

Influence of Boiling on the Physicochemical Properties of Tubers of *Diocorea Cayenensis-rotundata* Complex “Kponan” Variety

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Abstract Yam belong to the Dioscoreaceae family and the *Diocorea* genus. They are grown for their edible tuber, which is rich in starch and minerals, but low in protein and fat. In Côte d'Ivoire, the “Kponan” variety is particularly popular. Before consumption, the tubers are generally peeled, cut into pieces and cooked. However, when cooked in water, yams lose some of their nutrients. In this context, our study was conducted to assess the impact of cooking on the physical-chemical composition of the “Kponan” variety. The freshly harvested tubers were divided into two parts. The first part was used to prepare raw tuber flour, while the second part was cooked for 30 minutes. The results show a significant reduction in starch (from 70.83 ± 1.41 to 53.65 ± 1.24 %), protein (from 3.53 ± 0.14 to 1.18 ± 0.09 %), fibre (from 2.69 ± 0.05 to 1.81 ± 0.03 %) and energy (from 400.03 ± 1.94 to 388.86 ± 2.54 kcal) content in the cooked tuber compared with the control. Macro and micro-element content also fell. On the other hand, water content (from 4.28 ± 0.13 to 6.76 ± 0.04 %), reducing sugars and total sugars increased during cooking. However, lipid and carbohydrate contents were not affected by the cooking process. To compensate for these cooking-related nutrient losses, it is recommended that meat, fish, oils and vegetables be added to the consumption of tubers of the “Kponan” variety.

Keywords: Yam tubers, boiling, physicochemical properties, “Kponan” variety

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1. Introduction

Yam (*Dioscorea* spp) is a twining, annual herbaceous plant. It belongs to the Dioscoreaceae family and the Dioscoreales order. The genus *Dioscorea* comprises over 600 species spread over five continents [1]. This plant provides edible tubers used to feed people in tropical and subtropical zones of the globe, in particular countries of sub-Saharan Africa, South-East Asia, the Caribbean Islands, and part of Central and South America [2]. In addition to food, yam plays an economic and cultural role in many regions of Côte d'Ivoire where yam festival is celebrated. World yam production is dominated by West Africa, which accounts for nearly 93% of world production [3]. The main producing countries are Nigeria with over 48 million tons or 70% of the world's production followed by Côte d'Ivoire, nearly 6 million

tons or 9%, and Ghana with 4.7 million tons or 7% of the world's production [3].

Yam species cultivated in Côte d'Ivoire are the *Dioscorea cayenensis-rotundata* complex, *Dioscorea alata*, *Dioscorea dumeterum*, *Dioscorea bulbifera* and *Dioscorea esculenta* [4,5]. According to N'dabalishyè [5], the *Dioscorea cayenensis-rotundata* complex contains nineteen varieties including “Kponan”, “Krenglè”, “Lokpa”, “Zrèzrou”, “Cocoassié” etc. Of all the cultivated varieties, the “Kponan” variety is by far the most appreciated by populations [6]. The main production areas in Côte d'Ivoire are the regions of Gontougo, Bounkani, Poro, and Hambol [7]. These regions are the suppliers of the “Kponan” variety to the cities of Côte d'Ivoire, particularly to the city of Abidjan [7,8].

Yam tubers are a rich source of starch, hence provide a lot of energy. Their protein content is acceptable, with low lipid content. They also contain macro (Ca, K, Na, and Mg) and microelements (Fe, Zn, Cu, and Mn). To be consumed,

yam tubers must first be peeled, sliced, and washed, and then cooked in water until the tuber pieces soften. The traditional methods used are boiling, cooking over embers, and frying. These processes improve sensory, and nutrient bioavailability and digestibility. However, cooking can promote some nutrient losses [9]. Also, this study was conducted to assess the influence of boiling on the physico-chemical properties of the tubers of *D. cyenensis-rotundata* complex “Kponan” variety.

2. Material and Methods

Sampling

Yams used consisted of freshly harvested tubers of the “Kponan” variety of the *Dioscorea cayenensis-rotundata* complex. The tubers were obtained directly from farmers located in the Poro region especially in Korhogo (northern Côte d'Ivoire) during the harvesting period of July 2022.

