

Assessment of Some Antinutritional Compounds and Some Organic Acids of "bètè-bètè" yam (*Dioscorea alata*) Tubers as Influenced by Boiling Times

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ABSTRACT-- Yam tubers of "Bètè-bètè" variety belonging to *Dioscorea alata* species were boiled at different times (10 min, 20 min and 30 min). Some antinutritional factors and organic acids level of tubers were analyzed using standard procedures and methods during boiling times. The boiling reduced significantly ($p \leq 0.05$) the antinutrient contents such as total andsoluble oxalate, tannin, phytate and total phenolic compounds with respective loss of 46.92 %, 63.72 %, 38.89%, 37.02 % and 54.46 % until 30 min after boiling. It also decreased the phenolic compounds levels such as Gallic acid Catechin Quercetin Coumarin, the organic acids levels such as Tannic, fumaric, citric, Tartaric, Salicylic, Ascorbic and Sulfanilic acids at different boiling times. Furthermore, the reduction of oxalate content after the hydrothermal treatment seemed remarkable.

Keywords-- *Dioscorea alata*, "bètè-bètè", antinutritional, phenolic compounds, organic acids

1. INTRODUCTION

Yam (*Dioscorea* spp.) is important source of carbohydrate for many people of the Sub-Saharan region, especially in the yam zone of West Africa [1]. It contributes to more than 200 dietary calories per capita daily for more than 150 million people in West Africa and serve as an important source of income [2]. In Côte d'Ivoire, yam is cultivated and consumed in the center and the north-east but in a lesser quantity in the south and the west [3]. The total production is about 3 million tons per year. The most important species in Côte d'Ivoire are *Dioscorea cayenensis-rotundata* complex and *Dioscorea alata* [4]. The yams also provide protein three times more superior than the one of cassava and sweet potato [5]. Their tubers are not easily digested in their natural state and should be boiled before they are eaten. Boiling improves their digestibility, promotes palatability and improves their keeping quality as well as making the roots safer to eat. Indeed, Yam tubers are usually consumed in the forms of chunks, flour, fufu, and slices resulting from any of the processes of boiling, drying, fermentation, frying, milling, pounding, roasting, and steaming [6]. However, Fresh yams are difficult to store and are subject to post harvest losses during storage [7]. These losses serve as an impetus for processing this staple food into a product of longer shelf life. Yam flour is a fine powder made from the processing of yam tuber. The properties of flour vary considerably with botanical source, an environmental condition and composition and structure of starches [8]. Yams generally have high moisture content. Their dry matter is composed mainly of starch, vitamins, sugars and minerals. Nutrient varies with species and cooking procedures. Yams may also contain anti-nutrient content. Most of the elaborated biochemical compositions of yam only give nourishing elements content of the whole tuber.

Some researchers have however studied the physicochemical properties of some yam whole tubers from *D. alata* [3], [6], [9], [10], [11], [12]. So far the anti-nutrient composition of *D. alata* varieties during the boiling time has not been widely reported. Besides, anti-nutrients are chemicals which have been evolved by plants for their own defence, among other biological functions. They reduce the maximum utilization of nutrients (especially proteins, vitamins and minerals), thus preventing optimal exploitation of the nutrients present in a food and decreasing the nutritive value [13]. Indeed; phenomena of chelation or complex formation (phytic acid, condensed tannins, saponins) can reduce the absorption of mineral elements and vitamins [14]. However, boiling may affect the anti-nutritional composition in food. The present study aims at providing information on the antinutritional factors of "bèbè-bèbè" yam and how they are affected by boiling times.

2. MATERIAL AND METHODES

2.1 Raw materials

The "Bètè-Bètè" yam variety belonging to *D. alata* species was used in the present study. Tubers were harvested at physiological maturity from fields in the south of Côte d'Ivoire. They were immediately transported in a heap aired store and storage conditions in which the temperature and the relative humidity rate were 26.56 ± 3 °C and 82 ± 5 % respectively.

2.2 Sample Preparation

Two (2) kg "Bètè-bètè" yam tuber were washed with clean water. They 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 four lots of 500 g each. Three lots were boiled at 100°C for 10 min, 20 min and 30 min in a pan containing 1 L of water distilled. At the end of boiling, the three lots with treatment and the remaining one part with no treatment and were dried in an oven 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 for analysis [15].

