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# Comparison of physicochemical properties and anti-nutritional factors of raw and boiled tubers of *Dioscorea cayenensis-rotundata* complex cultivar "Krenglè"

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## Abstract

**Aim:** Yams are a staple food in many countries. They are generally consumed boiled. This study aimed to investigate the impact of boiling on the "Krenglè" cultivar yam tuber.

**Method:** Mature, healthy "Krenglè" cultivar yam tubers were harvested, placed in jute bags, and transported to the laboratory. The tubers were washed under running water, peeled, and cut into pieces using a stainless-steel knife. The resulting pieces were divided into two batches. The first batch was oven-dried at 45°C for 72 hours. The second batch was boiled in water for 30 minutes.

**Results:** The study of raw tuber flour and tuber flour cooked for 30 minutes showed that boiling in water resulted in a significant decrease in titratable acidity, vitamin C, carbohydrates, lipids, ash, and energy content. Protein content increased significantly.
Analysis of mineral content revealed a significant decrease in potassium (K), phosphorus (P), calcium (Ca), sodium (Na), and zinc. In contrast, the levels of minerals such as magnesium, iron, manganese, and copper remained unchanged during boiling. Phenolic compounds and antinutritional compounds were also reduced during the boiling of the tuber of the yam cultivar "Krenglè".

**Conclusion:** Boiling the tuber of the yam cultivar "Krenglè" for 30 minutes yielded a flour relatively rich in nutrient compounds while reducing the levels of antinutritional compounds.

**Keywords:** Yam; Cultivar; Flour; Krenglè; Boiling

## 1. Introduction

The yam is an herbaceous plant belonging to the Dioscoreaceae family, the Dioscoreales order and the Dioscorea genus, which comprises more than 600 species. It is a food crop that produces one or more tubers underground. Once harvested in the wild by hunters and fishermen for food, yams are now a cash crop and common consumer product that floods markets and feeds urban populations [1, 2]. These tubers constitute a staple food for populations living in tropical and subtropical regions of the world, some of whom originate from them. For example, *Dioscorea trifida* is native to tropical America, while *Dioscorea rotundata*, *Dioscorea cayenensis*, *Dioscorea bulbifera* and *Dioscorea*

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*dumetorum* originate from West Africa. *Dioscorea alata*, *Dioscorea esculenta*, *Dioscorea opposita* and *Dioscorea batatas*, on the other hand, come from Asia [3, 4]. Yam cultivation therefore contributes to improving the stability of the food system [1]. The most important yam production area in Africa, also known as the 'yam belt', extends from the Ivory Coast to western Cameroon [5]. Nigeria is the leading producer, with 65 million tonnes, followed by Ghana, with 8 million tonnes, and Côte d'Ivoire, with 7.6 million tonnes [6]. The main species of yam cultivated in Côte d'Ivoire are the *Dioscorea cayenensis–rotundata* complex, *D. alata, D. esculenta* and *D. bulbifera* [7]. The *Dioscorea cayenensis-rotundata* complex contains several species, including the "Kponan", "Krenglè" and "Lokpa" varieties. Unlike the “Kponan” and “Lokpa” varieties, which are double-harvested yams, the “Krenglè” variety allows for a single harvest [8]. It is produced in the regions of Dabakala, Kong and Korhogo. Cultivation takes place from March to April, after the first rains. The tubers are harvested in December, when the stems are senescing. This late yam variety plays a significant role in Côte d'Ivoire's food security and economy. Despite its economic and social importance, and despite much work having been devoted to yams in general, very little research has been carried out on this particular variety. This study therefore contributes to the promotion of the “Krenglè” yam produced in the Korhogo region.

## 2. Material and methods

### 2.1. Plant material

Mature, healthy tubers of “Krenglè” yam were harvested from a traditional plantation in Lataha, a village near Korhogo (northern Côte d'Ivoire). The tubers are then placed in jute bags and transported to the laboratory.