Preparation of sample

The manufacturing process for raw tuber flour

The freshly harvested tubers were washed, peeled, cut into tiny pieces, and dried in the oven at 45°C for 72 hours. The dried tiny pieces were ground using a kitchen grinder (Moulinex). The powder thus obtained is then sieved and packaged in clean glass jars

The manufacturing process for cooked tuber flour

Cooked tuber flour was prepared using the method described by [10]. The flour production process is similar to the method described above except for the step of cooking yam tuber pieces in water for 30 min.

Proximate analysis

Standard methods of the Association of Official Analytical Chemists [11] were used to determine the moisture content, crude protein content, crude fat content, ash content and crude fiber of flour samples.

Moisture content

Moisture content was determined by heating 2 g of each sample to a constant weight in a crucible placed in an oven maintained at 105°C.

Crude protein content

Nitrogen content was determined by the Kjeldahl method, and the crude protein content was calculated by multiplying the nitrogen content by 6.25.

Crude fat content

Crude fat content was exhaustively extracted with anhydrous hexane using a soxhlet apparatus

Ash was determined by the incineration of 2 g samples placed in a muffle furnace and maintained at 550°C for 5 h.

Ash content

Ash content was determined by measurement of residues left after incineration. (AOAC, 2005). About 3 g of yam flour was weighed in porcelain and placed in a Muffle furnace at 550 °C for 6 h until the ash turns white, then weighed.

Crude fiber

Crude fiber was obtained by digesting 2 g of sample

with H₂SO₄ and NaOH, and incinerating the residue in a muffle furnace maintained at 550°C for 6 h.

Total carbohydrate

Total carbohydrate content was obtained by difference based on this equation:

Total carbohydrate (%) = 100 - (% Moisture + % Crude protein + % Crude fat + % Ash + % Fiber).

Energy (Kilo calories)

Energy was calculated after multiplying the mean values of protein, lipid, and carbohydrate by their respective Atwater factors of 4, 9, and 4 [12].

Starch content

The starch assay was performed according to the method described by Jarvis and Walker [13]. 0.1 g of yam chip flour was dissolved in 5 ml of KOH 1 N. After homogenization, the unit was neutralized by 5 ml of HCl 1 N. The mixture thus obtained was allowed to boil for 15 min in a water bath. After filtration, the volume was adjusted to 10 mL. An aliquot of 50 µL was diluted to 5 mL with 4.85 mL of distilled water and 0.1 mL of reagent (I₂+KI) and incubated for 10 min. The absorbance of samples was carried out at 580 and 720 nm.

Quantification of ethanol soluble total sugars and reducing sugars

Extraction of sugar

Two (2) g of yam flour were macerated twice with 25 mL of ethanol at 70 % (w/v) at room temperature °C for 1 h. After maceration, the solvent was evaporated under reduced pressure by using a rotary evaporator (Buchi Rotavapor, Germany).

Total sugars ethanol soluble

Total sugars were quantified using the phenol-sulfuric acid method [14]. 1 mL of the sample was dissolved in 10 mL of dimethylsulfoxide (DMSO) 25 % (v/v). After 15 min of incubation in a water bath at 90 °C, 0.1 mL of the mixture was diluted into 9.9 of distilled water, and 0.5 mL of the previous mixture was added to 0.5 mL of phenol (5 %). Then 2 mL of sulfuric acid (95 %) were added. The absorbance was read at 492 nm. The blank sample was prepared following the same procedure.

Reducing sugars ethanol soluble

The reducing sugar was quantified using the 3,5-dinitrosalicylic acid (DNS) method. The measurement was performed according to the procedure of Lam *et al.* [15] with slight modification. 2 mL of DNS reagent was pipetted into a test tube containing 1 mL of sugar extract solution and kept at 100°C in water-bath for 5 min. After cooling, 7 mL of distilled water was added to the solution and the absorbance of the resulting solution was measured at 540 nm using a UV-VIS spectrophotometer (Shimadzu UV-1800). The reducing sugar content was calculated from the calibration curve of standard D-glucose (0-0.1 mg/L) and the results were expressed as mg of D-glucose equivalent (GE) per gram of dry extract weight.