2.3 Extraction of phenolics

Phenolics were extracted from partially defrosted blueberry fruits. Exactly 5 g of samples were weighed out and extracted using 20 mL of 80 % (by volume) aqueous ethanol. The mixture was extracted for 20 min in inert atmosphere (N₂), filtered through Whatman N° 4 filter paper (Whatman International Ltd, Kent, UK) using a Büchner funnel. Extraction of the residue was repeated using the same conditions. The filtrates were combined and adjusted to 50 mL in a volumetric flask with 80 % aqueous ethanol. The obtained extract was used for determination of total phenols (TPC).

2.4 Total phenolic compounds

The total phenolic compounds contents were assessed by the spectrophotometric method described by Swain and Hillis [16] using the Folin-Ciocalteu. 0.5 ml extract was added with 2.5 ml of Folin-Ciocalteu reagent followed by addition of 2 ml sodium carbonate (Na₂CO₃) (75 g/l). The sample was then incubated for 5 min at 50°C. The absorbance was then measured at 760 nm using Shimadzu UV-1650 PC Spectrophotometer (Kyoto, Japan). The results were then expressed as mg gallic acid equivalents per gram of extract (mg GAE/g) that was derived from a calibration curve.

2.5 Total and soluble oxalate

Oxalate content was determined according to Day and Underwood [17] method. 1g of sample was weighed into 100 ml conical flask. Approximately 75 mL of 15 N H₂PO₄ (for total oxalate) or 75 mL of distilled deionized water (for soluble oxalate) were added. The solutions were added and stirred for 1hr with a magnetic stirrer. These were filtered using a Whatman N° 1 filter paper. 25 mL of each filtrate were then taken and titrated while hot against 0.05M KMnO₄ solution until a faint pink colour appeared that persisted for 30 seconds. The oxalate and soluble contents were then calculated by taking 1mL of 0.05 M KMnO₄ as equivalent to 2.2 mg oxalate [18].

2.6 Phytate

Phytate was determined using [19] method. 4 g of the ground sample was soaked in 100 ml of 2 % hydrochloric acid (HCl) for 5 h and filtered. To 25 ml of the filtered, 5 ml of 0.3 % ammonium thiocyanate (NH₄SCN) solution was added. 53.5 ml of distilled water was also added to the mixture. This was then titrated against a standard iron (III) chloride solution until a brownish yellow colour persisted for 5 min.

2.7 Determination of Tannin

Makker and Godchild [20] method was used for the tannin determination. About 0.2 g of finely ground samples was weighed into a 500 ml sample bottle. 10 ml of 70 % aqueous acetone was added and properly covered. The bottles were put in an ice bath shaker for 2 hours at 30 °C. Each solution was then centrifuged and the supernatant stored in ice. 0.2 cm³ of each solution was pipette into the test tubes and 0.8 cm³ of distilled water was added. Standard tannin solutions were prepared from a 0.5 mg/ml stock and the solution made up to 1 ml with distilled water. 0.5 cm³ Folin-ciocalteu's

reagent was added to both sample and standard followed by 2.5 ml of 20 % Na₂CO₃. The solutions were then vortexed and allowed to incubate for 40 minutes at room temperature. Its absorbance was read at 725 nm against a reagent blank concentration of the same solution from a standard tannic acid curve.

2.8 Analysis of phenolic compounds

The separation of phenolic compounds was performed according to Servili *et al.* [21]. The HPLC system consisted of a Spectra System liquid chromatography model 2000 (Thermo Separation Product, USA), equipped with a 250 mm x 4.6 mm C18 Nova Pak column coupled with a UV detector. Individual phenolic compounds were detected at 278 nm. The flow rate was 1 mL/ min. The mobile phase used was 0.2 % (v/v) acetic acid in water (A) vs. methanol (B) for a total running time of 60 min and the gradient changed as follows: 95 % A / 5 % B for 2 min, 80 % A / 20 % B for 10 min, 70 % A / 30 % B for 10 min., 60 % A / 40 % B for 10 min, 40 % A / 60 % B for 10 min., 100 % A / 0 % B for 10 min until the end of running. Samples were dissolved in methanol; a sample loop of 20- μ L capacity was used for the introduction of the sample. Gallic, protocatechuic, p-hydroxybenzoic acid, vanillic, caffeic, syringic, p-coumaric, ferulic and o-coumaric acids were HPLC grade and purchased from Sigma Chemical Co (USA), tyrosol (98%) from Aldrich Chemie (Germany) and extra pure oleuropein from Extra synthese Co. (Genay, France).

