Biochemical Characteristics of Flours from Ivorian Taro (*Colocasia Esculenta,* Cv *Yatan*) Corm as Affected by Boiling Time

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Abstract: This study aimed at determining the chemical composition and physico-functional properties of flour from Ivorian taro (*Colocasia esculenta,* cv yatan) corm as affected by boiling time. The change in boiling time led to a significant ($p<0.05$) reduction in the iodine affinity of starch, total carbohydrate, total phenolic compound, reducing and total sugars contents, whereas the moisture content, water absorption capacity, water solubility index, paste clarity and foam capacity increased significantly ($p<0.05$). The crude fat, crude fibre, crude protein and total ash contents were not affected by the change in boiling time. The flour of Ivorian taro corm is a good source of carbohydrate, fiber and ash. It contained a fair amount of crude protein and showed a high water absorption capacity and iodine affinity of starch. Within this flour, calcium, iron, sodium, zinc and copper had the lowest values while phosphorus, potassium and magnesium had the highest values. Significant correlations were observed between such constituents and physico-functional properties as moisture and water solubility index; crude fat and iodine affinity starch; total carbohydrate and paste clarity; total phenolic compound and forming capacity. PCA showed that FRTC was located at the left of the score plot, while FBTC20, FBTC35 and FBTC50 had a positive score in the first principal component.

Key words: Chemical composition, mineral composition, physico-functional property, proximate composition

INTRODUCTION

Taro (*Colocasia esculenta*) and tannia (*Xanthosoma sagittifolium*) are widely cultivated in Africa (Nwanekezi *et al*., 2010) where they represent the third most important root crop after yam and cassava (Obomegheive *et al*., 1998). The corm of taro is relatively low in protein (1.5%) and fat (0.2%) and this is similar to many other tuber crops. It is a good source of starch (70-80 g/100 g dry taro), fiber (0.8%) and ash (1.2%) (Jane *et al*., 1992; Quach *et al*., 2000). Starch derived from the taro corm is unique because of its very small granular sizes ranging from 1 to 5 μ, significantly smaller than corn or wheat (Jane *et al*., 1992). The combination of small granules and high soluble dietary fiber content makes taro corm a good source of carbohydrate for extruded special products such as infant weaning diets and low glycemic index foods (Huang *et al*., 2000). Taro corm has reasonably high contents of potassium and magnesium, whose ranges are 2251-4143 and 118-219 mg/100 g dry matter,

respectively. It is a moderately good source of water-soluble vitamins, such as thiamin, riboflavin and ascorbic acid, compared to other tropical roots. Essential amino acid contents of taro corm proteins were fairly similar to the FAO reference pattern, except for the contents of sulfurcontaining amino acids, tryptophan and histidine (Huang *et al*., 2007).

Despite these nutritional benefits, taro corm is less valued in areas like South-Eastern Côte d'Ivoire where it is produced in abundance. A major problem of this taro is that the corms are susceptible to physical damage during harvesting and thus leading to high post harvest losses (Onwueme and Simha, 1991; FAO, 2006). To overcome these losses, Onyeike *et al*. (1995) reported that the corm may be processed into flour. According to Kwarteng and Towler (1994), the flours stores were much longer than the unprocessed corm of taro.

Flours milled from other crops such as maize, millet, sorghum, cassava, potatoes and rice had been added to wheat flour to extend the use of the local crops and reduce

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the cost of wheat importation. This is practiced mostly in tropical countries where the soil and climate are not favourable for commercial large scale production of wheat (Ojinnaka *et al.*, 2009). Satisfactory bread and bakery goods such as cookies, brand and cake have been made from such composite flour through a blend of wheat flour with other cereals and root crops (Ngoddy and Onuoha, 1983; Ofi, 1983; Kent and Evers, 1994; Sanni *et al.*, 2006; Odedeji and Adeleke, 2010). However, successful performance of flours as food ingredients depend upon chemical composition, functional characteristics and sensory qualities they impart to the end product (Kaur and Singh, 2007).

This study therefore, aimed at determining the chemical composition and physico-functional properties of flour from Ivorian taro (*Colocasia esculenta*, cv yatan) corm as affected by boiling time. This was done in order to be able to explore in future its potentials in food formulation.

MATERIALS AND METHODS

Materials: Taro (*Colocasia esculenta*, cv yatan) corms used for this work were randomly harvested at maturity (9 months after planting) from a farm in Affery, South-East portion of Côte d'Ivoire (West Africa) in May 2010. They were immediately transported to the Laboratoire de Biocatalyse et des Bioprocédés (Université d'Abobo-Adjamé, Abidjan, Côte d'Ivoire) and stored under prevailing tropical ambient conditions (19-28ºC, 60-85% RH) for 24 h before the preparation of flours from raw and boiled taro corms. All chemicals and reagents used were of analytical grade and purchased from Sigma Chemical Company (USA).