Mineral analysis

Minerals were analyzed by the method reported by Oshodi [16]. The ash obtained from 1g of sample was dissolved in 10% HCl, filtered and made up to standard

volume with deionized water. Flame photometry method reported by AOAC [11] was used to determine sodium and potassium contents of the sample. Calcium, Fe, Mg, Zn, Cu, and Mn were determined using Atomic Absorption Spectrophotometer (AAS). Phosphorus was estimated colorimetrically (UV-visible spectrophotometer, Model DR 2800/United States).

Anti-nutritional factors

Extraction of phenolic compounds

The extraction of phenolic compounds was conducted according to the method described by Mallek-Ayadi [17]. An aliquot of 2 mL of *n*-Hexane and 4 mL of a solution of methanol/water (60/40) were homogenized with 4 g of yam sample. After vigorous mixing, the suspension was centrifuged at 5000 trs for 3 min. The extraction was performed twice and the hydro alcoholic phases were pooled together. The hydro alcoholic fraction was washed with 4 mL of *n*-Hexane to eliminate the residue of oil, concentrated, and dried à 35°C using a rotary evaporator.

Total polyphenol

The total phenolic compounds of the yam tuber were determined using Folin Ciocalteu reagent according to Yoo *et al.* method [18]. An aliquot of 2.5 mL of 1/10 Folin Ciocalteu reagent was added to 5 mL of the phenolic compounds. The mixture was stirred and kept for 3 min in the dark. Then 1.5 mL of 20% Na₂CO₃ was added. The mixture was then shaken and incubated at room temperature in the dark for 30 min. The absorbance was measured at 517 nm using a spectrophotometer (Shimadzu, Japan). Gallic acid was used as a standard and the results were expressed as mg Gallic acid equivalents per 100 g of extract (mg GAE/100 g extract).

Phytic acid

Phytic acid was determined according to the method described by Zebib *et al.* [19]. This method consists of adding 0.25 g of flour of yam flour to 12.5 mL of hydrochloric acid 3%. The whole was placed for 45 min in a water bath at 30°C then centrifuged at 4000 rpm for 10 min. Four (4) ml of FeCl₃·6H₂O were mixed with 10 ml of the supernatant solution and the precipitate of ferric-phytate was analyzed for phosphorus phytate by measuring the absorbance at 822 nm using a spectrophotometer.

Tannins

Tannins were determined according to the method of Trease and Evans [20]. One (1) mL of methanolic extract was treated with a 5 mL reagent of Folin-Dennis in a basic medium. The absorbance of the mixture was read at 760 nm. The content of tannins was given using a curve standard built starting from a range of concentrations of gallic acid.

Oxalic acid

The oxalic acid was determined by KMnO₄ method described by AOAC [11]. One (1) g of sample was dissolved in 75 mL of sulfuric acid 15 N. The mixture was homogenized for one hour and filtered on Whatman No.1 paper. 25 mL of the filtrated solution were titrated with 0.005 M of permanganate of potassium.

3. Statistical Analysis

All experiments were performed in triplicate and the results were expressed as mean values and standard deviation. One-way analysis of variance (ANOVA) was used to determine significant differences among means and Tukey's test was used to perform multiple comparisons among means using Statistica software (version 7.1). The significance level was defined as $p < 0.05$.

4. Results and Discussion

Results

Physicochemical composition

The physicochemical composition of raw and cooked tuber flours of *D. cayenensis-rotundata* complex variety "Kponan" is presented in Table 1. The results showed a decrease ($p < 0.05$) in starch, proteins, total fiber, ash content and energy of cooked tuber flour compared to raw tuber flour, with values ranging from 4.28 ± 0.13 to 6.76 ± 0.04 %, 3.53 ± 0.14 to 1.18 ± 0.09 %, 70.83 ± 1.41 to 53.65 ± 1.24 %, 2.69 ± 0.05 to 1.81 ± 0.03 %, 1.7 ± 0.05 to 1.25 ± 0.28 %, and 400.03 ± 1.94 to 388.86 ± 2.54 Kcal respectively. However, the results showed an increase ($p < 0.05$) in moisture, reducing sugars, total sugars, and carbohydrates with values ranging from 4.28 ± 0.13 % to 6.76 ± 0.04 %; 0.09 ± 0.10 to 1.63 ± 0.41 %, 0.207 ± 0.35 to 2.39 ± 0.28 % for raw tuber flour and cooked tuber flour. Carbohydrates and lipids showed no significant difference ($p > 0.05$) between both studied flours. The values ranged from 88.76 ± 1.56 to 88.08 ± 0.366 % and 3.43 ± 0.05 to 3.18 ± 0.09 % for raw and cooked tuber flours respectively.