### 2.2. Sampling and flours production

The tubers were washed with tap water, peeled and cut into pieces using a stainless-steel knife, then washed a second time and divided into two lots. The first lot was sliced and oven dried at 45°C for 72 hours. The second lot was cooked before drying at 45°C for 72 hours.

#### *2.2.1. 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, France). The powder thus obtained is then sieved and packaged in clean glass jars

#### *2.2.2. The manufacturing process for cooked tuber flour*

Cooked tuber flour was prepared using the method described by [9]. 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.

### 2.3. Proximate analysis

Standard methods of the Association of Official Analytical Chemists [10] were used to determine the moisture content, crude protein content, crude fat content, ash content and crude fiber of flour samples.

#### *2.3.1. 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 for 24 h.

#### *2.3.2. 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.

#### *2.3.3. 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.

*2.3.4. Ash content*

Ash content was determined by measurement of residues left after incineration [10]. 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.

*2.3.5. Crude fiber*

Crude fiber was obtained by digesting 2 g of sample with $H_2SO_4$ and NaOH, and incinerating the residue in a muffle furnace maintained at 550°C for 6 h.

*2.3.6. Total carbohydrate*

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

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

*2.3.7. 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 [11].

*2.3.8. Titratable Acidity*

Titratable acidity was determined according to the method described by [12]. A homogeneous aqueous suspension of 10% (w/v) yam tuber flour was centrifuged in a benchtop centrifuge at 3000 rpm for 15 min. A 10 mL aliquot of the supernatant, collected in a beaker, was titrated with 0.1 N sodium hydroxide solution after adding 4 drops of 1% (w/v) phenolphthalein as a color indicator. Titratable acidity was calculated in g of lactic acid/100 g of sample.

### 2.4. Mineral analysis

Minerals were analyzed by the method reported by [13]. The ash obtained from 1 g of sample was dissolved in 10% HCl, filtered and made up to standard volume with deionized water. Flame photometry method reported by AOAC (2005) [10] 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).

### 2.5. Anti-nutritional factors

*2.5.1. Extraction of phenolic compounds*

The extraction of phenolic compounds was conducted according to the method described by [14]. 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 rpm 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.

*2.5.2. Total polyphenols*

The total polyphenolic compounds of the yam tuber were determined using Folin Ciocalteu reagent according to [15] method. An aliquot of 2.5 mL of 1/10 Folin Ciocalteu reagent was added to 5 mL of the phenolic extract. The mixture was stirred and kept for 3 min in the dark. Then 1.5 mL of 20% $Na_2CO_3$ 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).

*2.5.3. Tannins*

Tannins were determined according to the method of [16]. 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 standard curve constructed starting from a range of concentrations of gallic acid.

*2.5.4. Phytic acid*

Phytic acid was determined according to the method described by [17]. This method consists of adding 0.25 g of yam flour to 12.5 mL of hydrochloric acid of 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 $FeCl_3$-$6H_2O$ 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.

### 2.6. 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 $p < 0.05$.

## 3. Results and discussion

The biochemical composition of fresh tuber and cooked tuber flours of the yam *Dioscorea cayenensis rotundata* cv. "Krengle" is presented in Table 1.

The titratable acidity level in raw tuber flour was 9.33 ± 1.15%, while that of cooked tuber flour was 7.00 ± 1.00%, suggesting that cooking in water therefore led to a reduction in the titratable acidity level in the yam tuber. Our results differed from those found by [18], who obtained an increase in the titratable acidity level from 0.25% in the flour from the raw tuber to 0.28% in the flour from the cooked tuber.

In this study, analyses revealed a vitamin C level of 37.33 ± 0.28% in raw tuber flour, while that of cooked tuber flour was 25.85 ± 1.44%. Cooking therefore caused a loss of vitamin C in the yam tuber of the cultivar "Krenglè". Our results are contrary to those obtained by [19], who showed an increase in vitamin C levels in *Dioscorea opposita* tubers subjected to different cooking methods. This reduction could be due to the degradation of vitamin C during cooking. Since vitamin C is water-soluble and temperature sensitive, it is easily degraded during cooking [20].

