The Impact of Cooking on the Proximate Composition and Antinutritional Factors of yam *Dioscorea esculenta* Tubers

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***Abstract*:** Samples of raw and boiled water yam tubers (*Dioscorea esculenta*) were analyzed for proximate contents such as ash, moisture, total sugars and reducing sugars, crude protein, carbohydrate, crude fibre, crude fat, and antinutrients using standard procedures and methods. The crude protein contents (5.68 %), ash (2.33 %), crude fibre (5.02 %) and crude fat (0.61 %) were significantly ($p \leq 0.05$) lowered in the boiled tubers while the carbohydrate (83. 03 %), total and reducing sugar (13.45 % and 5.16 %) respectively and moisture (8.33 %) significantly ($p \leq 0.05$) increased in the boiled tubers. The antinutrients; phytate (280.76 %), alkaloids (43.66 %), oxalate (12.89 %) and tannins (5.80 %) significantly ($p \leq 0.05$) reduced in the boiled tubers. It was concluded that boiling had both positive and negative effect on water yam *D. esculenta*.

Keywords—*Dioscorea Esculenta, Yam Tubers, Boiling, Proximate Content, Antinutrients.*

I. INTRODUCTION

Yam (Dioscorea spp.) is a vegetatively propagated tuber food crop, belonging to the family Dioscoreaceae within the genus Dioscorea [1]. It is an energy-rich tuber and provides protein three times more superior than the one of cassava and sweet potato [2]. Thus, yam, *Dioscorea* (*spp.*) is an economically important food in many tropical countries particularly in West Africa, South Asia and Caribbean, where it also has a social and cultural importance [3]. It is an important food for about 300 millions people through the world [4] and hence generates more income in local markets than other crops [5]. Among the 600 species of the genus Dioscorea, six are cultivated for their edible corms, which constitute a staple food for many people in subtropical and tropical regions of the world [6]. Thus, the most important species of Dioscorea include *D. rotundata*, *D. alata*, *D. cayenensis*, *D. dumetorum*, *D. bulbifera* and *D. esculenta*. It is reported that, yams generally have high moisture content and the dry matter is composed mainly of starch, vitamins, sugars and minerals. Nutrient content varies with species and cooking procedures. Therefore, modern researchers have showed that yam extracts can reduce blood sugar [7] and blood lipid [8], inhibit microbe activity [9] and show antioxidant activity [10]. Yam also has pharmaceutical usage as they contain a steroid sapogenin compound called diosgenin, which can be extracted and used as a base for drugs such as cortisone and hormonal drugs [11]. Yams are also known to contain some antinutritional components that may have adverse effects on human nutrition [12] despite their high nutritional values. Thus, [13] reported that most yam tubers are acrid and they are associated with irritation and inflammation of the buccal cavity and throat; consumption can result in gastrointestinal disturbances, vomiting, and diarrhea especially when large amounts are ingested into the human body. These are mainly tannins, phenols, and phytic acid. However, bitter principles may be polyphenols or tannin-like compounds [14] while phytic acid (inositol hexaphosphate) is an organic acid found in plant materials [15] which combines with some essential elements such as iron, calcium, zinc and phosphorus to form insoluble salts called phytate which is not absorbed by the body thereby reducing the bioavailability of these elements. But, it is also reported that root crops are not easily digested in their natural state and should be cooked before they are eaten. 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 antinutrients in food. However, few studies have been carried out on the nutritional and antinutritional compositions in *Dioscorea esculenta* yam. Bourke and Vlassak [16] reported that *Dioscorea esculenta* (Lour.) Burk. is the least studied of the major staple yam species, although it is widely cultivated in southern Asia and the Pacific and is the dominant or co-dominant staple food in parts of India and Papua New Guinea. Thus, the aim of this study is to evaluate the nutritional and antinutrional composition of *Dioscorea esculenta* yams and how they are affected by cooking.

II. MATERIAL AND METHODS

A. Raw materials

Plant material: yam tubers from *Dioscorea esculenta* were harvested at physiological maturity at Touba (Côte d'Ivoire) in 2015-2016. These yam tubers were immediately transported in a heap aired store to the Laboratory of Biocatalysis and Bioprocessing of University Nangui Abrogoua (Côte d'Ivoire) where study was conducted.

