



Physicochemical Characterization of Agricultural By-Products: Case of the Peelings of Varieties of Yams Produced in Côte d'Ivoire

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ABSTRACT

In this study, the physicochemical characteristics of the peelings of three varieties of yam commonly called "Bètè Bètè", "Krenglè" and "Kponan" which are the most consumed in Côte d'Ivoire were evaluated in order to contribute to the determination of the nutritional value of this fraction of these yams which is very often thrown away as household waste. Known standard methods were used for this physicochemical characterization. The results obtained show that the peelings of the variety "Kponan" are the richest in fat ($2.33\% \pm 0.02$), carbohydrates ($82.95\% \pm 0.02$) and fiber ($1.58\% \pm 0.01$). On the other hand, the highest proteins content ($8.05\% \pm 0.1$) was observed in those of the variety "Bètè Bètè". This protein content is also higher than those observed in the flesh of yams. For major minerals such as magnesium and iron, the highest levels were observed in the peelings of the variety "Krenglè". Those of the variety "Kponan" are the richest in potassium. On the other hand, the peelings of the variety "Bètè Bètè" are the richest in calcium. These yam's peelings could thus be transformed for use in times of scarcity to fight against Hunger.

Keywords: Yam, peelings, dry matter, moisture, macronutrients, micronutrients

INTRODUCTION

Yam is a tuberous plant of the botanical genus *Dioscorea*, containing more than 600 species present in tropical zones [1]. World production was estimated at 71 million tons in 2017 [2]. It represents the staple food for over 500 million people in various tropical countries in Africa, the Caribbean, Oceania and Latin America [3]. This world production of yam is dominated by farmers from West Africa (Nigeria, Ivory Coast, Ghana, Benin and Togo) [4]. Indeed, they

produce more than 90% of the yams cultivated in the world [4]. This tuber is one of the most popular main foods in West Africa [5]. It is the leading food crop in the Ivory Coast with an annual production estimated at 7.148 million tons [2]. This country is also the second largest producer of this commodity in the world after Nigeria [6]. Thus, despite the importance of post-harvest losses, yams and cassava are the only food crops for which Côte d'Ivoire can display a status of food self-sufficiency [7].

This production is generally intended for human consumption in various forms (porridge, mash, fried and braised). The consumption of this tuber in Côte d'Ivoire is high and is estimated at 120 kg / inhabitant / year [8]. However, the various forms of yam consumption do not involve its peelings. They are classified as household waste. They represent a loss of 18 to 30% of the weight of fresh yam. Despite the wide availability of yam peelings, the lack of interest shown in this fraction of this tuber limits the scientific data and the fields of use of the latter. To make up for this deficit, specific studies on yam peelings are necessary with a view to enhancing the value of this fraction of this tuber. In this perspective, studies have shown the use of yam peelings in sheep farming in Benin [9] and in Côte d'Ivoire [10].

The present study thus proposes to determine the physicochemical characteristics of the peelings of three varieties of yams widely consumed in Côte d'Ivoire in order to help determine the nutritional value of this fraction of this tuber thrown as household waste.

MATERIAL AND METHODS

Biological Material

The biological material was the peelings of yams. For this study, three varieties of yam more consumed in Côte d'Ivoire were used [11]. Two of these varieties namely «Kponan» and «Krenglè» belong to the species *Dioscorea cayenensis-rotundata* and the other one namely «Bètè-bètè» belongs to the species *Dioscorea alata* (Figure 1). For each variety of yam three samples of 1 kg each were taken and the peelings were collected to form batches of peelings. These batches were analyzed to determine their physicochemical characteristics.

Methods

Determination of the physicochemical characteristics of yam's peelings

Determination of the moisture content and dry matter content of yam's peelings

The moisture content and that of the dry matter were determined according to AOAC Standard 950.01 [12]. The yam peelings were grated using a stainless steel knife and then mixed to obtain a homogeneous sample. From this, a test sample of 100 g was placed in a box of mass (m_0) and the whole was weighed to give the mass (m_1). The box containing the sample was then placed in a MEMMERT brand oven at 105 ° C +/- 5 ° C until a constant mass was obtained. After baking, the sample was allowed to cool before being reweighed to give the mass (m_2). This same operation was carried out for the three varieties of yams studied.

