaves (Abara, 2011). This species of yam is not popular among farmers or consumers and does not enjoy the patronage that some of the other edible yam species enjoy. Aerial yam is popular and prevalent within Enugu-East senatorial district of Enugu State and Abakiliki agro-ecological zone of Ebonyi state, Nigeria where it is called local called "*Aduh*" (Oko & Famurewa, 2015).

The bitterness of aerial yam is useful in treatment of worms, stopping vomiting and per-oxidation of blood lipids (Onyeka *et al*., 2006). This lowers the level of triglycerides and is good for treating cardiovascular diseases (Bhandari and Kawabaka, 2003). Bulbifera was used in folk medicines in the plants' natural range (Abara, 2011). Among the many documented medicinal folk uses of the plant, some of the most well-known include the use of bulbils for external treatment of sores and the internal treatment of hemorrhoids in India (Abara, 2011). The use of a paste created from the bulbils to treat swelling as a cure for snake bites and scorpion stings in Africa and central Asia. In China, it is used for the treatment of sore throat and struma and remedy diabetes (Sanful *et al*., 2015). In Japan, it is used for treatment of leprosy and tumors (Udensi *et al*., 2010). Yams may also contain small quantities of polyphenolic compounds (e.g. tannins), alkaloids (e.g. dioscorine), steroid derivatives (e.g. diosgenin), calcium oxalate crystals and phytic acid (Sanful *et al*., 2015). *D. bulbifera* cultivars possess a higher content of protein, vitamin C and low lipids than *D. alata, D.* cayenensis, *D. escunlenta*, *D. rotundata* and *D. trifida* (Ezeocha and Ojimelukwe, 2012). Root crops are not easily digested in their natural state and are rather processed been eaten.

Phytonutrients are plant components, primarily secondary metabolites that have health promoting properties. The most predominant phytochemical characteristics of yam is dioscorine alkaloid and dioscorine saponin (Eka, 1998). Although dioscorine and diosegenin traditionally are considered toxic, such toxicity is removed by washing, boiling and cooking (Eka, 1998). The pigments found in aerial yams may be due to the presence of flavonoids and carotenoids (Okwu and Ndu 2006; Markson *et al*., 2010). The main physiological function of carotenoids is as precursor of vitamin A (Nocolle *et al*., 2003) It is already known that these toxic principles exhibit useful medicinal properties, so their presence in the yam species is a pointer to the medicinal value of yam flour samples (Afiukwa *et al*., 2015; Osagie 1992). Various preparation techniques such as boiling, steaming or baking over coals of fire after peeling or before peeling have been employed in processing aerial yam tubers (Kayode *et al*., 2017). Cooking improves their digestibility, promotes palatability and improves their keeping quality as well as making the roots safer to eat. However, cooking may affect the nutritional composition and phytoconstituents in food. The objective of this study is to evaluate the effects of cooking on the nutritional and antinutrient composition of aerial yam tubers.

Materials and Methods

Sample Collection

Yellow colour of *Aduh* (aerial yam/air potato) tubers (2.0 Kg) were purchased from *Eke-Agbani* markets in Nkanu-West Local Government Area of Enugu State, Nigeria. The tubers were transported to Food Science Department at Institute of Management and Technology (I.M.T) Enugu. The tubers were sorted by removal of defected tubers and divided into two equal portions of one kilogram each for the pre-treatments. Modified pre-treatment method of Princewill-Ogbonna and Ezembaukwu (2015) method was used.

Preparation of samples

The samples taken were each divided into two portions. One portion was prepared raw while the other portion was boiled.

Preparation of Raw Aerial Yam Flour

Raw aerial yam flour was prepared using the method described by the authors (Okechukwu *et al*., 2023). One kilogram (1 Kg) of the aerial yams which were free from dirt and other extraneous materials were weighed, cleaned, peeled and sliced into chips manually (using knife) and rewashed using tap water. The chips were rinsed and dried in a hot air oven (Model DHG 9101 ISA) at 60 ^{O}C for 24 h with occasional stirring of the chips at intervals of 30 min to ensure uniform drying. The dried chips were milled into flour using the attrition mill and sieved using a China-made mechanical sieve shaker with 500micron mesh sieve. The flour produced was packaged in an airtight plastic container, labeled and kept in a refrigerator until needed for analysis.