Production of taro corm flours: The Ivorian taro (*Colocasia esculenta*, cv yatan) corms were thoroughly sorted to remove bad ones from the lot. The retained corms were washed with clean water to eliminate adhering soil, dirts and extraneous materials. The corms were thereafter peeled using a stainless steel knife. The peeled samples were rewashed with clean water in order to remove much mucilaginous material. After washing, they were cut into slices (2 cm thickness). Two liters of clean water were put inside each pot and boiled on a hot plate at the temperature of 100ºC. Approximately, two (2) kg of the sliced corms were placed inside the boiling water and each of them was boiled for periods of 0, 20, 35 and 50 min. At the end of boiling, the water was drained off and the hot samples were exposed to the air to allow surface water to evaporate for 20 min. Then, they were cut into 5 mm thick slices and dried at 52ºC in a ventilated oven (MMM MED center) for 48 h. The dried samples were ground into fine powder in a Hammer mill (Campsas 82370, Labastide St-Pierre, France) to pass through a 250

µm sieve. Dried powdered samples were packed into airtight sealed plastic bags and stored in the refrigerator for later analysis. Each of the four sets (raw and boiled for 20, 35 and 50 min) of homogenized samples from Ivorian taro corm was analyzed in triplicate for their chemical composition and physico-functional properties.

Proximate composition: The dry matters contents of the flours from Ivorian taro (*Colocasia esculenta,* cv yatan) corm were determined by drying in an oven at 105ºC during 24 h to constant weight (AOAC, 1990). The crude protein contents were calculated from nitrogen contents (N x 6.25) obtained using the Kjeldahl method by AOAC (1990). The crude fat contents were determined by continuous extraction in a Soxhlet apparatus for 8 h using hexane as solvent (AOAC, 1990). The crude fibre contents were determined according to standard method (AOAC, 1990). The total ash contents were determined by incinerating flour (3 g) in a furnace at 550ºC for 6 h, then weighing the residue after cooling to room temperature in a desiccator (AOAC, 1990). The method described by Dubois *et al*. (1956) was used for the total sugar contents analysis. The reducing sugar contents were determined according to the method of Bernfeld (1955) using 3.5 dinitrosalycilic acids. The total phenolic compound contents were determined as described in Hanson *et al*. (2004) from the methanol extracts using Folin-Ciocalteu reagent (Singleton and Rossi, 1965). The carbohydrate contents were determined by deference that is by deducting the mean values of other parameters that were determined from 100. Therefore % carbohydrate = 100-(% moisture +% crude protein + % crude fat + crude fibre + % ash).

Mineral composition: The minerals, such as calcium, copper, iron, magnesium, sodium, potassium and zinc of flours from Ivorian taro (*Colocasia esculenta,* cv yatan) corm were analyzed according to the method prescribed by Onwuliri and Anekwe (1992) with an atomic absorption spectrophotometer (Pye-Unicam 969, Cambridge, UK). Phosphorus contents were estimated colorimetrically (UV-visible spectrophotometer, JASCO V-530, Model Tudc 12 B4, Japan Servo Co. Ltd., Indonesia), using potassium dihydrogen phosphate as the standard (AOAC, 1980).

Water absorption capacity and water solubility index: The water absorption capacity and solubility index of flours from Ivorian taro (*Colocasia esculenta,* cv yatan) corm were evaluated according to Phillips *et al*. (1988) and Anderson *et al*. (1969) methods, respectively. The flours from taro corm (2.5 g) were each weighed into a centrifuge tube and 30 mL distilled water added. The content of the centrifuge tube was shaken for 30 min in a KS 10 agitator. The mixture was kept in a water-bath

(37ºC) for 30 min and centrifuged (Ditton LAB centrifuge, UK) at 5000 rpm for 15 min. The resulting sediment (M2) was weighed and then dried at 105ºC to constant weight (M1). The WAC was then calculated as follows:

$$WAC(\%) = \frac{M2 - M1}{M1} \times 100 \quad (1)$$

While the WSI was calculated using the following equation:

$$WSI(\%) = \frac{M0 - M1}{M0} \times 100 \quad (2)$$

Foam capacity and foam stability: The foam capacity (FC) and stability (FS) of flours from Ivorian taro (*Colocasia esculenta,* cv yatan) corm were studied by the method of Coffman and Garcia (1977). Three (3) g of flour were transferred into clean, dry and graduated (50 ml) cylinders. The flour samples were gently levelled and the volumes noted. Distilled water (30 mL) was added to each sample; the cylinder was swirled and allowed to stand for 120 min while the change in volume was recorded every 15 min.

$$FC(\%) = \frac{Vt - Vo}{Vo} X 100 \quad (3)$$

$$FS(\%) = \frac{FC}{FCo} \times 100 \quad (4)$$

where V_0 is the original volume of sample (mL), Vt is the total volume after different times (mL) and FC_0 is the foam capacity (FC) at 0 min.

Iodine affinity of starch: The iodine affinity of starch of flours from Ivorian taro (*Colocasia esculenta,* cv yatan) corm was assayed using guidelines of Kawabata *et al.* (1984). Three (3) g of flour were introduced into 50 ml beakers and made up to 30 mL dispersions using distilled water. The dispersion was stirred occasionally within the first 30 min and then filtered through Whatman no.42 filter paper. A 10 mL aliquot of the filtrate was pipetted into a conical flask, phenolphthalein (four drops) was added, and the filtrate titrated with 0.1N I_2 solution to a bluish black end-point. The starch cell damage (free starch content) was calculated using the titre value and expressed as iodine affinity of starch, IAS (ppm):

$$IAS(ppm) = \frac{VD}{VA} \cdot \frac{Vt}{Ms} \cdot \frac{NA}{100}.106 \quad (5)$$

where VD = Total volume of dispersion:

VA = Volume of aliquot used for titration
Vt = Titre value
Ms = Mass (db) of flour used
Na = Normality of iodine solution used

Paste clarity: The paste clarity of flours from Ivorian taro (*Colocasia esculenta,* cv yatan) corm was determined according to the method of Craig *et al.* (1989). A 1% aqueous suspension was made by suspending 0.2 g of flour in 20 ml of distilled water in a stoppered centrifuge tube and vortex mixed. The suspension was heated in a boiling water (100ºC) bath for 30 min. After cooling, clarity of the flour was determined by measuring percent transmittance at 650 nm against a water blank on a spectrophotometer JASCO V-530 (UV/VIS, Model TUDC 12 B4, Japan Servo CO. LTD Indonesia).