The results were calculated for three replicates and were expressed in g / 100 g. The humidity content was given by the following formula:

$$\text{Humidity} = [(m_1 - m_2) / (m_1 - m_0)] \times 100$$

Dry matter content:

$\text{Dry matter content (\%)} = 100 - \text{Humidity}$
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m0 = mass of the box

m1 = mass (box + sample) before baking

m2 = mass (box + sample) after baking

Determination of proteins content of the peelings of yam

The method used for the determination of proteins content was the standard ISO 5983-1:2005 [13] (method of Kjeldahl). This analysis consisted in digestion by heating the sample (leaves or leaves fortified by peanut paste) in the presence of sulfuric acid, anhydrous sodium sulfate and copper. The solution in the digestion flask is then made alkaline by addition of sodium hydroxide. The nitrogen content is then estimated by titration of the ammonium borate formed with standard sulfuric. The nitrogen concentration of the sample was determined using the following equation:

$$\% N = \frac{x \text{ moles}}{1000 \text{ cm}^3} \times \frac{(v_s - v_b) \text{ cm}^3}{m \text{ g}} \times \frac{14 \text{ g}}{\text{moles}} \times 100$$

Where v_s and v_b are the titration volumes of the sample and blank, and 14g is the molecular weight of nitrogen N. Once the nitrogen content has been determined, it is converted to a protein content:

$\% \text{ proteins} = F. \% N. \text{ Where } F =$

Three essays were done.

Determination of raw ash content of the peelings of yam

The raw ash contents was determined by method ISO 2171:2007 [14]. The sample (leaves or leaves fortified by peanut paste) was dried in an incubator at 103°C until constant weight. The dried sample was then burned at 500 °C. Three essays were done. The ash content was expressed on dry basis:

$$\% \text{ Ash (dry basis)} = \frac{M_{\text{ASH}}}{M_{\text{DRY}}} \times 100$$

M_{ASH} is the mass of ash and M_{DRY} is the mass of dried sample obtained after drying until constant weight of the sample.

Determination of fibers content of the peelings of yam

The method used for the determination of the fibers content was the standard NF V 03-040:1993 [15]. This method consisted firstly in enzymatic digestion of the sample (peelings of yam) by α -amylase. The homogenate obtained was precipitated and filtrated. The residue obtained was used for ash analysis.

The fibers content = Weight (residue) – Weight (ash + proteins). Three essays were done.

Determination of lipids content of the peelings of yam

The lipids content was determined by the method of the settlement CE N° 152/2009 of European Union [16]. The extraction was made in Soxhlet extractor used hexane at 68 °C for 12

hours. The solvent was then removed from the extract in a rotary evaporator at 40 °C under vacuum. The amount of lipid recovered was determined as below:

Mass of lipid = (weight of the flask + boiling chips + extracted oil) – (weight of the flask + boiling chips).

The lipids content was then determined as below:

Lipid content (%) = mass of lipid extracted (g)/sample weight (g) × 100. Three essays were done.

Determination of carbohydrates content of the peelings of yam

The carbohydrates content of the peelings of yam was obtained by the difference between the dry matter content and the sum of the protein, lipid, fibers and raw ash contents of the sample [17].

Determination of the minerals content of the peelings of yam

The atomic absorption spectrometric method (standard ISO 6869: 2000) [18] was used for the determination of calcium (Ca), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), potassium (K), sodium (Na), Cobalt (Co), Chrome (Cr) and zinc (Zn). For this study, the samples were digested by microwave. The contents of minerals were determined by Absorption/flame atomic emission spectrometer VARIAN Spectra AA 110. The standard minerals from Central Laboratory of Food Hygiene of LANADA (Abidjan, Côte d'Ivoire) were used for quality control. For each mineral, three essays were done.