B. Sample Preparation

Two (2) kg of yam tubers from *Dioscorea esculenta* were washed with clean water. They were peeled and cut into small slices (3x3x3 cm thickness) using a stainless steel knife. The slices were rewashed with clean water in order to remove much mucilaginous material. After washing, they were divided into two lots of 1 kg each. One lot was boiled at 100 °C for 15 min in a pan containing 1 L of distilled water. At the end of boiling, the slices were cooling to room temperature for 25 min. After these steps, the lot with treatment and the remaining one part with no treatment were dried in an oven (MEMMERT^R) at 45 °C for 48 hours. The dried slices were ground into powder, sieved with 250 µm mesh sieve and then stored in airtight containers in a desiccator for analysis [17].

C. Proximate Composition Analysis

Moisture and dry matters were determined by drying in an oven at 105 ºC during 24 h to constant weight [17].Total ash and organic matters were determined by incinerating in a furnace at 550 ºC [17]. Crude protein was calculated from nitrogen (Nx6.25) obtained using the Kjeldahl method by AOAC [17]. Crude fat was determined by continuous extraction in a Soxhlet apparatus for 8 h using hexane as solvent [17]. Reducing sugars were analyzed according to the method of Bernfeld [18] using 3.5 dinitrosalycilic acids (DNS). The carbohydrate contents were determined by deference that is by deducting the mean values of other parameters that were determined from 100. Therefore % carbohydrate = 100 - (% moisture +% crude protein + % crude fat + crude fibre + % ash) [19**;** 20]

D. Antinutrients analysis

Alkaloid content was estimated by the filtration method of Harbone [21]. Oxalate content was determined by the modified method of Ukpabi and Ejidoh [22]. Tannin content was estimated by the colometric method described by Makkar *et al* .[23]. Phytate content was determined by the spectrophotometric method described by Mohamed *et al.* [24]. Lignin content was estimated by Saura-Calixto *et al.* [25] method. Each of the samples from *Dioscorea esculenta* flour was analyzed in triplicate for their physico-chemical and antinutrients properties.

E. Statistical analyses

All analyses were performed in triplicates. The results were processed by the software STATISTICA 7 (Stat soft Inc, Tulsa-USA, Headquarters). Results were expressed as means ± standard deviation. Statistical significance was established using Analysis of Variance (ANOVA) models to estimate the effect of storage period on biochemical composition of different parts of yam tubers. Thus, means were separated according to Duncan's Multiple Range Test (DMRT ($p \leq 0.05$).

III. RESULTS AND DISCUSSION

A. Proximate nutritional composition

Results of the analyses show that the flour from raw *Dioscorea esclenta* yam tubers has higher % ash, crude protein and crude fibre, but lower moisture and carbohydrate content than the boiled *D. esculenta* yam tubers (Table 1). The moisture, carbohydrate, total and reducing sugars contents increased while the other parameters reduced after cooking (Table 1).

1. Total ash content

The total ash content is presented in table 1. The values of total ash content ranged from 3.19 ± 0.03 % dw to 2.33 ± 0.05 % dw for the flour from raw and boiled tubers respectively. It appeared slight differences between ash content of flour from raw *Discorea esculenta* yam tuber and the flour from the boiled tuber. These results are within the acceptable ash content mean values of legumes of 2.4 to 5.0 % recommended by FAO [26]. Ash represents the mineral matter left after food material is burnt in oxygen [27]. It is used as a tool to measure the mineral content in any sample [27]. The *Dioscorea esculenta* yam tubers had moderately high values of ash (2.33 ± 0.05 % and 3.19 ± 0.03 %), which indicate that the yam tubers have good mineral content, hence, can serve as a viable tool for nutritional evaluation [28]. Thus, the result of the ash content in the sample is a suggestion of a low deposit of mineral elements in the samples compare to the recommended values by the FAO [26]. This may indicate that *Dioscorea esculenta* yam tubers would likely contain very high qualities essential minerals. Since ash content is an index to evaluate and grade the nutritive quality of foods [29].