2.9 Analysis of organic acids

The organic acids were determined by HPLC, using the extraction and analysis method developed by Holloway *et al.* [22]. A 7.8 x 300 mm ion exclusion column (HPX-87H, Bio-Rad) was used with 0.0125 M H₂SO₄ as mobile phase, at a flow rate of 0.5 ml/min, and the UV detector operating at 214 nm. Organic acids were quantified by an internal standard calibration method [23] by using glutaric acid as the internal standard. The calculated results are expressed as milligramme per 100 g dw (dry weight).

2.10 Statistical analysis

All analyses were carried out in triplicates. Results were expressed by means of \pm SD. Statistical significance was established using one-way analysis of Variance (ANOVA) models to estimate the effect of boiling times on some anti-nutritional compounds and some organic acid levels of flour from yam at 5 % level. Means were separated according to Duncan's multiple range analysis ($P < 0.05$), with the help of the software STATISTICA 7 (Statsoft Inc, Tulsa-USA Headquarters) and XLSTAT-Pro 7.5.2 (Addinsoft Sarl, Paris-France).

3. RESULTS

3.1 Anti-nutrient contents

The anti-nutrient composition of flour from raw and boiled tubers of «Bètè-bètè» yam is shown in Table 1.

The total and soluble oxalate contents ranged from 650.00 ± 0.01 mg/100 g dw (dry weight) to 345.00 ± 0.01 mg/100g dw and from 397.00 ± 0.02 mg/100 g dw to 144.00 ± 0.01 mg/100g dw during boiling times respectively. The flour from boiled yam tuber at 30 min had the highest total and soluble oxalate contents, while the lowest total and soluble oxalate contents were obtained with the flour from the raw tuber. Otherwise, the Analysis of Variance (ANOVA) revealed that the boiling time main effect appeared significant ($P \leq 0.05$) (Table 2). Indeed, the boiling reduced significantly ($P \leq 0.05$) oxalate content at different boiling times.

The tannin content varied from 183.00 ± 3.00 mg/100 g dw to 84.33 ± 1.53 mg/100 g dw for flours from the raw tuber and the boiled tuber at 30 min respectively. The highest tannin content was found for flour from raw tuber whereas the lowest tannin content was obtained with the flour from boiled tubers. Moreover, the result of analysis of variance showed that the boiling had significant effect ($p \leq 0.05$) on tannin content (Table 2). It decreased meaningfully ($p \leq 0.05$) the tannin content during the boiling times.

The phytate content ranged from 840.00 ± 0.06 mg/100 g dw to 529.00 ± 0.05 mg/100 g dw during the boiling, representing 37.02 % of decrease. The highest phytate content was obtained with the flour from raw tuber while the lowest phytate content was found for the flour from boiled tuber. Otherwise, analysis of variance test indicated that the boiling appeared significant ($P \leq 0.05$) (Table 2). Indeed, boiling reduced meaningfully ($p \leq 0.05$) the phytate until 30 min after boiling.

The total phenolic compound contents varied from 332.90 ± 2.00 mg/100 g dw to 151.60 ± 7.37 mg/100 g dw for flour from raw tuber and flour from boiled tuber at 30 min respectively, representing 54.46 % of loss. The flour from boiled yam tuber at 30 min had the highest total phenolic compound contents, whereas the lowest total phenolic compound content were obtained with the flour from the raw tuber. Furthermore, the Analysis of Variance (ANOVA) revealed that the boiling time main effect appeared significant ($P \leq 0.05$) (Table 2). It reduced significantly ($P \leq 0.05$) total phenolic compound content during boiling. They differed meaningfully ($p < 0.05$) at different boiling times.

Table 1: Anti-nutrient contents of flours from raw and boiled yam specie (*Dioscorea alata*, "Bètè-Bètè" variety) tubers (mg/100 g dw)

Parameters	Flour from raw "Bètè-bètè" yam	Flours from boiled "Bètè-bètè" yam		
		10 min	20 min	30 min
Total oxalate	650.00 ± 0.01 ^d	512.00 ± 0.02 ^c	470.00 ± 0.11 ^b	345.00 ± 0.01 ^a
soluble Oxalate	397.00 ± 0.02 ^d	293.00 ± 0.01 ^c	221.00 ± 0.01 ^b	144.00 ± 0.01 ^a
Tannin	138 ± 3,00 ^d	125.33 ± 5.03 ^c	109.00 ± 2.65 ^b	84.33 ± 1.53 ^a
Phytate	840 .00 ± 0.06 ^d	717.00 ± 0.04 ^c	613.00 ± 0,03 ^b	529.00 ± 0.05 ^a
Total phenolic compounds (mg/100 g de MS)	332.90 ± 2.00 ^d	250.80 ± 1.65 ^c	217.6 0 ± 1.03 ^b	151.60 ± 7.37 ^a

Each value is an average of three replicate. Values are mean ± standard deviation. Means not sharing a similar letter in a line are significantly different $p \leq 0.05$ as assessed by the test of Duncan.