Statistical analysis

The statistical analysis of data was made by Analysis of Variance (ANOVA) using 5% level of significance. The statistical package used was IBM SPSS Statistics version 20. Tukey's Multiple Comparison test was used to identify these differences.

RESULTS AND DISCUSSION

Physicochemical characteristics of the peelings of the three varieties of yam

Physiques characteristics

Peelings yield of obtained

The peelings yield obtained for the three varieties of yam are similar. Indeed, the statistical analysis carried out showed no significant difference between these yields ($P > 0.05$). The values obtained were, $25\% \pm 1$, $25\% \pm 1$ and $24\% \pm 1$ respectively for the peelings of the varieties of yam "Bètè Bètè", "Krenglè" and "Kponan" (Table I).

Moisture content and dry matter content of yam's peelings

The moisture content of the peelings determined are significantly different ($P < 0.05$). These humidity levels are $5.94\% \pm 0.03$, $7.88\% \pm 0.03$ and $4\% \pm 0.02$ respectively for the peelings of the varieties "Bètè Bètè", "Krenglè" and "Kponan" (Table I). Moreover, the peelings of the variety "Krenglè" have the highest moisture content. These results show that the peelings of yam are poor in water unlike whole tubers. Indeed, some authors have shown that yam tubers have a high moisture content [17]. These authors obtained a moisture content of 77.3% in fresh tubers of yam of *D. alta* and 65.7% in fresh tubers of yam of the species *D. cayenensis-rotundata*

complex. Our results confirm that the moisture content in yam peelings as well as in fresh yams varies among varieties.

In addition to the moisture content, the determination of the dry matter content of the peelings of yam also vary from variety of yam to another. Indeed, the values obtained are significantly different ($P < 0.05$). These values are $94.06\% \pm 0.06$, $92.12\% \pm 0.03$ and $96\% \pm 0.1$ respectively for the peelings of the varieties "Bètè Bètè", "Krenglè" and "Kponan" (Table I). Moreover, it was noted that the peelings of the variety "Kponan" had the highest dry matter content. The dry matter content obtained in the present study is higher than that obtained in previous studies [9], which is $88.99\% \pm 0.02$. However, the amount of the dry matter in "Krenglè" peelings is similar to that recorded in 2017 in cassava peelings by these authors ($92.75\% \pm 0.05$) [9]. Our results show much higher dry matter content than those reported by [18] in whole tubers which are between 26.3 to 27.9 g / 100 g MF. These amounts are also higher than those obtained by [19] with whole tubers of the varieties "Bètè Bètè" (22.9 g / 100 g MF) and "Krenglè" (30.8 g / 100 g MF). The dry matter levels in the peels of yam vary from variety to variety. This same variation was noted in whole tubers.

Chemical characteristics

Proteins content

The protein contents of the yam peelings obtained vary from variety of yam to another with contents of 8.05%, 6.47% and 5.77% respectively for the peelings of the varieties "Bètè Bètè", "Krenglè" and "Kponan". Indeed, the statistical analysis carried out showed that these protein contents are significantly different ($P < 0.05$) (Table I). Moreover, the highest protein content is that of the peelings of the variety "Bètè Bètè".

The peelings of these three varieties of yam have very interesting protein contents but the values obtained are lower than the content recorded by [20] in the peelings of yam, which amount noted was 12.2%. However, the peelings in the present study have protein contents much higher than the protein amount obtained by [20] in the sweet potato peelings, which was 4.9%. The protein contents obtained in our study are also higher than the rate obtained by [21] in sweet banana peelings which was 1.80%. Moreover, the protein contents obtained in the peelings of the variety of yam "Bètè Bètè" ($8.05\% \pm 0.10$) and those of the variety "Krenglè" ($6.470\% \pm 0.01$) are much higher than the amount of protein obtained by [20] in cassava peelings (5.2%). The protein contents in the peelings ($5.770\% \pm 0.03$ to $8.05\% \pm 0.10$) obtained in our study are slightly higher than those found by [18] in whole tubers which vary from 6.12 g / 100 g DM at 7.07 g / 100 g DM. Also, the peelings of the variety "Bètè Bètè" recorded the highest protein content. This same observation was noted in the whole tubers by [17].