2. Moisture content

The moisture content of flour from raw and boiled tubers of *D. esculenta* yam is shown in Table 1. The moisture content varied from 7.70 ± 0.23 % dw to 8.33 ± 0.04 % dw (dry weight) for the flour from raw and boiled tubers respectively. The highest moisture content was found to be 8.33 ± 0.04 % dw for the flour from the boiled tubers, while the lowest moisture content was obtained with flour from the raw tubers. These values are fairly higher than 5.24 ± 0.05 % and lower than 11.0 % reported by Ogungbenle [30]. The result of Rehman *et al.* [31] also shows higher content of 17.70 ± 0.03 for hard date palm. The Analysis of Variance (ANOVA) revealed that the boiling main effect appeared significant at 0.05 level. There were significant variations at 0.05 level between the moisture contents of flour from raw and boiled tubers. Indeed, the boiling increased significantly ($p \leq 0.05$) the moisture content of flour from a mean value of 1.00 % during boiling time. This increase after cooking is referred to water absorption during boiling process [32]. It may be also attributed to the cell damage due to the effect of boiling. Similar increase in moisture content during the boiling time was observed by Bell [33] in yam tubers; Harada *et al.* [34] in potato tubers and Amon *et al*. [35] in taro tubers. The moisture levels were however within the acceptable limit of not more than 10 % for long term storage of flour [36]. It should be pointed out that when these products are allowed to equilibrate for periods of more than one week at 60 % relative humidity and at room temperature (25 to 27 °C), moisture content might increase [37]. Indeed, the result revealed that the moisture content of the flours from raw tubers and boiled tubers at the both times (10 min and 20 min) were all below 10 %, thereby giving the flours a better shelf life. This biochemical parameter is important in the storage of flour, levels greater than 12 % allow for microbial growth. Chew *et al*. [38] reported that reduced moisture content ensured the inhibition of microbial growth, hence is an important factor in food preservation.

3. Total sugar and Reducing sugar content

The total and reducing sugar contents in flour from raw and boiled tubers of yam (Table 1) increased from 13.13 % to 13.45 % and from 5.06 % to 5.16 % in proportion respectively. This behaviour of flour from tuber, usually in hydrothermal treatments could be explained by the hydrolysis that occurs in tubers transforming carbohydrates and starch in particular, soluble sugars [39]. This is in accordance with the observation of Sahoré and Amani [40] on of *Dioscorea alata* tubers.

4. Carbohydrate content

The results showed that carbohydrates (81.19 ± 0.54 to 83.03 ± 0.18 %) for the flour from raw and boiled tubers respectively are the most important chemical component in the flours(Table 1). This finding corroborated well with those reported by Aboubakar *et al.* [41] for six varieties of Cameroon taro flours. It is an excellent energy supplier [42]. But these values are slightly higher than 80.67± 0.05 % obtained by Ogungbenle [30]). It reported that carbohydrate provides energy to the cells in the body, particularly the brain, which is the only carbohydrate-dependent organ in the body [27]. It is necessary for maintenance of the plasma level, it spares the body protein from being easily digested and helps to prevent the using up of protein. The high carbohydrate content found in flour of *D. esculenta* yam tubers suggests high caloric value. Thus, yam is a source of carbohydrate and has a lower glycaemic index which makes it a sustainable source of energy and gives better protection against obesity and diabetes [43**,** 44, 2].

5. Fiber content

The fiber contents (5.32 ± 0.05 % and 5.02 ± 0.15 %) for the flour from raw and boiled tubers respectively (Table 1) are quite significant and comparably higher than that of polished rice; 0.2% [45]. It appeared slight differences between fiber content from raw yam tubers and boiled yam tubers. But, these values are higher than 4.34 ± 0.03 % and 4.00 ± 0.02 obtained by Ogungbenle [30] and Rehman *et al.* [31]. They are also higher than crude fiber content of flours from taro (*Colocasia esculenta*) corms and fruits originated to Nigeria (0.20-1%, [46, 47, 48]). Fiber is regarded as essential, as it absorbs water and provides roughage for the bowels, assisting intestinal transit. Crude fiber decreases the absorption of plasma cholesterol from the gut in addition to delaying the digestion and conversion of starch to simple sugars, an important factor in the management of diabetes [49]. Dietary fiber serves as a useful tool in the control of oxidative processes in food products and as functional food ingredient [50]. Therefore, that aids digestion and reduces the risks of cardiovascular diseases [51]. Thus, the fairly high content of *D. esculenta* yam fiber can enhance satiety, regulate intestinal transit, reduce energy consumption and promote weight loss in users [52].