Table 2: ANOVA table for one-way of main effect of boiling times on anti-nutritional composition during boiling

Parameters	Effect	Degrees of freedom	Sum of squares	Mean square	F-ratio	P-value
Total Oxalate	Boiling time	3	142310	47437	4412.7	3.2729E-13*
	error	8	86	11		
	Total	11	142396			
Soluble Oxalate	Boiling time	3	104336.3	34778.8	2782.30	2.0679E-12*
	error	8	100,0	12.5		
	Total	11	104436.3			
Tannin	Boiling time	3	1074360	358120	24985	3.33E-16*
	error	8	115	14		
	Total	11	1074475			
Phytate	Boiling time	3	163108	54369	2548.6	2.9362E-12*
	error	8	171	21		
	Total	11	163279			
TCP	Boiling time	3	50661.0	16887.0	7213.7	4.59E-14*
	error	8	18.7	2.3		
	Total	11	50679.7			

The symbol of * state shows significant difference at 5% level

3.2 Qualitative and quantitative analysis of phenolic compounds

The qualitative results of phenolic compounds detected in flour from raw and boiled yam species (*D. alata*, "Bètè-Bètè" variety) tubers are presented in figure 1. These results obtained indicated that gallic acid catechin quercetin coumarin were found in the four analyzed sample, excepted the flour from boiled tubers at 30 min which did not contain coumarin compound. The table 3 showed that gallic acid was the major phenolic compound found in the four analyzed samples. All phenolic compound contents decreased significantly ($P < 0.05$) during boiling times. The gallic acid, catechin, quercetin content varied from 97.40 ± 1.56 mg/100 g dw (0 min) to 59.20 ± 0.23 mg/100 g dw (30 min), 32.40 ± 1.75

mg/100 g dw (0 min) to 10.50 ± 0.98 mg/100 g dw (30 min) and 37.50 ± 0.68 mg/100 g dw (0 min) to 3.20 ± 0.79 mg/100 g dw (30 min) respectively. Its losses were 39.22 %, 67.59 % and 91.47 % respectively. Besides, the coumarin compound not detecting in flour from boiled yam tuber at 30 min, had rate of loss of 62.17% from first boiling time (0 min) to fourth boiling time (20). Its content ranged from 23.00 ± 0.36 mg/100 g dw to 8.70 ± 1.18 mg/100 g dw.