The dry matter content in the raw tuber and cooked tuber flours are 88.54 ± 0.01% and 88.46 ± 0.12%, respectively. There was no significant difference (P > 0.05) between these values. Our results are close to those of [21], who obtained a moisture content of 5.3 ± 0.01%, or approximately 94.70% dry matter, in yam flour (Dioscorea spp.). The high values of dry matter content of raw and cooked yam tuber flours in this study express low moisture contents, which makes it possible to avoid microbial contamination and thus have a longer shelf life of the flour.

As for carbohydrates, the levels obtained in raw tuber flour and cooked tuber flour were 81.30 ± 0.10% and 80.62 ± 0.15%, respectively. The carbohydrate content of the yam tuber of the cultivar "Krenglè" decreased significantly during cooking in water. Similar results were obtained by [22], who observed a decrease in carbohydrate levels of 28 to 25% in taro tubers after cooking in boiling water. This result could be explained by the fact that carbohydrates break down into water-soluble sugars which diffuse into the cooking water. Some authors, such as [23], believe that this decrease could be attributed to their thermal decomposition into carbonic acid and carbon dioxide during boiling.

The results of this work showed that the lipid content decreased from 4.05 ± 0.06% to 2.79 ± 0.06% after cooking the tuber of the yam cultivar "Krenglè" in water. This result is similar to that of [24], who also observed a decrease in lipid content from 5.00 ± 0.09 to 4.60 ± 0.39 in wild yam (*Dioscorea praehensilis* Benth.) tubers after cooking.

Boiling resulted in a significant increase in protein levels, from 3.87 ± 0.01% to 4.37 ± 0.06%. Contrary to our results, some authors, such as [25], observed a decrease in protein content from 8.19 ± 0.04% to 7.11 ± 0.03% and from 5.29 ± 0.01% to 4.08 ± 0.02%, respectively, in the tubers of green yam and red yam, two cultivars of *Dioscorea Bulbifera*.

The analyses showed an energy value of 374.57 ± 0.37 Kcal in the raw tuber flour compared to a value of 367.89 ± 0.57 Kcal in the cooked tuber flour. Cooking therefore reduced the energy value. Our results are similar to those of [26] who obtained a reduction in the energy value from 369.94 Cal/g to 363.82 Cal/g by cooking the tuber of the yam *Dioscorea bulbifera* in water. The decrease in energy value during cooking in boiling water could be due to the decrease in carbohydrate levels because the higher the amount of glucose, the more the total energy increases [27].

The flour from the yam tuber *Dioscorea cayenensis rotundata* cv “Krenglè” obtained after 30 minutes of cooking is energetically rich and contains almost all the nutrients. This flour could be used as an ingredient in baking.

**Table 1** Proximate composition of raw and boiled yam of *Dioscorea cayenensis rotundata* cv “Krenglè”

| Parameters (%) | RYF | BYF |
|---|---|---|
| Titratable Acidity | 9.33 ± 1.15$^{b}$ | 7.00 ± 1.00$^{a}$ |
| Vitamin C | 37.33 ± 0.28$^{b}$ | 25.85 ± 1.44$^{a}$ |
| Dry matter | 88.54 ± 0.01$^{a}$ | 88.46 ± 0.12$^{a}$ |
| Carbohydrates | 81.30 ± 0,10$^{b}$ | 80.62 ± 0,15$^{a}$ |
| Proteins | 3.87 ± 0.01$^{a}$ | 4.37 ± 0.06$^{b}$ |
| Lipids | 4.05 ± 0.06$^{b}$ | 2.79 ± 0.06$^{a}$ |
| Ash | 2.09 ± 0.01$^{b}$ | 1.98 ± 0.01$^{a}$ |
| Gross energy (Kcal) | 374.57 ± 0.37$^{b}$ | 367.89 ± 0.57$^{a}$ |

RYF= Raw yam flour; BYF= Boiled yam flour; Mean ± standard deviation; n = 3.
Values in the same row assigned different letters are significantly different (p ≤ 0.05) according to Tukey's Test.