Statistical analysis: The mean values and standard deviations of each analysis are reported. Analysis of variance (ANOVA) was performed as part of the data analyzes (SAS, 1989). When F-values were significant ($p < 0.05$) in ANOVA, then least significant differences were calculated to compare treatment means. Pearson correlation coefficients (r) for relationships between various flour properties were calculated. The variations observed in the chemical composition and physico-functional properties of the flours from taro com were examined by Principal Component Analysis (PCA) with the Minitab Statistical Software version 13.

RESULTS AND DISCUSSION

Principal component analysis: Principal Component Analysis (PCA) was used to visualize the variation in the properties among flours from different boiling times. This analysis showed two axes explaining the essential variability that were axis 1 and 2. The first and the second PCs described 65.36 and 22.08% of the variance respectively. Together, the first two PCs represented 87.44% of the total variability. FRTC was located at the left of the score plot, while FBTC20, FBTC35 and FBTC50 had a large positive score in the first Principal Component (PC1) (Fig. 1). FRTC had a large negative score, whereas FBTC20, FBTC35 and FBTC50 had a positive score in PC1. FBTC20 showed a large positive score while FBTC50 had a negative score in second Principal Component (PC2). The loading plot of the two PCs provided the information about correlations between the measured properties (Fig. 2). The properties whose curves lie close to each other on the plot were positively correlated while those whose curves run in opposite directions were negatively correlated.

Proximate composition: The proximate composition of flours from raw and boiled taro (*Colocasia esculenta,* cv

Table 1: Proximate composition of flours from raw and boiled taro (*Colocasia esculenta,* cv yatan) corm

Parameters	Flour from raw taro corm	Flours from boiled taro corm (% dry weight)		
		20*	35	50
Moisture	6.92[a]±0.21	8.33[b]±0.32	10.07[c]±0.54	10.40[c]±0.34
Crude protein	5.88[a]±0.14	5.87[a]±0.07	5.85[a]±0.09	5.87[a]±0.07
Reducing sugars	0.99[a]±0.01	0.99[a]±0.03	0.87[b]±0.01	0.85[c]±0.02
Total sugars	5.84[a]±0.07	3.63[b]±0.01	3.63[b]±0.01	4.10[c]±0.04
Total carbohydrate	80.94[a]	79.53[a]	77.53[b]	76.86[b]
Crude fat	0.87[a]±0.02	0.85[a]±0.05	0.86[a]±0.01	0.87[a]±0.01
Crude fibre	1.22[a]±0.05	1.20[a]±0.10	1.22[a]±0.01	1.20[a]±0.02
Total phenolic compound	0.41[a]±0.02	0.20[b]±0.01	0.16[c]±0.01	0.21[b]±0.01
Total ash	4.07[a]±0.23	4.27[a]±0.46	4.47[a]±0.30	4.37[a]±0.21

The obtained values are averages ± standard deviation of triplicate determinations. On the lines of each parameter, the averages affected of no common letter are significantly different between them on the threshold of 5% according to the test of Duncan. *: boiling time in minute

Table 2: Pearson correlation coefficients between various chemical composition and physico-functional properties of flours from raw and boiled taro (*Colocasia esculenta,* cv yatan) corm

	WAC	WSI	IAS	PC	FC	M	CP	TC	CF	Cfib	TPC	TA
WAC	1.00											
WSI	0.86	1.00										
IAS	- 0.60	- 0.46	1.00									
PC	- 0.44	- 0.80	- 0.11	1.00								
FC	0.78	0.84	- 0.86	- 0.42	1.00							
M	0.71	0.96	- 0.21	- 0.94	0.67	1.00						
CP	- 0.34	- 0.70	0.50	0.65	- 0.79	- 0.70	1.00					
TC	- 0.70	- 0.94	0.14	0.95	- 0.62	- 0.99	0.65	1.00				
CF	- 0.46	- 0.26	0.98	- 0.32	- 0.73	0.01	0.35	- 0.08	1.00			
Cfib	- 0.84	- 0.48	0.35	0.06	- 0.37	- 0.31	- 0.23	0.32	0.30	1.00		
TPC	- 0.84	- 0.95	0.72	0.61	- 0.97	- 0.83	0.79	0.79	0.54	0.41	1.00	
TA	0.67	0.95	- 0.46	- 0.83	0.84	0.94	- 0.89	- 0.91	- 0.26	- 0.17	- 0.93	1.00