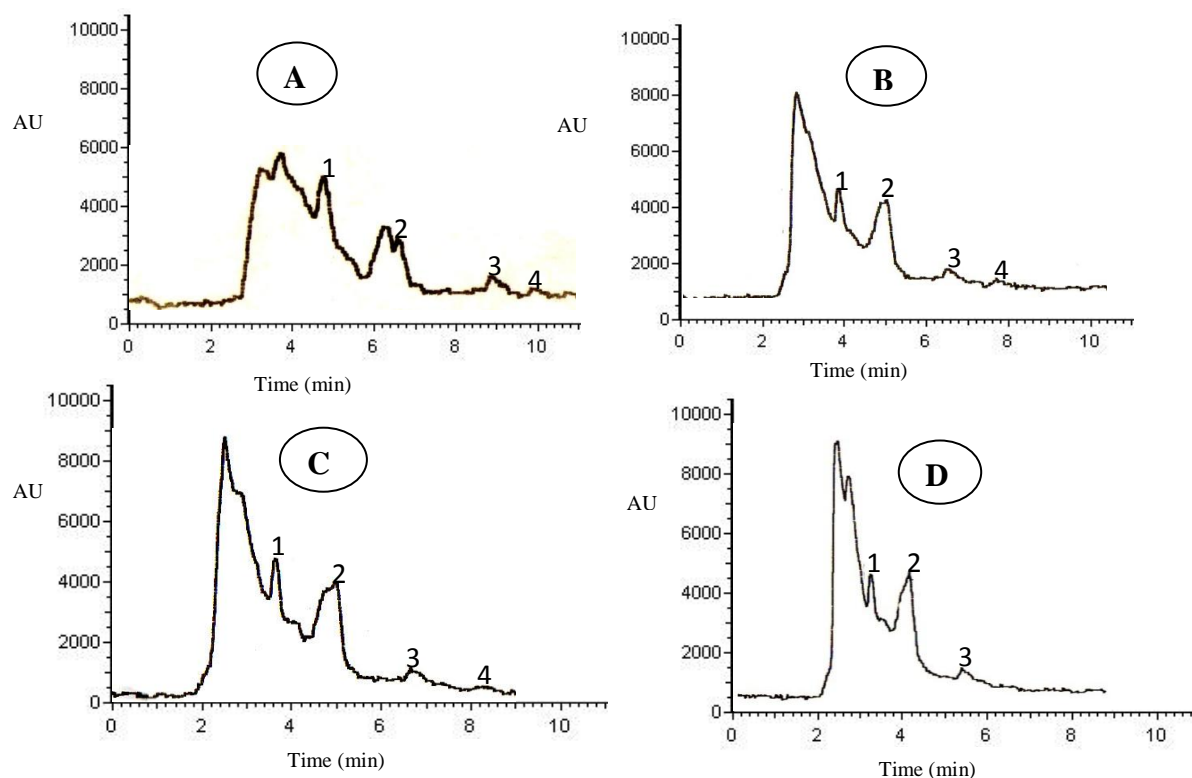


Figure 1. HPLC phenolic compounds of flour from boiled tubers of "Bètè-bètè" yam (*Dioscorea alata*) at 0 min (A), 10 min (B), 20 min (C), and 30 min (D). Peaks are indicated as follows: (1): Gallic acid; (2): Catechin; (3): Quercetin; (4): Coumarin. AU: Absorbance unit.

Table 3: Phenolic compounds content (mg/100 g dw) in flour from raw and boiled yam species (*Dioscorea alata*, "Bètè-Bètè" variety) tubers determined by reversed phase-high performance liquid chromatography, with UV-visible detection.

Parameters	Flour from raw "Bètè-bètè" yam	Flours from boiled "Bètè-bètè" yam		
		10 min	20 min	30 min
Gallic acid	97.40 ± 1.56^c	71.50 ± 0.89^b	70.60 ± 1.03^b	59.20 ± 0.23^a
Catechin	32.40 ± 1.75^b	24.90 ± 1.01^a	16.50 ± 1.55	10.50 ± 0.98
Quercetin	37.50 ± 0.68^c	32.00 ± 1.33^b	21.80 ± 1.21^a	3.20 ± 0.79^a
Coumarin	23.00 ± 0.36^d	17.00 ± 0.22^c	8.70 ± 1.18^b	ND

ND: Not detected

Each value is an average of three replicate.

Values are mean \pm standard deviation.

Means not sharing a similar letter in a line are significantly different $p \leq 0.05$ as assessed by the test of Duncan.

3.3 Qualitative and Quantitative Determination of Organic acids

The organic acids were extracted of flour from raw and boiled «bètèt-bètè" (*D. alata*) yam tubers at different times (10 min, 20 min and 30 min). They have been identified using paper chromatographic technique systems and specific spray reagents (figure 1). Tannic, fumaric, citric, Tartaric, Salicylic, Ascorbic and Sulfanilic acids were observed. All the acids are not present at the different boiling times in the flours from boiled yam tubers. Table 4 clearly indicated that the organic acids (Tannic acid, fumaric Acid, citric Acid, Tartaric Acid , Salicylic acid, Ascorbic acid and Sulfanilic acid) contents had been influenced at different boiling times. They all decreased significantly ($P < 0.05$) during boiling. Observing the results presented in Table 3, tannic, citric and tartaric acids were the major phenolic compounds found in the four analyzed sample .After the second boiling time (10 min), fumaric acid and sulfanilic acid have been not detected. Its contents were 4.00 ± 0.10 mg/100 g dw and 12.00 ± 0.26 mg/100 g dw in flour from raw yam tuber (first boiling time (0 min)) respectively. As for the salicylic acid, it has been after the third boiling time (20 min) and it content ranged from 111.00 ± 0.96 mg/100 g dw (0 min) to 12.00 ± 1.21 mg/100 g dw (10 min). Concerning tartaric acid, citric acid and ascorbic acid, they have been not detected after the fifth boiling and its contents varied from 1013.00 ± 0.77 mg/100 g dw (0 min) to 825.00 ± 2.05 mg/100 g dw (20 min), $1130.00 \pm 1,71$ mg/100 g dw (0 min) to 130.00 ± 1.23 mg/100 g dw (20 min) and 880.00 ± 1.02 mg/100 g dw (0 min) to 97.00 ± 2.00 mg/100 g dw (20 min) respectively. Indeed, the losses of these organic acids were 18.56 %, 88.49 % and 88.98 % during boiling respectively. On the other hand, tannic acid only was detected until 30 min after boiling. Its content ranging from 1380.00 ± 0.10 (0 min) to 831.00 ± 0.10 (30 min), represented 39.78 % of increase.

