Original Research Article

Effect of SomeThermal Processing Conditions on the Physicochemical and Moisture- Sorption Characteristics of Two Cocoyam (*Colocasiaesculenta*) Varieties

.

ABSTRACT

Two cocoyam varieties (*Colocasia esculenta)* known as taro grown in Cross-River State and Bendel were subjected to different processing conditions (boiling and drying) and the effect of boiling temperature, boiling time and drying temperatures were investigated. They were processed into flour using standard methods, packaged in low-density polyethylene bags and kept in the laboratory for analysis. The results obtained showed that crude fat, crude protein, ash, moisture, crude fibre and carbohydrate contents ranged from 0.42-0.92%, 6.03-9.01%, 2.13-3.90%, 5.20-12.07%, 0.43-0.77% and 73.32-81.73%, respectively. The anti-nutrients contents of the samples showed that oxalate ranged from 0.01-0.99 mg/g, alkaloids (0.12-0.73 mg/g), flavonoids (0.00-0.83 mg/g), phytate (0.01-1.90 mg/g), saponin (0.00-0.83 mg/g) and tannin (0.00-0.01 mg/g). The investigation revealed that there were significant ($p<0.05$) variations in the functional properties of the cocoyam samples with the water absorption capacity ranging from (1.56-3.01 mg/g), bulk density(0.58-0.82 mg/g), swelling index (1.54-2.91 mg/g), Oil absorption capacity (1.32-1.67 mg/g), while porosity ranged from 0.30-0.76 mg/g. There were also significant ($p<0.05$) variations in the thermal diffusivity of the samples with the samples of Cross River Cocoyam having higher thermal diffusivity compared to sample of Bendel Cocoyam. The higher thermal diffusivity observed in the cross river cocoyam could be due to the lower moisture content of the samples. The result of the pasting properties showed that the peak viscosity, peak time, final viscosity, breakdown and set back viscosities ranged from 10.88-15.81 N/m^2, 7.87-20.87 mins, 8.00-9.97 N/m^2, 15.10-17.90 N/m^2, 6.0-7.5 N/m^2 and 2.3-3.8 N/m^2. The research discovered that sample with less pasting temperatures and high peak viscosity had better thickening effect as seen in sample of Cross River Cocoyam. The moisture sorption isotherms had sigmoid-shaped profiles for all of the three temperatures. The hysteresis effect at the three temperatures was distinctly expressed. The increasing temperatures resulted in less hysteresis effect on taro flour which meant the adsorption and desorption curves were closer.

Keywords: Cocoyam,Physicochemical,Moisture-sorption Isotherm, thickener, Thermal Conductivity

1. INTRODUCTION

Cocoyam is an herbaceous perennial plant that belongs to the family Araceae. The genus *Colocasia esculenta* and the genus *Xanthosoma sagittifolium* are the most consumed and cultivated species all over the world. Though all parts of the cocoyam plant can be eaten, they are grown mainly for their edible roots also called corms. Cocoyam grows from the fleshy corm (tuber) that can be boiled, baked, mashed into a meal and used as staple food or snack. In the eastern part of Nigeria, it serves as a staple food and is used as a thickener in food preparations.

According to Ejoh *et al*. (2013), cocoyam accounts as one of the most important root and tuber crops worldwide. As one of the oldest food crops in the world (more than nine thousand years old), it is cultivated throughout the tropical world (Wang, 1983). Nigeria ranks first in world production of cocoyam (47.5% supply in the world and 77.9% supply in Africa) with 5,387,000 Mt valued at approximately USD 555M. In Nigeria, Ebonyi State (11.5%) is the highest producer of cocoyam followed by Ondo State while Cross River State ranked third. However, the cultivation of cocoyam in Nigeria is declining and there is need to step up research in cocoyam production and utilization. Cocoyam is rich in nutrients and has some therapeutic effects for increased immune system (Alabi *et al.,* 2019). Furthermore, the improvement in the production potentials of cocoyam would lead to commensurate economic benefits for many subsistence households and increased food security.

Taro (*Colocasia esculenta*) and Tania (*Xanthosoma sagittifolium*) are the important species of edible aroids grown in tropical and sub-tropical countries (FAO, 2006). It is an under-exploited tuber crop, although the literature is replete with its potential nutritional applications (Amandikwa, 2012). Annual production of taro in Nigeria is estimated at 2.59 million tons while China and Cameroon ranked second and third, respectively, in world taro production (McGregor, 2010). In terms of nutrition, taro is rich in nutrients especially vitamins (vit. E, C and Vit. B_6) and minerals (potassium, copper, phosphorous and folates). The crop has a gummy texture when cooked which has been exploited by the consumers as a veritable source for food thickening. In light of its importance in food processing and preservation, it is imperative that research in the thermal processing of the taro crop into flour be given prominence in the food industry.