The peelings of yam are thus a great source of proteins.

Fat content

The fat contents of the peelings of the three varieties of yam are significantly different ($P < 0.05$). The highest content was determined in the peelings of the variety of yam "Kponan" (Table II). The values obtained in the present work (Table I) are higher than that recorded in previous study which was 1.1% [20]. They are also much higher than the fat content obtained by [9] in yam peels ($0.32\% \pm 0.01$). In general, the peelings showed low fat content. Moreover, this fat

content is similar to that of whole tubers. However, previous other studies have shown that, yams consumed in Côte d'Ivoire have low fat content [21].

Ash contents

The ash contents of the peelings of the three varieties of yam ("Bètè Bètè", "Krenglè" and "Kponan") determined are significantly different ($P < 0.05$). That of the peelings of the "Bètè Bètè" variety is the highest, followed by that of the peelings of the variety "Kponan" and finally that of the peelings of the variety "Krenglè" (Table I). The values recorded ranged from $2.45\% \pm 0.03$ to $3.76\% \pm 0.16$.

These values are lower than that obtained in previous study which was 8.7% [20]. Crude ash contents thus vary from variety to variety. This observation could be due to the various varieties of yams analyzed.

Fibers content

The fiber contents of the peelings of the three varieties of yam ("Bètè Bètè", "Krenglè" and "Kponan") determined are significantly different ($P < 0.05$). Furthermore, the highest fiber content was determined in the peelings of the variety "Kponan" (Table I). It was noted that all the values obtained (Table I) are much higher than those determined in whole tubers. Indeed, [17] recorded a crude fiber content of 1.88% in tubers of "Bètè Bètè" and 0.63% in tubers of yams of the *D. cayenensis-rotundata* complex.

Carbohydrate content

The carbohydrate content of the peelings of the three varieties of yam ("Bètè Bètè", "Krenglè" and "Kponan") determined are significantly different ($P < 0.05$). It is also noted that the highest carbohydrate content is that of the peelings of the variety of yam "Kponan". This is followed by the carbohydrate content of the peelings of the variety of yam "Krenglè" and then that of the peelings of the variety of yam "Bètè Bètè" (Table I). The peelings analyzed in this study showed high carbohydrate contents ranging from $79.97\% \pm 0.01$ to $82.95\% \pm 0.02$. These values are close to the carbohydrate contents of fresh tubers. Furthermore, the average of carbohydrate content of the peelings of the variety of yam "Krenglè" ($80.18\% \pm 0.02$) is statistically identical to that obtained by [22]. Indeed, these authors recorded a carbohydrate content of 80 g / 100 g in the tubers of the *D. cayenensis-rotundata* complex from Cameroon. These high carbohydrate contents show that yam peelings are also important sources of energy like fresh tubers. This could justify their use in animal feed as pointed out previously by [9, 23].

Magnesium (Mg) content

The magnesium contents of the peelings of the three varieties of yam (varieties "Bètè Bètè", "Krenglè" and "Kponan") are significantly different ($P < 0.05$) with the highest magnesium content noted in the peelings of the variety of yam "Krenglè" (Table II).

Iron (Fe) content

The iron contents of the peelings of the three varieties of yam are significantly different ($P < 0.05$) with the highest content observed in the peelings of the variety of yam "Krenglè" (Table II).

Calcium content (Ca)

The analysis carried out showed that the calcium contents of the peelings of the varieties "Bètè Bètè", "Krenglè" and "Kponan" are significantly different ($P < 0.05$). Moreover, the peelings of the variety of yam "Bètè Bètè" are the richest in calcium (Table II).