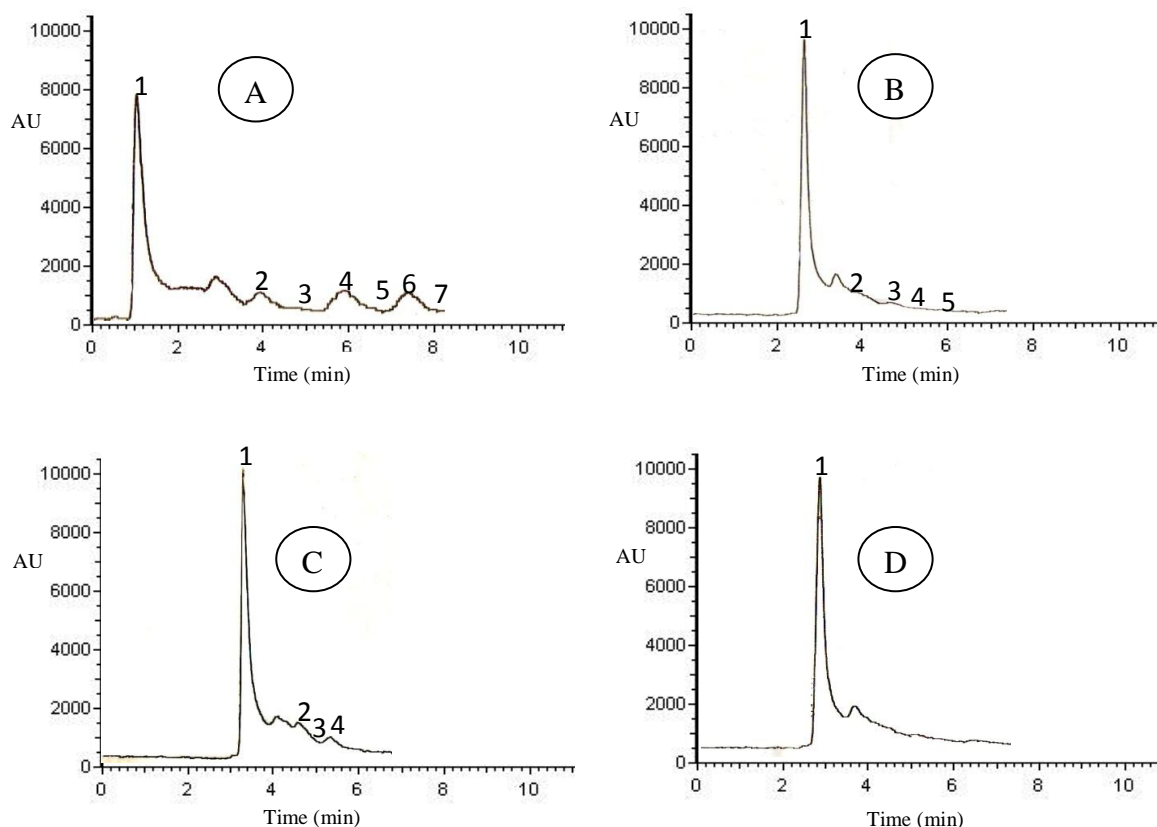


Figure 2. HPLC organic acids of flour from boiled tubers of "Bètèt-bètè" yam (*Dioscorea alata*) at 0 min (A), 10 min (B), 20 min (C), and 30 min (D). Peaks are indicated as follows: (1): Tannic acid; (2): Tartaric acid; (3): citric acid; (4): Ascorbic acid; (5): Sulfanilic acid; (6): Fumaric acid; (7): Salicylic acid. AU: Absorbance Unit.