WAC: Water absorption capacity; WSI: Water solubility index; IAS: Iodine affinity of starch; PC: Paste clarity; FC: Foam capacity; M: Moisture; CP: Crude protein; TC: Total carbohydrate; CF: Crude fat; CFib: Crude fibre; TPC: Total phenolic compounds; TA: Total ash
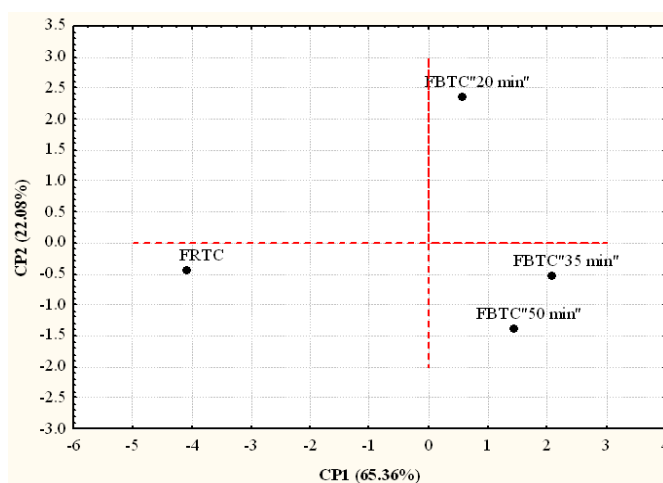

Fig. 1: Sample plot of principal components 1 and 2 of flours from raw and boiled taro (*Colocasia esculenta* cv *yatan*) corms. FRTC: Flour from raw taro corm; FBTC20 min": Flour from taro corm boiled in water during 20 min; FBTC "35 min": Flour from taro corms boiled in water during 35 min; FBTC"50 min": Flour from taro corm boiled during 50 min WAC: Water absorption capacity; WSI: Water solubility index; IAS: Iodine affinity of starch; PC: Paste clarity; FC: Foam capacity; M: Moisture; CP: Crude protein; TC: Total carbohydrate; CF: Crude fat; CFib: Crude fibre; TPC: Total phenolic compounds; TA: Total ash; PC: principal component

yatan) corm were presented in Table 1. The change in boiling time led to a significant (p<0.05) reduction in the total carbohydrate, reducing and total sugars and total phenolic compound levels, whereas the moisture content increased significantly (p<0.05). The crude fat, fibre, protein and total ash contents were not affected by the changes in boiling time. The decrease in the parameter contents of flour from boiled taro corm may be attributed
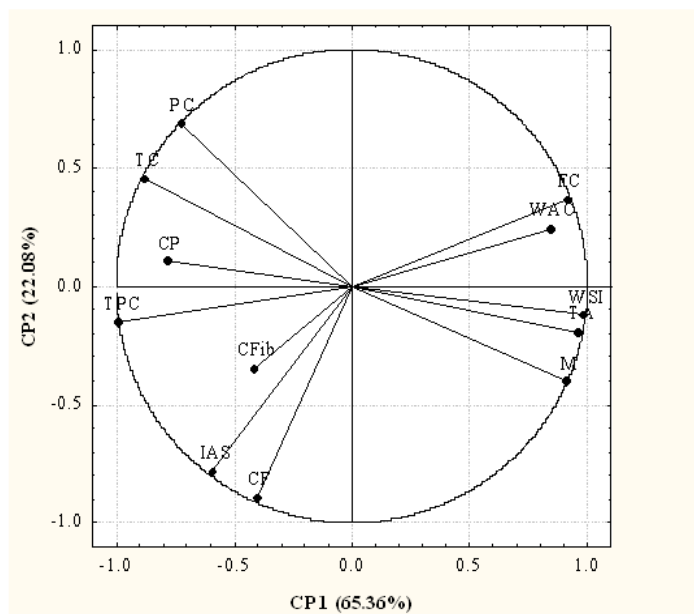
Fig. 2: Circle of correlation of chemical composition and physic-functional properties of flours from raw and boiled taro (*Colocasia esculenta* cv *yatan*) corms on axes 1 and 2. WAC: Water absorption capacity; WSI: Water solubility index; IAS: Iodine affinity of starch; PC: Paste clarity; FC: Foam capacity; M: Moisture; CP: Crude protein; TC: Total carbohydrate; CF: Crude fat; CFib: Crude fibre; TPC: Total phenolic compounds; TA: Total ash; PC: principal component

to the high cell damage due to the effect of the long boiling time which caused loss of these parameters in the taro corm (Fox and Cameron, 1984). This result is in agreement with those of Onuegbu *et al.* (2009) in three-leaved yam (*Dioscorea dumetorum pax*) tubers. Moisture contents of the flours from Ivorian taro corm were below 11%, thereby giving the flours a better shelf life. This biochemical parameter is important in the storage of flour, levels greater than 12% allow for microbial growth. Low levels are favorable and give relatively longer shelf life (Aryee *et al.*, 2006). Also, the lower moisture content of the flours the more the efficiency of the drying method because this shows that much of the water contained in the raw and boiled samples had been removed during drying (Pierre, 1989). Moisture levels of flours from Ivorian taro corm are lower than that of wheat flour (12.4%, Gupta *et al.*, 2010). Moisture content was shown to be positively correlated to the total ash ($r = 0.94$, $p<0.05$) level and negatively correlated to crude protein ($r = -0.70$, $p<0.05$), total phenolic compound ($r = -0.83$, $p<0.05$) and total carbohydrate ($r = -0.99$, $p<0.05$) contents both by Pearson correlation (Table 2) and PCA analysis (Fig. 2). The result showed that total carbohydrate (76.86 to 80.94%) is the most important chemical component in the flours. This finding corroborated well with those reported by Aboubakar *et al.*(2008) and Gupta *et al.* (2010) for flours of six varieties of Cameroon taro and wheat (71.1%)