Zinc content (Zn)

The zinc contents of the peelings of the three varieties ("Bètè Bètè", "Krenglè" and "Kponan") are significantly different ($P < 0.05$). Moreover, the highest zinc content was obtained in the peelings of the variety of yam "Bètè Bètè", followed by that obtained in the peelings of the variety of yam "Kponan" and then that obtained in the peelings of the variety of yam "Krenglè" (Table II).

Potassium content (K)

The potassium contents of the peelings of the varieties of yam "Bètè Bètè" and "Krenglè" are similar ($P > 0.05$). However, a significant difference was noted between these similar contents and that of the peelings of the variety of yam "Kponan" ($P < 0.05$) (Table II).

Sodium content (Na)

The analysis carried out did not reveal any significant difference between the sodium contents of the peelings of the varieties of yam "Bètè Bètè", and "Kponan" ($P > 0.05$) (Table II). However, these similar contents are significantly different from that of the peelings of the variety of yam "Krenglè" ($P < 0.05$) (Table II). Moreover, the peelings of the varieties of yam "Bètè Bètè" and "Kponan" contained the highest content of sodium in this study.

Chromium content (Cr)

The chromium contents of the peelings of the three varieties of yam ("Bètè Bètè", "Krenglè" and "Kponan") are significantly different ($P < 0.05$). Moreover, the peelings of the variety of yam "Bètè Bètè" are the richest in this mineral (Table II).

Cobalt content (Co)

The analysis carried out showed a significant difference between the cobalt contents of the peelings of the varieties of yam "Bètè Bètè", "Krenglè" and "Kponan" ($P < 0.05$). The peelings of the variety of yam "Kponan" are the richest in this mineral (Table II).

Manganese content (Mn)

The analysis carried out did not reveal any significant difference between the manganese contents of the peelings of the varieties "Bètè Bètè", "Krenglè" and "Kponan" ($P > 0.05$) (Table II).

Copper content (Cu)

The analysis carried out did not reveal any significant difference between the copper content of the peelings of the variety of yam "Bètè Bètè" and that of the peelings of the variety of yam "Kponan" ($P > 0.05$). However, these copper contents are significantly different from the copper content determined in the peelings of the variety of yam "Krenglè" ($P < 0.05$) (Table II).

The determination of all the minerals described above shows that the peelings of the three varieties of yams studied contain high levels of minerals. Moreover, the highest contents in all the types of peelings of yam are those of potassium (K), calcium (Ca), magnesium (Mg) and zinc (Zn). These mineral contents are similar to those contained in whole roots and tubers mentioned by [23]. Previous studies have shown that potassium is the most abundant mineral in yam tubers [24, 25]. Sodium is the second abundant mineral in yam tubers according to [24]. Our results confirm that yam peelings are real sources of minerals, especially potassium and calcium. However, most of these earlier studies, unlike the present study, did not mention the varieties of yam from which the peelings used were obtained.

CONCLUSION

Yam is a tuber that is widely consumed in Côte d'Ivoire. The yam varieties "Krenglè", "Kponan" and "Bètè Bètè" are moreover the most popular. The consumption of these yams generates a large amount of peelings which are underexploited due to the lack of scientific data on these peels. The present work, which consisted in evaluating certain physicochemical parameters of yam peelings, revealed that these peelings of the three varieties of yam ("Krenglè", "Kponan" and "Bètè Bètè") have a large amount of dry matter and carbohydrates. They represent real sources of protein compared to those obtained in yam tubers. These yam peelings are also rich in minerals. Indeed, these are rich in Ca, K, Mg and Zn. This study provides for the first time, data on the physicochemical parameters of the peelings of the varieties of yams "Krenglè", "Kponan" and "Bètè Bètè" consumed in Côte d'Ivoire. These scientific data obtained thus offer a new way of valuing these yam peelings. Indeed, on the one hand, they could be transformed into flour for consumption in times of scarcity and on the other hand, be transformed into by-products under the action of fermentative microorganisms.