Table 4: Organic acid contents of flours from raw andboiled yam specie (*Dioscorea alata*, "Bètè-Bètè" variety) tubers (mg/100 g dw)

Parameters	Flour from raw "Bètè-bètè" yam	Flours from boiled "Bètè-bètè" yam		
		10 min	20 min	30 min
Tannic acid	1380.00 ± 0.10 ^d	1200.00 ± 0.12 ^c	1171.00 ± 0.10 ^b	831.00 ± 0.10 ^a
Fumaric acid	4.00± 0.10	ND	ND	ND
Citric acid	1130.00 ± 1.71 ^c	952.00 ± 2.53 ^b	130.00 ± 1.23 ^a	ND
Tartaric acid	1013.00 ± .77 ^c	976.00 ± 1.62 ^b	825.00 ± 2.05 ^a	ND
Salicylic acid	111.00 ± 0.96 ^b	12.00 ± 1.21 ^a	ND	ND
Ascorbic acid	880.00 ± 1.02 ^c	356.00 ± 0.69 ^b	97.00 ± 2.00 ^a	ND
Sulfanilic acid	12.00 ± 0.26	ND	ND	ND

ND: Not detected

Each value is an average of three replicate.

Values are mean ± standard deviation.

Means not sharing a similar letter in a line are significantly different $p \leq 0.05$ as assessed by the test of Duncan.

4. DISCUSSION

4.1 Anti-nutrient contents

The total and soluble oxalate contents of flour from raw tuber and boiled tuber decreased significantly ($P \leq 0.05$) during the boiling time. The total and soluble oxalate contents of flour from raw tuber were lower than the values reported for flour from boiled tuber at different times. 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 observed high reduction in oxalate level up on boiling [24]. Similar trends have been recorded by Sahoré and Amani [25], who reported the decrease of 20% in wild yam tuber of *Dioscorea togoensis* and *Dioscorea burkilliana* during the boiling. Our results obtained for raw tubers were very higher than the 100 mg/100 g dw and 330 mg/100 g dw noted for raw tubers of *Dioscorea wallichii* and *Dioscorea pentaphylla* [26]. 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 at different boiling times reduced meaningfully ($P \leq 0.05$). This 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 "bète-bètè" yam tubers. This agrees with the fact that tannins are polyphenols or polyphenolic compounds which are soluble in water [13]. Besides, the decrease was reported by Khattab and Arntfield [27] on boiling, autoclaving and microwave cooking of legume. 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 [28]. The tannin contents of these raw samples were lower when compared with the value 560mg/100g dw reported by Shanthakumari *et al.* [26] on raw tubers of *Dioscorea esculenta*. These results were higher than the 26.45 mg/100g dw recorded by Ugwu and Oranye [13] on African breadfruit. 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 [29]. Tannins may decrease protein quality by decreasing digestibility and palatability, damaging the intestinal tract, and enhancing carcinogenesis [20]. They also bind iron, making it unavailable [30].

Concerning the phytate content, there was a significant difference ($P < 0.05$) among the samples during boiling. Indeed, the phytate content decreased significantly ($P < 0.05$) until 30 min after boiling. This observed loss of phytate content from yam samples was noted by Nzewi and Egbuonu [31] on asparagus bean (*Vigna sesquipedalis*) flour during boiling times. Our results of phytate contents being to 37.02 mg/100g dw during boiling at 30 min was lower than that reported by Nzewi and Egbuonu [31] on asparagus bean (*Vigna sesquipedalis*) flour as affected by boiling at the same boiling time (67 %). Similar decrease in phytate content was recorded by Bhandari and Kawabata [32] 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 [24]. Furthermore, the knowledge of the phytate level in foods is necessary because high concentration can cause adverse effects on the digestibility [33]. Okaraonye and Ikewuchi [34] also reported that phytate forms stable complexes with Cu^{2+} , Zn^{2+} , Co^{2+} , Mn^{2+} , Fe^{2+} .