respectively. The taro (*Colocasia esculenta*, cv yatan) corm is therefore an important staple food in Côte d'Ivoire (West Africa). It is an excellent energy supplier (Huang *et al.*, 2007). Onwueme (1978) reported that taro corm is a source of carbohydrate for diabetics and for those with gastrointestinal disorders. This may suggest that taro corm contain slowly digestible starches and dietary fibre which are of nutritional importance (Srilakshmi, 2008). This improve taro competitiveness along side other roots and tuber crops, enhance its application in other food systems and improve marketing potential. Pearson correlation (Table 2) and PCA analysis (Fig. 2) revealed a negative correlation of total carbohydrate level with moisture ($r = -0.99$, $p<0.05$) and total ash ($r = -0.91$, $p<0.05$) contents and a positive with crude protein ($r = 0.65$, $p<0.05$) and total phenolic compound ($r = 0.79$, $p<0.05$) levels. The result also showed that besides carbohydrates, total ash and crude fibre represented another important group of component in taro (*Colocasia esculenta*, cv yatan) corm flours. Their content in flours of Ivorian taro corm ranged from 4.07 ± 0.23 to 4.47 %±0.30 and from 1.20 ± 0.02 to 1.22 ± 0.01%, respectively. The total ash content is higher compared to those of flours from wheat (1.59%, Gupta *et al.*, 2010) and taro (*Colocasia esculenta*) corms cultivated in India (0.71%, Kaur *et al.*, 2011) and Nigeria (1.40%, Alinnor and Akalezi,2010). This suggests that the flours from Ivorian taro corm could be a source of

Table 3: Mineral composition of flours from the raw and boiled taro (*Colocasia esculenta,* cv yatan) corms

Minerals	Flour from raw taro corm (mg/100 g dry weight)	Flours from boiled taro corm (mg/100 g dry weight)		
		20*	35	50
Calcium	38.07[a]±2.77	38.90[a]±5.60	37.27[a]±4.47	36.57[a]±4.60
Iron	4.20[a]±0.94	4.03[a]±0.61	4.05[a]±0.20	3.83[a]±0.40
Magnesium	96.84[a]±0.85	94.20[a]±3.83	97.50[b]±0.81	78.07[c]±2.15
Phosphorus	362.11[a]±7.35	365.21[a]±8.37	355.18[a]±8.72	364.72[a]±7.88
Potassium	225.69[a]±31.59	208.15[a]±3.05	211.73[a]±15.49	219.69[a]±4.12
Sodium1	9.56[a]±2.75	22.00[a]±1.34	30.76[b]±1.70	31.10[b]±1.90
Zinc	7.05[a]±0.70	7.08[a]±1.92	4.53[b]±0.01	4.63[c]±0.80
Copper	0.47[a]±0.30	0.46[a]±0.15	0.46[a]±0.55	0.43[a]±0.20
K/Na	11.53	9.46	6.88	7.06
Ca/P	0.10	0.10	0.10	0.10

The obtained values are averages ± standard deviation of triplicate determinations. On the lines of each parameter, the averages affected of no common letter (a or b) are significantly different between them on the threshold of 5% according to the test of Duncan. *: boiling time in minute

Table 4: Some physico-functional properties of flours from the raw and boiled taro (*Colocasia esculenta,* cv yatan) corms

Properties	Flour from raw taro corm	Flours from boiled taro corm		
		20*	35	50
Water absorption capacity (%)	312.21[a]±27.32	518.42[b]±91.54	444.56[c]±26.21	526.76[d]±35.36
Water solubility index (%)	11.83[a]±0.15	20.70[b]±0.33	23.90[fc]±0.01	24.76[d]±0.25
Iodine affinity of starch (ppm)	1153.33[a]±15.34	735.03[b]±15.43	878.33[c]±7.63	1066.66[d]±11.53
Paste clarity (% T)	20.16[a]±0.35	20.00[b]±0.44	10.06[c]±1.36	9.02[c]±0.85
Foam capacity (%)	9.22[a]±0.02	10.01[b]±0.08	10.05[b]±0.05	9.75[c]±0.04

The obtained values are averages ± standard deviation of triplicate determinations. On the lines of each parameter, the averages affected of no common letter (a or b) are significantly different between them on the threshold of 5% according to the test of Duncan; T: transmittance; *: boiling time in minute