Boiled Aerial Yam Flour

The methodology described by the authors (Okechukwu *et al*., 2023) was adopted for the study. One kilogram (1 Kg) of the aerial yams which were free from dirt and other extraneous materials were weighed, cleaned, peeled and sliced into chips manually (using knife) and rewashed using tap water. The chips were rinsed and placed in stainless pot and boiled with 3.5 litres of potable water on a hot plate at 100 ^{o}C for 60 min. The boiled chips were drained, spread on the tray and dried in a hot air oven (Model DHG 9101 ISA) at 60 ^{O}C for 32 h with occasional stirring of the chips at intervals of 30 min to ensure uniform drying. The dried chips were milled into flour using the attrition mill and sieved using a China-made mechanical sieve shaker with 500micron mesh sieve. The flour produced was packaged in an airtight plastic container, labeled and kept in a refrigerator until needed for analysis.

Determination of proximate composition of aerial yam flour

The proximate composition (moisture, protein, fat, ash and crude fiber) contents were determined according to AOAC (2010). The total carbohydrate (CHO) was determined by difference: CHO =100- (% moisture + % protein + % fat + % ash).

Determination of mineral composition of aerial yam flour

The mineral elements namely calcium, magnesium, iron, zinc, copper, sodium and potassium content of the flour samples were analysed using the absorption and emission spectrophotometry and phosphorous by molybdovanadate methods of AOAC (2010).

Determination of phytonutrient composition of aerial yam flour

The method of were determined using the spectrophotometric method of Onwuka (2005) was adopted for the determination of the alkaloid, saponin, phenol, tannin and flavonoid content of the yam flour samples.

Statistical Analysis

The data generated after the analysis were subjected to Analysis of Variance (ANOVA) using special package for social sciences (SPSS version 20, 2013) to detect significant differences among the sample means at ($p \leq 0.05$). Significant means were separated using Turkey's Least Significance Difference (LSD) test.

Results and Discussion

The proximate composition of raw and boiled samples of aerial yam are presented in Table 1. The samples showed moisture values between 6.37 and 9.18%. The boiled purple aerial yam had higher moisture content (9.18%.) than the raw purple aerial yam (6.37%). More water absorption was observed in samples processed by boiling. These findings agree with Ayo *et al.* (2018) who reported that moist-heating causes increase in the moisture content of aerial yam unlike dry-heating that reduces the moisture content. Ojinnaka *et al*. (2017) reported that the moisture content of the raw purple cultivar was higher (7.12%) while the yellow cultivar had the least moisture content value of 6.99%. The quantity of solid matter present in a flour sample and the rate of spoilage are directly proportional to the volume of free-water present in the foods (Sanful, Oduro, & Ellis, 2013). The level of moisture in this study shows that the boiled aerial yam flour may not easily spoil owing to their low moisture level. Moist-cooking of *D. bulbifera* for 60 min reduced the ash content from 2.33% to 1.56 %. The phenomenon can be attributed to the leaching away of minerals into the boiling water. Cooking/boiling for 60 min reduced the crude fibre content significantly ($P<0.05$) from 3.64 to 1.36%. Protein content of the boiled tuber was 6.59% whereas that of the raw sample was 9.81 %. A great significant difference ($p<0.05$) was observed between the crude protein content of the raw and boiled tubers. The crude protein contents reduced significantly ($p<0.05$) with increase in the boiling time. Boiling effected a significant decrease ($p<0.05$) in the crude protein of *D. bulbifera*. The reduction in the protein contents of boiled sample could be attributed to the leaching of some soluble proteins into the boiling water during processing. The crude fat content reduced significantly with boiling from 3.86 to 2.46%. The observed decrease in fat contents of boiled flour sample could be due to the oxidation of fat as a result of heat penetration during processing. Fat is important in human diets because it is a high energy-yielding nutrient. Also, the carbohydrate composition of *D. bulbifera* decreased significantly ($p<0.05$) with boiling treatment from 77.21 to 75.61%. The decrease could be attributed to thermal decomposition of carbohydrate into carbonic acid and carbon dioxide by boiling treatment (Obasi and Wogu, 2008).