Mineral composition

The composition of macro and micro minerals of raw and cooked tuber flours of *D. cayenensis-rotundata* complex "Kponan" variety is presented in Table 2. The results showed a significant difference ($p < 0.05$) in the levels of macro and micro elements for each flour. Values obtained for macro elements are as follows: Sodium 425.22 ± 1.18 - 209.25 ± 0.72 mg/100g dry basis (d.b.), Magnesium 137.03 ± 0.57 - 76.16 ± 0.60 mg/100g d.b., Phosphorous 59.67 ± 0.24 - 53.42 ± 0.46 mg/100g d.b., Potassium 169.54 ± 0.25 - 146.15 ± 0.14 mg/100g d.b. and Calcium 370 ± 0.20 - 365.21 ± 0.61 mg/100g d.b. for raw and cooked tuber flours, respectively. Also, values obtained for microelements were between 376.45 ± 0.47 and 354.19 ± 0.46 mg/100g d.b. for Manganese, 127.83 ± 0.10 and 120 ± 0.57 mg/100g d.b. for Iron, 306.69 ± 0.37 and 107.26 ± 1.22 mg/100g d.b. for Copper, and finally 122.77 ± 0.4 and 120.61 ± 0.3 mg/100g d.b. for zinc, respectively for raw and cooked tuber flours.

Anti-nutritional factors

Table 3 presents the composition of anti-nutritional factors in raw and cooked tuber flours. The contents of total polyphenols, oxalic acids, and tannins observed in raw tuber flours are $14.10^{-3} \pm 0.00$, $29.30. 10^{-3} \pm 0.00$ and 0.9 ± 0.04 respectively, while the values for cooked tuber

flours were $14.10^{-3} \pm 0.00$, $3.60.10^{-3} \pm 0.00$, $21.10.10^{-3} \pm 0.0$ and 0.71 ± 0.01 respectively. The phytate content was zero for both types of flour.

5. Discussion

The results presented in the current study showed a decrease in starch, proteins, total fiber, and ash content when tubers were cooked. This decrease in starch could be explained by the hydrolysis of starch during boiling in water, resulting in the release of glucose, maltose, and limit-dextrins; thus, reducing the molecular weight of the starch [21]. The hydrolysis of the starch consequently increases the level ($p < 0.05$) of reducing sugars, which are made up of glucose and maltose, hence the increase in total sugar rate observed with boiled tubers. Similar results have been observed by Chan *et al.* [22] and Aina *et al.* [23] who reported an increase in reducing sugars and total sugars in boiled sweet potatoes. Carbohydrate content was found to increase also when tubers were cooked with water.

In addition, results showed a decrease in proteins ($p < 0.05$) when raw tubers were boiled. Indeed, this drop in protein content observed in the flour of cooked tubers results from the denaturation of proteins caused by heat during cooking. These results are in concordance with the literature [24].

Lipids have some stability when exposed to high temperatures. Lipids content did not vary ($P > 0$) when tubers were boiled. Our results are not in agreement with those obtained by Kenfack and colleagues [28] who reported a drop in lipid levels when tubers of wild yam (*Dioscorea praehensilis* Benth) were cooked in water.

Raw tubers boiling increased ($p < 0.05$) in moisture. Yam tubers are rich in starch. Yet, when starch is subjected to regular heating at increasing temperature (60-100°C) in the presence of an excess of water, starch granules gradually hydrate and swell as the temperature increases, with the loss of the Malt cross [26]. Our results differed from those obtained by Ogliary *et al.* [21] who showed a decrease in values when potato tubers were boiled.