mineral elements having nutritional importance. The result in the present study indicated that flours from Ivorian taro corm had higher crude fibre content than those of flours from sweet potato (0.75%, Oladebeye *et al*., 2008) tubers, red (0.50%, Oladebeye *et al*., 2008) and white (1.00%, Alinnor and Akalezi, 2010) taro (*Colocasia esculenta*) corm. This finding is important because crude fibre has useful role in providing roughage that aids digestion (Eva, 1983). The importance of fibre clinically has been reported by Umoh *et al*. (1984) which stated that fibre depleted diets cause pathological effects which manifest in the gastro-intestinal tracts as well as other anatomical structures such as the arteries, lower limb veins and gall bladder, suggesting therefore that there is need for minimum obtainable level of fibre in diets. The total and reducing sugar contents of flours ranged from 3.63±0.01 to 5.84±0.07% and from 0.85±0.02 to 0.99±0.01% respectively. The variability of these levels may be due to the hydrolysis of polysaccharides of taro corm into simple sugars during boiling in water. Reducing sugars level in taro (*Colocasia esculenta,* cv yatan) corm flour is lower than those of flours from taro (*Colocasia esculenta*) cv *Sosso Chad* (2.3%) and *Ibo ekona* corm (1.3%) reported by Njintang *et al*. (2007). It has been suggested that reducing sugars in taro corm flour may cause caking and damping during their storage because of sugar's hygroscopic property. However, sugars may be desirable in bakery products like bread and cake where the tenderising effects positively affect texture and where sugars serve as substrate for fermentation of the dough (Aina *et al*., 2010). In comparison to flours from different rice cultivars (0.08 to 0.39%, Yu *et al*., 2010) and red taro corm (1.41%, Oladebeye *et al*., 2008), flours of Ivorian taro corm exhibit higher crude protein content (5.88±0.14%). However, its protein content is lower than that of wheat flour (11.5%, Gupta *et al*., 2010). This pattern indicates that taro (*Colocasia esculenta,* cv yatan) corm flours have a moderate content of protein. Crude protein content was shown to be positively correlated to the total carbohydrate (r = 0.65, p<0.05) and phenolic compound (r = 0.79, p<0.05) levels and negatively correlated to moisture (r = -0.70, p<0.05) and total ash (r = -0.89, p<0.05) contents both by Pearson correlation (Table 2) and PCA analysis (Fig. 2). The crude fat content of the flour from Ivorian taro corm (0.60±0.01 to 0.75±0.05%) is below 1%, Similar observations were recorded by Owuamanam *et al*. (2010) when using *Colocasia exculenta* cv ede cocoindia (0.82±6 x 10^{-3}%), *Colocasia exculenta* cv ede ofe (0.78±0.00%), *Xanthosoma sagittifolium* cv ede uhie (0.8±9.6 x 10^{-3}%) and *Xanthosoma sagittifolium* cv ede ocha (0.74±1.89 × 10^{-2}%) corms. The crude fat content of the flour from Ivorian taro corm was lower than that of wheat flour (1.49%, Gupta *et al*., 2010). The total phenolic compound content of the four from Ivorian taro corm (ranged from 0.16±0.01 to 0.41±0.02%) is within the range (0.04 to 0.35%) for most flours of wheat, buckwheat, corn, oats sprouts, seedlings (Randhir *et al*., 2008), fifteen dry edible bean (*Phaseolus vulgaris* L.) varieties (Luthria and Pastor-Corrales, 2006) and potato

(Natella *et al*., 2010). This pattern indicates that taro (*Colocasia esculenta,* cv yatan) corm could exhibit a wide range of health promoting function such as antibacterial, antiinflammatory, anti-allergic, hepato-protective, anti-thrombotic, anti-viral, anti-carcinogenic, anti-diabetic and anti-hypertensive activities (Middleton *et al*., 2000; Shetty, 1997).

Mineral composition: The result presented in Table 3 showed the mineral composition of the flours from Ivorian taro (*Colocasia esculenta*, cv yatan) corm. Generally, the mineral contents were not affected significantly ($p < 0.05$) by the change in boiling time. Within these flours, calcium (38.07 ± 2.77 mg/100 g dry weight), iron (4.20 ± 0.94 mg/100 g dry weight), sodium (19.56 ± 2.75 and 31.10 ± 1.90 mg/100 g dry weight), zinc (4.53 ± 0.01 and 7.08 ± 1.92 mg/100 g dry weight), copper (0.47 ± 0.30 mg/100 g dry weight) had the lowest values while phosphorus (225.69 ± 31.59 mg/100 g dry weight), potassium (225.69 ± 31.59 mg/100 g dry weight) and magnesium (78.07 ± 2.15 and 97.50 ± 0.81 mg/100 g dry weight) had the highest values. The K: Na ratio (7.06-11.53) is close to the recommended 5.0 (Szentmihalyi *et al*., 1998). Dietary changes leading to reduce consumption of potassium than sodium have health implications. Diets with higher ratio K: Na is recommended and these are found usually in whole foods (Arbeit *et al*., 1992). Foods naturally higher in potassium than sodium may have a K/Na ratio of 4.0 or more (CIHFI, 2008). The high K: Na suggests that the flours from taro (*Colocasia esculenta,* cv yatan) corm could be suitable in helping to ameliorate sodium-related health risk (Appiah *et al*., 2011). The Ca: P ratio (0.10) of the flours from Ivorian taro corm was below 1. However, according to SCSG (2007) a good menu should have a Ca: P ratio over 1. Foods high in phosphorus and low in calcium tend to make the body over acid deplete it of calcium and other minerals and increase the tendency towards inflammations (Appiah *et al*., 2011). In order to avoid this problem, these flours need supplementation with calcium to prevent mineral and osmotic imbalance (Appiah *et al*., 2011).