The mineral composition of raw and boiled *Aduh* flour samples are presented in Table 2. The calcium content of the raw aduh flour was 205.60µg/100g while the boiled sample has 205.60µg/100g. There were significant ($p<0.05$) differences in the calcium content of the flour samples. The decrease in the calcium contents could be caused by leaching of the mineral element into the boiling water during processing. Calcium helps in bone formation. The calcium content of the raw aduh flour was 161.00µg/100g while the boiled sample has 139.00µg/100g. Magnesium helps in the maintenance of electrical potential in nerves (Etong *et al*., 2013). The potassium content of the raw aduh flour was 920.00µg/100g while the boiled sample has 440.00µg/100g. The result showed that boiling treatment had more reductive effects on potassium content when compared to the raw sample. Potassium is essential in blood clotting and muscle contraction (Eze *et al*., 2019). The sodium content of the raw and boiled aduh flour samples were 640.00µg/100g and 5500.00µg/100g, respectively. There were significant ($p<0.05$) differences in the sodium

content of the flour samples. Sodium is the principal cation in extracellular fluids. It regulates plasma volume and acid-base balance (Okaka *et al*., 2006). The iron content of the raw aduh flour was 1735.00µg/100g while the boiled sample has 590.00µg/100g. There were significant ($p<0.05$) differences in the iron content of the flour samples. Iron is also an essential element that is needed in humans and plants. It occurs predominantly in plants in the form of phytate complexes. The zinc content of the raw aduh flour was 412.00µg/100g while the boiled sample has 152.00µg/100g. The result of the study showed that both the raw and boiled aduh samples contained low level of zinc. Thus, aduh may not be a good source of zinc mineral. Generally, there was a decrease in the mineral elements content of boiled aduh flour which could be attributed to degradation and leaching out of the mineral element into the boiling water during processing.

Table 1: Proximate composition of raw and boiled *D. bulbifera*

Treatments/Parameters (%)	Raw	Boiled
Moisture	6.37±0.35^{a}	9.18±0.03^{b}
Ash	2.33±0.04^{b}	1.56±0.06^{b}
Crude fibre	3.64±0.02^{b}	1.38±0.35^{c}
Crude protein	9.81±0.08^{a}	6.59±0.07^{b}
Crude Fat	3.86±0.06^{a}	2.46±0.04^{c}
Carbohydrate	77.21±0.05^{a}	75.61±0.19^{b}
Energy (Cal/g)	369.94	363.82

Values are mean ± standard deviation of 3 replicate. Means within each column not followed by the same superscript are significantly different ($p<0.05$) from each other.

The level of phytonutrient in *aduh* is shown in Table 3. The level of alkaloid in the raw and boiled aduh flour samples were 2.16% and 0.19%, respectively. The levels were reduced significantly ($p < 0.05$) by boiling when compared to the raw samples. The presence of alkaloid in the *Aduh* flour samples indicates that raw yam tubers are not good for human consumption. Researchers have sown that high level of alkaloids in foods can cause gastro-intestinal upset and neurological disorders (Okaka *et al*., 1999).

Table 2: Mineral element content of raw and boiled *Aduh* samples (µg/100 g)

Element	Boiled	Raw
Calcium	205.60±4.24	316.31±4.34
Magnesium	139.00±2.83	161.00±2.80
Potassium	440.00±3.54	920.00±7.07
Sodium	550.00±6.36	640.00±5.66
Iron	590.00±0.28	1735.00±0.95
Zinc	152.00±0.16	412.00±0.06

Values are mean± standard deviation of 3 replicate. Means within each column not followed by the same superscript are significantly different ($p<0.05$) from each other.