Table 2 presents the mineral composition of the raw and boiled yam tuber of *Dioscorea cayenensis rotundata* cv “Krenglè”.

The levels of potassium (K), phosphorus (P), calcium (Ca), sodium (Na) and zinc in the flour of the raw tuber are respectively 933 ± 5.00 mg/100g DM, 99.66 ± 10.01 mg/100g DM, 1223.00 ± 1.00 mg/100 g DM, 1.02 ± 0.04mg/100 g DM and 0.4 ± 0.02 mg/100 g DM. Their respective contents in the cooked tuber flour are 639.00 ± 1.00 mg /100 g of DM for potassium (K), 50.00 ± 6.00 mg /100 g of DM for phosphorus (P), 1220.00 ± 1.08 mg /100 g of DM for calcium (Ca), 0.77 ± 0.03 mg /100 g of DM for sodium (Na) and 0.23± 0.00 mg/100 g DM for zinc. Cooking in boiling water therefore led to a loss of these minerals in the yam tuber cultivar “Krengle”. Our results confirm those of [28] who observed that different traditional processing methods, such as boiling, water soaking and sun drying of yam tuber resulted in a significant decrease in mineral content. These authors noted that this decrease was more pronounced during boiling and soaking, due to the leaching of minerals.

On the other hand, the levels of minerals such as magnesium, iron, manganese and copper did not undergo any variation when cooking the yam tuber in boiling water. This cooking method therefore made it possible to retain as many of these minerals as possible. Our results are similar to those obtained by [29] whose work showed that boiling sweet potato tubers in water retained more iron and copper than frying. Cooking the yam *Dioscorea cayenensis rotundata* cv “Krenglè” in boiling water produced a flour relatively rich in minerals, making it a good ingredient for the formulation of food for infants and the elderly.

**Table 2** Mineral composition of raw and boiled yam of *Dioscorea cayenensis rotundata* cv "Krenglè"

| Parameters (mg/100 DM) | RYF | BYF |
|---|---|---|
| Potassium (K) | 933 ± 5.00$^{a}$ | 639.00 ± 1,00$^{b}$ |
| Phosphorus (P) | 99.66 ± 10,01$^{b}$ | 50.00 ± 6.00$^{a}$ |
| Magnesium (Mg) | 408 ± 1,00$^{a}$ | 408.00 ± 1.00 $^{a}$ |
| Calcium (Ca) | 1223.00 ± 1.00 $^{a}$ | 1220.00 ± 1,08 $^{b}$ |
| Sodium (Na) | 1.02 ± 0,04$^{b}$ | 0.77 ± 0.03 $^{a}$ |
| Iron (Fe) | 2.09 ± 0.00$^{a}$ | 2.09 ± 0.00 $^{a}$ |
| Manganese (Mn) | 0.24 ± 0.00$^{a}$ | 0.23 ± 0.00$^{a}$ |
| Copper (Cu) | 0.16 ± 0,02$^{a}$ | 0.15 ± 0,00$^{a}$ |
| Zinc (Zn) | 0.4 ± 0.02$^{b}$ | 0.23± 0.00$^{a}$ |

RYF= Raw yam flour; BYF= Boiled yam flour; Mean ± standard deviation; n = 3.
Values in the same row assigned different letters are significantly different (p ≤ 0.05) according to Tukey's Test.

The composition in anti-nutritional factors of raw and boiled yam of *Dioscorea cayenensis rotundata* cv "Krenglè" is presented in Table 3.