Physico-functional properties: In this study, the change in boiling time led to a significant ($p < 0.05$) reduction in iodine affinity of starch, whereas the water absorption capacity, water solubility index, paste clarity and foam capacity increased significantly ($p < 0.05$) as shown in Table 4. Water absorption is important for certain product characteristics, such as the moistness of the product, starch retrogradation, and subsequent product scaling (Siddiq *et al*., 2010). The water absorption capacity of flour from raw taro (*Colocasia esculenta,* cv yatan) corm was $312.21 \pm 27.32\%$ while that of flour from boiled taro

corm ranged from 444.56 ± 26.21 to $526.76 \pm 35.36\%$, indicating that cooked sample has higher water absorption capacity. This behavior indicates that flour of boiled taro corm has more hydrophilic constituents (Hodge and Osman, 1976). These results are in close conformity with the findings of Fagbemi and Olaofe (2000) in flours from raw and pre-cooked taro. The range of water absorption capacity observed for the flour from Ivorian taro corm is higher compared to those of flours from raw wheat (*Aestium triticium*) (130.70%, Ikpeme *et al*., 2010) and raw and precooked taro (*Colocasia esculenta*) corms cultivated in Hawaii (150-180%, Tagodoe and Nip, 1994), India (2.2 g/g, Kaur *et al*., 2011), Cameroon (270-375g/100 g, Mbofung *et al*., 2006; Njintang *et al*., 2007) and Chad (242.45 to 374.86 g/100 g, Mbofung *et al*., 2006). The ability of food materials to absorb water is sometimes attributed to its protein contents (Kinsella, 1976) and to the capacity of boiling to dissociate or alter the protein molecules to monomeric subunits which may have more water-binding sites (Lin *et al.,* 1974). In this study, a poor negative correlation ($r = -0.44$, $p < 0.05$) between water absorption capacity and protein content of flour from Ivorian taro corm was observed (Table 2 and Fig. 2). This observation deviates from the accepted theory that protein solubility is positively correlated with water absorption capacity. This may suggest that the proteins of Ivorian taro corm are rigid or folded. Therefore, the observed water absorption capacity of the flour from Ivorian taro corm cannot be attributed only to the proteins. Also, Aboubakar *et al*. (2008) suggested that the non-starch component of the flours contribute highly to the water absorption of taro flours. This pattern is in close conformity with the results of Pearson correlation (Table 2) and PCA analysis (Fig. 2) which revealed a positive correlation of water absorption capacity with foam capacity ($r = 0.79$, $p < 0.05$), water solubility index ($r = 0.79$, $p < 0.05$), moisture ($r = 0.79$, $p < 0.05$) and total ash ($r = 0.79$, $p < 0.05$) levels and a negative with iodine affinity starch ($r = 0.79$, $p < 0.05$), total carbohydrate ($r = 0.79$, $p < 0.05$), crude fibre ($r = 0.79$, $p < 0.05$) and total phenolic compound ($r = 0.79$, $p < 0.05$) contents. Viscosity development of a paste has been mainly related to the water binding capacities of the dry ingredients (Dogan *et al*., 2005). According to these authors, flour which binds the maximum amount of water exhibits a high viscosity. In this respect, the good WAC of flour from Ivorian taro corm may prove useful in enhancing the applicability of this flour in products where good viscosity is required, such as in soups and gravies (Kaur *et al*., 2011). Foams are used to improve texture, consistency and appearance of foods (Akubor, 2007). Under the conditions of the present study, foam stability tended to decrease with the passage of time at room temperature (Fig. 3). This result may be due to collapsing and bursting
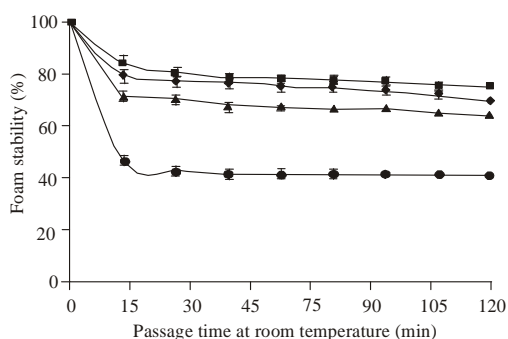
Fig. 3: Foam stability of flours from raw and boiled taro (*Colocasia esculenta* cv *yatan*) corms after 15, 30, 45, 60, 75, 90, 105 and 120 min of storage. The obtained values are averages±standard deviation of triplicate determinations. (♦): Flour from raw taro corms; (■): Flour from taro corm boiled in water during 20 min; (▲): Flour from taro corms boiled in water during 35 min; (●): Flour from taro corm boiled during 50 min

of the formed air bubbles (Kinsella, 1976). The flour of boiled taro com exhibited the highest foam capacity. The value ranged from 9.75±0.04 to 10.05±0.05%. Similar observations were recorded by Mbofung *et al*. (2006) when using flours of six varieties from taro (*Colocasia esculenta*) corm originated from Cameroon. This suggests that heating affected positively the primary factors involved in foam formation which are surface tension, viscosity and the character of the protein film that is formed at the surface of the liquid (Kinsella, 1979). The boiling of the Ivorian taro corm in water denatured its proteins, thus promoting the formation of protein aggregation through hydrophobic and disulphide interchange bonding mechanisms (Morr, 1990). It is well known that, for a protein to have good foaming properties, it has to be very soluble, because foam capacity requires rapid adsorption of protein at the air-water interface during whipping, penetration into the surface layer and re-organisation at the interface (Were *et al*., 1997). It is important to note that foaming capacity in this study was shown to be negatively correlated to the total phenolic compound (r = 0.79, p<0.05), crude fat (r = 0.79, p<0.05), crude protein (r = 0.79, p<0.05) and total carbohydrate (r = 0.79, p<0.05) contents and positively correlated to water absorption capacity (r = 0.79, p<0.05), water solubility index (r = 0.79, p<0.05), moisture (r = 0.79, p<0.05) and total ash (r = 0.79, p<0.05) levels both by Pearson correlation (Table 2) and PCA analysis (Fig. 2). This suggests that phenolic compound, crude fat, crude protein and carbohydrate affected negatively the FC. Kinsella (1979) reported that phenolic compound and crude fat could affected the FC by destabilising the protein films surrounding the air droplets and causing the foam to collapse. The negative action of the carbohydrates in foam formation may be attributed probably to the high