Table 3: Effect of boiling on the phytonutrient composition of *aduh* (mg/g)

Sample	Alkaloid	Flavonoid	Saponin	Tannin	Phytate
Boiled	0.19±0.01^{a}	0.65±0.01^{b}	0.54±0.03^{b}	0.16^{a}	1.33^{a}
Raw	2.16±0.03^{ab}	1.75±01^{a}	1.27±0.30^{a}	0.21^{b}	1.88^{c}

Values are mean± standard deviation of 3 replicate. Means within each column not followed by the same superscript are significantly different ($p<0.05$) from each other.

The concentration of flavonoid in raw *Aduh* was 1.75% whereas boiling for 60 min significantly reduced it to 0.65%. The finding of the study is in agreement with the report of Ezeocha and Ojimelukwe (2012) who stated that boiling has the ability to significantly ($p<0.05$) decrease the flavonoid concentration of boiled yam flour samples. Flavonoids serve as antioxidants in various biological systems such as inflammation, free radicals, platelet aggregation, microbes, ulcers, viruses and tumors (Okwu, 2004; Okwu and Omodamiro, 2005). The level of saponin in the raw and boiled aduh flour samples were 1.27% and 0.54%, respectively. The saponin levels in the boiled samples were reduced significantly when compared with the raw sample. Saponin is an antinutritional factor whose toxicological effects should be balanced with its benefits. Some of the general properties of saponins include formation of foams in aqueous solution, hemolytic activity and

cholesterol binding properties and bitterness (Sopido *et al*., 2000). Saponins natural tendency to ward off microbes makes them good candidates for treating fungal and yeast infections. These compounds serve as natural antibiotics, which help the body to fight infections and microbial invasion. The level of saponin in the raw and boiled aduh flour samples were 0.21% and 0.16%, respectively. Boiling reduced the level of tannin in boiled. Tannin affects the nutritive value of food products by forming complex with protein (both substrate and enzyme) thereby inhibiting digestion and absorption (Ezeocha and Ojimelukwe, 2012). They also bind iron, making it unavailable and other evidence suggests that condensed tannins may cleave DNA in the presence of copper ions. The reduction of tannin concentration of boiled Dioscorea varieties is expected, since earlier report indicated that processing methods such as soaking, boiling and fermentation lowered the tannin contents of the foods (Jude *et al*., 2009). The decrease in the levels of tannin during cooking may be due to the thermal degradation and denaturation of the tannin as well as the formation of insoluble complexes. Raw *aduh* had phenol concentration of 1.88% while the boiled sample contained 1.33%; the variation in phenol content cannot be solely attributed to heat application. In some species of yam tubers, browning reactions occur when the tissues are injured and exposed to air. This type of browning is due to the oxidation of phenolic constituents, especially o-hydroxy or trihydroxy phenolics, by a phenol oxidase present in the tissue. The presence of phenols indicates that aduh species could act as anti-inflammatory, anti-clotting, antioxidant, immune enhancers and hormone modulators (Okwu and Omodamiro, 2005).

Applying boiling treatment process to *aduh* tuber flour resulted in reduction of the levels of the phytonutrients. This trend may be due to higher ability of hydrolyzing the anti-nutritional factors as boiling period increased. The determination of the anti-nutritional substances was of interest because of their toxicity in yams, negative effects on mineral bioavailability and their pharmacological effect. These metabolites occur in varying concentrations in yam tubers.

Conclusion

The results of this study showed that boiling has positive effect on *aduh* tuber flours. Boiling treatment led to great reduction of the anti-nutritional factors. However, a slight reduction in the nutrient parameters was observed for the boiled sample but such reduction cannot be compared with the positive gains of removal of antinutrients. Thus, it is recommended that *Aduh* be properly cooked for at least 60 min before consumption.

Conflict of Interest

The authors declare that they have no conflict of interest.

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