The total phenolic compound content of flour from raw tuber and boiled tuber decreased significantly ($P \leq 0.05$) during the boiling time. This observed decrease was reported by Shanthakumari *et al.* [26] for tubers of *D. esculenta*, *D. bulbifera* and *D. alata* during the boiling after 90 min, with 71 %, 13 % and 61 % rate of loss respectively. Our results of raw yam tuber were higher than that published by Djè *et al.* [3] for tubers of "krenglè" variety belonging *D. cayenensis-rotundata* that is 255.66 mg/100 g dw. It's were also higher than those obtained for some tropical leafy vegetables ranging from 0.32 to 0.83 mg/100 g [18]. Phenolic compounds were also responsible for the bitterness and astringency associated with many foods. It's are the substrates responsible for the browning reaction, which occur when the tubers are cut or damaged [35]. The phenolic compounds are in meager quantities than other phytonutrients determined in the yam tubers. Moreover, the capacity of a plant species to resist the attack of the bugs and microorganisms is often correlated with the phenolic compounds contents [36].

4.2 Qualitative and quantitative analysis of phenolic compounds

The separation and identification of individual phenolic compounds in flour from raw and boiled yam tubers extracts was conducted by HPLC method. Sample peak was identified by against retention time of known phenolic standards under the same chromatography condition. This method identified some phenolic compounds especially coumarin (peak 4) and phenolic acids such as gallic acid (peak 1), and flavonoids containing Flavan-3-ols such as catechin (peak 2) and flavonols such as quercetin (peak 3). All samples contained these phenolic compounds, excepted the obtained sample at 30 min after boiling, which did not contain coumarin. Besides, the presence of phenolic compounds such as gallic acid and catechin was reported in tubers of *Dioscorea histida* Dunt [37]. In addition, the presence of various phenolic compounds have been reported in some species of domesticated yam tubers [35], [38]. Otherwise, the phenolic compounds decrease significantly ($P < 0.05$) during boiling. This result showed that boiling affected negatively these phenolic compounds. Yam tuber samples were studied after boiling, as yams are not consumed raw.

4.3 Qualitative and quantitative determination of some organic acids

The observed organic acids were tannic, fumaric, citric, tartaric, salicylic, ascorbic and sulfanilic acids. There is little information regarding the qualitative determination of organic acids of raw and boiled yam (*D. alata* "Bètè-bètè" variety) tubers. However, the presence citric and ascorbic acids in yam (*D. esculenta*) tuber were reported by Panneerelvam and Abdul [39]. Likewise, Bhandari and Kawabata [40] detected this acid in wild yam of Nepal. Furthermore, Wichrowska *et al.* [41] recorded fumaric, tartaric, citric and malic acids in potato tubers during storage and storage conditions. The presence of citric, malic and ascorbic acids was noted by Kristin *et al.* [42] in potato tubers. Similar works carried out by Badshah and Iritani [43], indicated the presence of malic and citric acid during growth and storage of potato. Concerning quantitative assessment of organic acids, it is very difficult to compare our results, because very scarce data on these compound quantities in yam tubers have been reported. All obtained organic acids contents of different sample decreased significantly ($P < 0.05$) during boiling time. This reduction may be the possible reasons for the acidity decrease in the boiled tubers. It may also be that when the cell wall was heated, it was damaged and this caused the organic acids in the cell sap to be released from the tubers into the liquid and some heat labile acids were destroyed [44]. Indeed, the loss of the organic acid as ascorbic acid could be attributed to the fact that L-ascorbic acid is very soluble in water and not stable at high temperature. Our results were in agreement with Zhang and Hamazu [45] and Gliszczynska-Swiglo *et al.* [46], who observed a decrease of the vitamin C content in broccoli after boiling and microwave cooking. Similar result was carried out by Yvette [47], who recorded dramatically decrease of ascorbic acid content in green broccoli and purple-sprouting broccoli after cooking. Otherwise, the organic acids content in food not only influences their flavour, but also their stability, nutrition, and acceptability [48]. It may be the intermediates of the total antioxidant capacity cycle followed during dormancy of these organs.

5. CONCLUSION

"Bètè-bètè" yam tubers contained some antinutritional factors such as total and soluble oxalate, tannin, phytate and total phenolic compounds. It also contained the phenolic compounds such as gallic acid catechin quercetin coumarin and the organic acids such as tannic, fumaric, citric, tartaric, salicylic, ascorbic and sulfanilic acids oxalates and phytates. All these biochemical parameters decreased significantly ($P < 0.05$) during boiling times. Furthermore, the reduction of oxalate content after the hydrothermal treatment seemed remarkable. Indeed, this reduced oxalate content on boiled "bètè-bètè" 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 decreased tannin contents in boiled yam tubers were found to be too low to cause any adverse effect on the consumers. Otherwise, reduced value as of phytate obtained in boiled yam tubers was expected to enhance the bioavailability of protein and dietary minerals for consumers.

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