Ash content decreased ($p < 0.05$) when raw tubers were cooked in water. This decrease is linked to the loss of macro and micro elements content during the cooking by leakage. These results are in agreement with the studies carried out by Laurent [27] and Trèche [28].

Tannins, oxalates, and total polyphenols values were lower in raw tubers of *Dioscorea cayenensis-rotundata* complex variety “Kponan” tubers while phytates were found to be inexistent. After boiling in water, cooked tubers levels decrease in these compounds apart from phytates where values remained inexistent. This decrease of anti-nutritional factors may attribute to the inactivation of enzymatic activities caused by the heat when cooking the tubers [29,30].

6. Conclusion

Boiling reduces major physicochemical properties of yam tubers such as proteins, starch, mineral elements, anti-nutritional factors, and energy. To compensate for

these losses due to cooking, the consumption of tubers of *Dioscorea Cayenensis-rotundata* complex “Kponan” variety should be supplemented by meat, fish, oil, and vegetables.

Table 1. Physicochemical composition of raw and cooked tuber flours of *D. cayenensis-rotundata* complex “Kponan” variety

Paramètres (%)	Farine crue	Farine cuite
Moisture	4.28 ± 0.13^b	6.76 ± 0.04^a
Proteins	3.53 ± 0.14^a	1.98 ± 0.09^b
Lipids	3.43 ± 0.05^a	3.18 ± 0.09^a
Fibre	1.7 ± 0.05^a	1.25 ± 0.28^b
Ash	2.69 ± 0.05^a	1.81 ± 0.03^b
Total carbohydrate	88.76 ± 1.56^a	88.08 ± 0.36^a
Starch	70.83 ± 1.41^a	53.78 ± 1.24^b
Total sugars	0.207 ± 0.35^b	2.39 ± 0.28^a
Reducing sugar	0.09 ± 0.10^b	1.63 ± 0.41^a
Energy (Kcal)	400.03 ± 1.94^a	388.86 ± 2.54^b

Values are Means $\pm$ SD (standard deviation) of three determinations. In the same row, mean values followed by the different letters (superscript) are significantly different ($P < 0.05$).

Table 2. Minerals composition of raw and cooked tuber flours of *D. cayenensis-rotundata* complex “Kponan” variety

Minerals (mg/100g ms)	Raw tuber flour	Cooked tuber flour
Macro elements		
Sodium (Na)	425.22 ± 1.18^a	209.25 ± 0.72^b
Magnésium (Mg)	137.03 ± 0.57^a	76.16 ± 0.60^a
Phosphorous (P)	59.67 ± 0.24^a	53.42 ± 0.46^b
Potassium (K)	169.54 ± 0.25^a	146.15 ± 0.14^a
Calcium (Ca)	370 ± 0.20^b	365.21 ± 0.61^a
Micro elements		
Manganese (Mn)	376.45 ± 0.47^a	354.19 ± 0.46^b
Iron (Fe)	127.83 ± 0.10^b	120 ± 0.57^a
Copper (Cu)	306.69 ± 0.37^a	107.26 ± 1.22^b
Zinc (Zn)	122.77 ± 0.40^a	120.61 ± 0.30^b

Values are Means $\pm$ SD (standard deviation) of three replicates. In the same row, mean values followed by the different letters (superscript) are significantly different ($P < 0.05$).

Table 3. Anti-nutritional factors content of raw and cooked tuber flours of *D. cayenensis-rotundata* complex “Kponan” variety

Parameters	Raw tuber flour	Cooked tuber flour
Tannins (mg EAT/g MS)	0.90 ± 0.04^a	0.71 ± 0.01^b
Total Polyphénols (mg EAG/g MS)	$14.10^{-3} \pm 0.00^a$	$3.60.10^{-3} \pm 0.00^b$
Phytates (%)	0.00	0.00
Oxalic acid (mol/ml)	$29.30.10^{-3} \pm 0.00^a$	$21.10.10^{-3} \pm 0.0^b$

Values are Means $\pm$ SD (standard deviation) of three replicates. In the same row, mean values followed by the different letters (superscript) are significantly different ($P < 0.05$).

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Conflict of Interest

The authors do not have any conflict of interest.

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