increase of the viscosity at the surface of the colloidal solution, thereby reducing coalescence of gas bubbles. The water solubility index reflects the extent of starch degradation (Diosady *et al*., 1985). The water solubility index (7.84±0.34 %) observed for the flour of raw taro corm is lower compared to that of flour from boiled taro (9.72±0.37-16.06±0.27%, Table 4), indicating that boiling time had more profound effect on starch degradation. Similar observations were recorded by Hsu *et al*. (2003) when using yam (tubers of the *Dioscorea* spp) flours (9.26±0.11 to 15.31±0.85%). Pearson correlation (Table 2) and PCA analysis (Fig. 2) revealed a positive correlation of water solubility index with foam capacity (r = 0.84, p<0.05), water absorption capacity (r = 0.86, p<0.05) total ash (r = 0.95, p<0.05) and moisture (r = 0.96, p<0.05) contents and a negative with paste clarity (r = -0.80, p<0.05), total phenolic compound (r = -0.95, p<0.05), total carbohydrate (r = -0.94, p<0.05) and crude protein (r = -0.70, p<0.05) levels. The pasting characteristics play an important role in the selection of a variety for use in the industry as a thickener, binder or for any other use (Kaur *et al*., 2011). The iodine affinity of starch from raw taro com flour (28.56±0.61 ppm) is lower than that for flour from boiled taro com (37.30±0.41 to 49.30±1.10 ppm). The result showed that the boiled taro corm flour contained starch granules with the highest affinity for iodine or, in consonance with reports by Raja (1992), contains more amylose. Brunnschweiler *et al*. (2006) reported that amylose aggregation has a strong impact on the texture of the pastes. Changes in the amylose fraction are also found to influence the texture of other starch rich products such as pasta, mashed potatoes and bread (Escher *et al*., 1979; Hug-Iten *et al*., 2001; Moss *et al*., 1987). This is why, the iodine affinity of starch was shown to be high positively correlated to the total carbohydrate level (r = 0.99, p<0.05) both by Pearson correlation (Table 2) and PCA analysis (Fig. 2). Starch gel clarity is a much desirable functionality of starches for its utilization in food industries since it directly influences brightness and opacity in foods that contain it as thickeners (Mweta *et al*., 2008). Light transmittance of flour from taro corm ranged between 28.56±0.61%T and 49.30±1.10 %T. The low clarity of the flour from raw taro corm would be explained by the fact why the not swollen starch granules remained dense, thus, they reflected the maximum of light entering the medium (Tetchi *et al*., 2007). Consequently, pastes appeared turbid or opaque, in agreement with literature (Craig *et al*., 1989). The increase in transmittance (flour of boiled taro corm) shows that it evolved with the gelatinization phenomenon. Pastes obtained after gelatinization are more transparent than native starch suspension (Lizuka and Aishima, 1999; Nuessli *et al*., 2000). The increasing in starch paste clarity could be due to reduction in light refraction by the granules remnants (Tetchi *et al*., 2007). Amylose content is known to influence the clarity of

starch pastes as lower amylose starches are easily dispersed, increasing transmittance and clarity. On the other hand, Craig *et al.* (1989) suggested that paste clarity is influenced by so many factors, not only amylose to amylopectin ratio. Tetchi *et al.* (2007) reported that light transmittance (%T) of the paste depended mainly on the spectrophotometer type, starch concentration, treatment temperature and storage time. In this respect, Pearson correlation (Table 2) and PCA analysis (Fig. 2) revealed a positive correlation of paste clarity with total phenolic compound ($r = 0.99$, $p<0.05$) and total carbohydrate ($r = 0.99$, $p<0.05$) levels and a negative water solubility absorption ($r = 0.99$, $p<0.05$), moisture ($r = 0.99$, $p<0.05$) and total ash ($r = 0.99$, $p<0.05$) contents.

CONCLUSION

This report shows that the boiling time have significant ($p<0.05$) effect on the moisture, reducing sugars, total sugars, total phenolic compound, total carbohydrate contents, iodine affinity of starch, water absorption capacity, water solubility index, paste clarity and foam capacity of the taro corm flours. However, the crude fibre, crude protein, crude fat and total ash contents were not affected significantly ($p<0.05$) by the change in boiling time. Flour of Ivorian taro (*Colocasia esculenta,* cv yatan) corm is a good source of carbohydrate, crude fibre and total ash going by the chemical score and therefore should be appreciated as a food security crop those people living in Côte d'Ivoire (West Africa) where this taro corm is produced in abundance. The Ivorian taro corm flour exhibits highest WAC and lowest foam capacity in comparison to other flours. The high WAC of taro flour makes it a good body providing agent and can thus be used as a thickener or gelling agent in various food products.

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