6. Crude fat and crude protein contents

The values of crude fat content ranged from 0.69 ± 0.01 % dw to 0.61 ± 0.01% dw for the flour from raw and boiled tubers respectively (Table 1). It appeared slight differences between the crude fat content of flour from raw yam tubers and boiled yam tubers. They were lower if compared to 0.70 and 1.10 % record by Amani and Kamenan [53] for "Florido" and "Kponan".

The boiling reduced slightly the crude fat content of flour from yam tuber. But, in comparison to other flours, flours of *D. esculenta* yam tuber exhibit higher fat content than those recorded by Yi-Chung *et al*. [54] on the yam whole tubers who found the rate of 0.20 % dw *for Dioscorea batata* ("Hualien"cultivar). These results indicated that yam tubers are not a good source of fat.

The crude protein content is presented in table 1. The values of crude protein content ranged from 7.25 ± 0.33 % dw to 5.68 ± 0.18 % dw for the flour from raw and boiled tubers respectively. The flour from the raw tuber had the highest crude protein content whereas the flour from the boiled tuber had the lowest crude protein content. These values were affected significantly at 0.05 level.

The boiling reduced meaningfully ($p \leq 0.05$) the crude protein content of flour from yam tuber. Decrease in cooking time resulted to progressive decrease in the protein isolate yield from the flour [55]. It appeared that protein content of yam tuber flour was higher than that reported on bananas (1.09%), [56]; white yam (5.15%) and sweet potato (3.64%), [45].

Thus, incorporating yam tuber flour in diet could contribute in amino acid balance.

Parameters	Values (% DW)	
	Flour from raw yam	Flour from boiled yam
Ash	3.19 ± 0.03^b	2.33 ± 0.05^a
Moisture	7.70 ± 0.23^a	8.33 ± 0.04^b
Total sugar	13.13 ± 0.03^a	13.45 ± 0.24^a
Reducing sugar	5.06 ± 0.02^a	5.16 ± 0.01^b
Carbohydrates	81.19 ± 0.54^a	83.03 ± 0.18^b
Crude fat	0.69 ± 0.01^b	0.61 ± 0.01^a
Fiber	5.32 ± 0.05^b	5.02 ± 0.15^a
Cellulose	2.69 ± 0.06^b	2.39 ± 0.05^a
Crude protein	7.25 ± 0.33^b	5.68 ± 0.18^a

B. Antinutrient contents

The nutritional importance of a given food depends on the nutrients and anti-nutritional constituents of the food [57]. Thus, the anti-nutrient composition of flour from raw and boiled tubers of *D. esculenta* yam is shown in Table 2.

1. Alkaloid, tannin, oxalate and phytate content

The alkaloid, tannin, oxalate and phytate contents decreased and ranged from 63.66 ± 0.53 % dw to 43.66 ± 1.27 % dw, from 5.86 ± 1.35 % to 5.80 ± 0.16 %, from 17.56 ± 0.41 % to 12.89 ± 0.16 %, and from 286.02 ± 1.35 % to 280.76 ± 0.16 % for the flour from raw and boiled tubers respectively. Thus, the highest values were obtained with raw yam tubers and the lowest values with the boiled yam tubers. Indeed, the boiling reduced significantly ($P \leq 0.05$) all the antinutrients factors after cooking.

The availability of alkaloids in the tubers of *D. esculenta* indicates that yam tubers cannot be eaten raw. Most alkaloids are known for their pharmacological effects rather than their toxicity. However when alkaloids occur in high levels in foods, they cause gastro-intestinal upset and neurological disorders [58].