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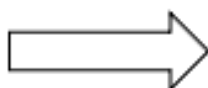
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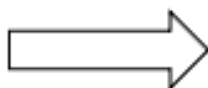
Tuber of variety "Bètè Bètè"



Peelings of the tuber of variety "Bètè Bètè"



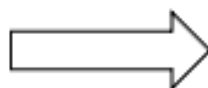
Tuber of variety "Kponan"



Peelings of the tuber of variety "Kponan"



Tuber of variety "Krenglè"



Peelings of the tuber of variety "Krenglè"

Figure 1: Fresh tubers and peelings of three varieties of yam more consumed in Côte d'Ivoire**Table I: Physical characteristics and macronutrients of the peelings of three varieties of yam more consumed in Côte d'Ivoire**

Physical characteristics and macronutrients of the peelings	Variety of the peelings of yam		
	Variety «Bètè Bètè»	Variety « Krenlè»	Variety «Kponan»
Yield for obtaining peelings	25 ± 1 ^a	25 ± 1 ^a	24 ± 1 ^a
Moisture content (%)	5.94 ± 0.03 ^b	7.88 ± 0.03 ^c	4 ± 0.02 ^a
Dry matter content (%)	94.06 ± 0.06 ^b	92.12 ± 0.03 ^a	96 ± 0.1 ^c
Proteins content (%)	8.05 ± 0.1 ^c	6.47 ± 0.01 ^b	5.77 ± 0.03 ^a
Fat content (%)	1.33 ± 0.03 ^a	1.66 ± 0.02 ^b	2.33 ± 0.02 ^c
Carbohydrate content (%)	79.97 ± 0.01 ^a	80.18 ± 0.02 ^b	82.95 ± 0.02 ^c
Raw ash contents (%)	3.76 ± 0.16 ^c	2.45 ± 0.03 ^a	3.37 ± 0.09 ^b
Fibers content (%)	0.95 ± 0.01 ^a	1.36 ± 0.01 ^b	1.58 ± 0.01 ^c

Values are means ± S.D (n=3); Means in each row followed by different letters are significantly different (p<0.05)

Table II: Micronutrients of the peelings of three varieties of yam more consumed in Côte d'Ivoire

Micronutrients of the peelings	Variety of the peelings of yam		
	Variety «Bètè Bètè»	Variety « Krenglè»	Variety «Kponan»
Mg (mg/Kg)	593.19 ± 5.90 ^b	772.23 ± 5.78 ^c	432.99 ± 5.71 ^a
Fe (mg/Kg)	276.74 ± 4.84 ^b	298.47 ± 4.37 ^c	265.17 ± 4.13 ^a
Ca (mg/Kg)	22862.52 ± 1471.81 ^c	9251.21 ± 134.844 ^a	16975.81 ± 51.99 ^b
Zn (mg/Kg)	491.62 ± 5.90 ^b	451.1 ± 4.68 ^a	455.326 ± 4.07 ^a
K (mg/Kg)	12394.6 ± 335.02 ^a	12774.64 ± 195.07 ^a	14520.8 ± 951.28 ^b
Na (mg/Kg)	41.96 ± 2.29 ^b	33.56 ± 3.47 ^a	46.45 ± 1.06 ^b
Cr (mg/Kg)	167.50 ± 2.54 ^c	129.04 ± 1.94 ^a	140.43 ± 2.28 ^b
Co (mg/Kg)	195.5186 ± 4.08 ^b	151.3 ± 3.95 ^a	223.36 ± 1.64 ^c
Mn (mg/Kg)	411.61 ± 12.32 ^a	412.20 ± 3.47 ^a	397.50 ± 11.95 ^a
Cu (mg/Kg)	212.55 ± 1.30 ^b	204.25 ± 5 ^a	217.76 ± 3.98 ^b

Values are means ± S.D (n=3); Means in each row followed by different letters are significantly different (p<0.05)