The level of flavonoids in raw tuber flour is 9.34 ± 3.18 mg EQ / 100g DM. After cooking in boiling water, the level of this compound decreased to 2.75 ± 0.19 mg EQ/100g DM. Cooking therefore caused a loss of flavonoids. Flavonoids are a widely distributed group of polyphenolic compounds, characterized by a common benzopyrone ring structure, which have been reported to act as antioxidants in various biological systems [30]. The reduction of these polyphenolic compounds could have an impact on the level of total phenolic compounds. Thus the analyses revealed that cooking in boiling water also caused a loss of total phenolic compounds, the rate of which decreased from 167.65 ± 1.42 mg EQ/100g DM in the flour from the raw tuber to 73.40 ± 1.24 mg EQ/100g DM in the flour from the cooked tuber. This result is corroborated by that of [31] who noted a reduction in the level of total phenolic compounds from 478 ± 11.62 mg gallic acid equivalent/100 g to 306 ± 7.7 mg gallic acid equivalent/100 g during cooking of the yam *Dioscorea alata*. The loss of phenolic compounds during cooking in water could be due to their degradation by heat and their diffusion in the cooking water because according to [32], heat tends to degrade certain compounds such as phenols, flavonoids, tannins and saponins with antioxidant properties.

As for tannins, the analyses showed that their level in the raw tuber flour was 63.12 ± 6.34 mg EAT/100 g DM while the cooked tuber flour gave a level of 47.05 ± 5.93 mg EAT/100 g DM. There was therefore a significant reduction ($P < 0.05$) in the tannin level in the yam tuber. Our results are corroborated by those of [33] who observed a decrease in the tannin level from 47.67 ± 0.11 mg/100g to 43.68 ± 0.18 mg/100g in the taro tuber. This reduction could be due to the diffusion of hydrolyzable tannins in the cooking water [31, 32]. The maximum tannin content in food ingredients set by the acceptable daily intake (ADI) is 560 mg/kg body weight per day [34]. Therefore, the low level of tannin in yam tuber flour (raw and cooked) makes it safe for consumption.

The level of phytic acid which was 32.15 ± 1.34 mg/100 g DM increased to 30.46 ± 1.94 mg/100 g DM. Cooking in water had a reducing effect on the level of phytates in the yam tuber. A similar result was obtained by [35] who observed that the phytate level was reduced from 23.75 mg/kg to 20.39 mg/kg after boiling the cassava tuber. Reducing the level of phytates could have a beneficial effect on the consumer because according to [36], phytic acid is an anti-nutrient because it reduces the bioavailability of minerals by forming insoluble complexes with calcium, iron, zinc and magnesium and inhibits digestive enzymes such as trypsin and amylase.

**Table 3** Anti-nutritional factors of raw and boiled yam of *Dioscorea cayenensis rotundata* cv "Krenglè".

| Parameters | RYF | BYF |
|---|---|---|
| Flavonoids (mg EQ/100g DM) | 9.34 ± 3.18[b] | 2.75 ± 0.19[a] |
| Total polyphenols (mg GAE/100g DM) | 167.65 ± 1.42[b] | 73.40 ± 1.24[a] |
| Tannins (mg EAT/100 g DM) | 63.12 ± 6.34[b] | 47.05 ± 5.93[a] |
| Phytic acid (mg/100 g DM) | 32.15 ± 1.34[b] | 30.46 ± 1.94[a] |

RYF= Raw yam flour; BYF= Boiled yam flour; Mean ± standard deviation; n = 3.
Values in the same row assigned different letters are significantly different ($p \leq 0.05$) according to Tukey's Test.

## 4. Conclusion

Cooking the tuber of the yam *Dioscorea cayenensis rotundata* cv "Krenglè" in water for 30 minutes made it possible to obtain a flour relatively rich in nutritious organic compounds, minerals and antioxidant compounds (phenolic compounds). This cooking method also reduced levels of anti-nutritional compounds such as tannins and phytates. This flour could be used as an ingredient in pastry products, in the formulation of infant and elderly foods.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

The authors declare no conflict of interest.

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