The total oxalate contents of flour from raw tuber and boiled tuber decreased significantly ($P \leq 0.05$) during the boiling. Besides, the higher percentage of oxalate reduction in the value of the oxalate contents of flour from yam tubers during boiling may also be due to its solubility in boiling water. Boiling may cause considerable skin rupture and facilitate the leakage of soluble oxalate into cooking water. This may be the possible reason to observe high reduction in oxalate level up on boiling [59]. Similar trends have been recorded by Sahoré and Amani [60] who reported the decrease of 20 % in wild yam tuber of *Dioscorea togoensis and Dioscorea burkilliana* during the boiling. Otherwise, the reduced oxalate content on boiled tubers could have positive impact on the health of consumers. The reduction of oxalate levels on cooking is expected to enhance the bioavailability of essential dietary minerals of the tubers and reduce the risk of kidney stones occurring among consumers.

The tannin content of flour from yam tuber reduction could be as result of leaching and/or the effect of the heat on the heat labile tannins contained in the flour from raw and boiled *D. esculenta* yam tubers. This agrees with the fact that tannins are polyphenols or polyphenolic compounds which are soluble in water [61]. The decrease in the levels of tannin during cooking may be also due to the thermal degradation and denaturation of the tannin as well as the formation of insoluble complexes [62] raw tubers of *Dioscorea esculenta*. Moreover, the decreased tannin content has positive effect on the health of consumers. Tannins affect the nutritive value of food products by forming insoluble complexes with proteins thereby decreasing the digestibility of proteins [63]. Tannins may decrease protein quality by decreasing digestibility and palatability, damaging the intestinal tract, and enhancing carcinogenesis [59]. They also bind iron, making it unavailable [64].

Concerning the phytate content, there was a significant difference ($P \leq 0.05$) among the samples during boiling. Indeed, the phytate content decreased significantly ($P \leq 0.05$) after boiling. This observed loss of phytate content from yam samples was noted by Nzewi and Egbuonu [65] on asparagus bean (*Vigna sesquipedalis*) flour during boiling times. Our results of phytate contents being to 286.02 ± 1.35 % (flour from raw tubers and 280.76 ± 0.16 % (flour from boiled tubers) were higher than that reported by Nzewi and Egbuonu [65] on asparagus bean (*Vigna sesquipedalis*) flour as affected by boiling. Similar decrease in phytate content was recorded by Bhandari and Kawabata [13] on wild yams tubers of Nepal that range from 3 % to 20 %. Indeed, the apparent decrease in phytate content during cooking may be partly due either to the formation of insoluble complexes between phytate and other components, such as phytate protein and phytate-protein–mineral complexes or to the inositol hexaphosphate hydrolyzed to penta and tetraphosphates [66]. Furthermore, the knowledge of the phytate level in foods is necessary because high concentration can cause adverse effects on the digestibility [67]. This is important because high phytate content is of significance as it lowers the availability of many essential minerals. Phytate could be substantially reduced or eliminated by soaking, germination and cooking [68].

Parameters	**Values (% DW)**	
	Flour from raw yam	**Flour from boiled yam**
Alkaloid	63.66 ± 0.53^b	43.66 ± 1.27^a
Tannin	5.86 ± 1.35^a	5.80 ± 0.16^a
Oxalate	17.56 ± 0.41^b	12.89 ± 0.16^a
Phytate	286.02 ± 1.35^b	280.76 ± 0.16^a

CONCLUSION

Dioscorea esculenta yam tubers are a good source of biochemical parameter (ash, moisture, total and reducing sugar, carbohydrate, crude protein and crude fat). But, they contained some antinutritional factors such as such as total oxalate, tannin, phytate and alkaloid. Besides, this study showed that boiling had both positive and negative effect on some in flour from tubers of *Dioscorea esculenta* yam. Indeed, the negative effect will be derived from the reduction of the fibre and crude protein contents and the increase of the moisture content while the positive effect was as a result of the increase of carbohydrate, total and reducing sugar content. All the antinutrient factors decreased significantly ($P \leq 0.05$) during boiling. Furthermore, these reduced antinutrients content on boiled *Dioscorea esculenta* tubers could have positive impact on the health of the consumers, particularly the reduction of oxalate levels by boiling was expected to enhance the bioavailability of essential minerals of yam and reduced the risk of kidney stones formation among consumers. Besides, the reduced value as of phytate obtained in boiled yam tubers was expected to enhance the bioavailability of protein and dietary minerals for consumers. However consumption in large amount of plants with higher levels of antinutrients should be avoided.

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