The tuber crop is rich in anti-nutrients such as saponin, alkaloids, phytates, among others. Saponin has the ability to increase the body's levels of immune response. According to Sidhu *et al.* (1996), saponin is used as a component of spermicides and vaccines, and is reported to inhibit the growth of benign and malignant tumors to have microbial and anti-viral properties (Ocheja *et al*., 2013). Saponin, though non-toxic, exhibit cytotoxic effects and growth inhibition against variety of cells making it to have anti-inflammatory and anti-cancer properties (Akindahunsi *et al*., 2002). Researchers also revealed that alkaloids help biologically in storage of waste nitrogen, cationic balancing and protection against parasites (Humphrey, 2011; Achilonu *et al.,* 2018). Alkaloids are used as medicine for reducing headache and fever. These are attributed for anti-bacterial and analgesic properties (Shi *et al*., 2004).

This research evaluated the effect of some processing conditions on the physicochemical and moisture sorption characteristics of two cocoyam varieties for improved commercial production and utilization by the consumers.

2. MATERIAL AND METHODS

2.1 Raw Materials

Freshly harvested taro (*Colocasia esculenta*, Bendel cultivar) (BDB) was purchased from Eke-Awka market in Awka South Local Government area of Anambra State, Nigeria while Cross river cultivar (BDC) was purchased from Ogbete Main Market, Enugu, Enugu State. They were brought to the Department of Food Science and Technology Laboratory. Both cultivars were processed immediately after purchase into flours.

2.2 Production of Fresh Cocoyam Flour

Cocoyam corms were peeled with stainless steel knife. The peeled corms were cut into slices and boiled at different temperatures and time. Thereafter, they were dried at different drying temperatures with the use of an oven (Model, YC-1, China). After drying, they were milled with disc attrition mill into flours and then sieved using muslin cloth to obtain fine flours. The flours were packaged with low-density polyethylene bag and stored at room temperature in the Food Science and Technology Laboratory until they were needed for laboratory analysis.

Freshly harvested Taro
↓
Cleaning (washing, peeling)
↓
Slicing
↓
Boiling
↓
Drying
↓
Grinding (Disc attrition mill)
↓
Cocoyam Flour
↓
Packaging
↓
Storage (at room temperature)

Fig.1: Flow diagram of cocoyam flour production modified from Mbanali *et al.* (2019)

2.2.1 Experimental Design

The research was designed using 2 X 3^n Full Factorial Design using Minitab Software Version 20.0. The Table 1 showed the independent variables that were considered in the research design.

Table 1 Experimental Design Applied in this Study

S/N	Sample Runs	Boiling Temp. (˚C)	Boiling Time (Min)	Drying Temp. (˚C)
1	BDC1	100	30	50
2	BDC2	100	30	80
3	BDC3	100	50	50
4	BDC4	100	50	80
5	BDC5	70	50	80
6	BDC6	70	50	50
7	BDC7	70	30	80
8	BDB1	100	30	50
9	BDB2	100	30	80
10	BDB3	100	50	50
11	BDB4	100	50	80
12	BDB5	70	50	80
13	BDB6	70	50	50
14	BDB7	70	30	80

2.3 Proximate analysis

The moisture, ash, crude fat, crude protein and Crude fiber contents were determined using AOAC (2010) while the total carbohydrate content was calculated by difference.

2.4 Determination of Anti-Nutrients

The oxalate was determined according to the method of Sefa-Dedeh and Agyir-Sackey (2004). The saponin, phytate and alkaloids contents were determined by the method of Onwuka (2012) while the flavonoids were determined according to the method described by Bohm and Kouipai-Abyazani (2004).

2.5 Determination of Functional Properties

The Water absorption capacity, bulk density, oil absorption capacity, porosity and swelling index were determined using AOAC (2019).

2.6 Determination of Pasting Properties

The pasting characteristics of the composite flour were evaluated using Rapid-ViscoAnalyser (RVA) described by Awolu (2017).

2.7 Determination of Thermal Diffusivity

The thermal diffusivity of the samples was determined using the equation reported by Sopa *et al*. (2008).

2.8 Determination of Moisture-Sorption Characteristics of Varieties of Cocoyam Flour

Moisture Analyzer MX-50 was used to determine the moisture contents of taro flour samples immediately before measuring the sorption isotherms of the taro flour as described by Bell and Labuza (2000).

2.9 Statistical analysis

Data was analyzed statistically using Minitab software, version 20.0. In order to correlate the response variable to the independent variables, multiple regressions was used to fit the coefficient of the polynomial model of the response. The quality of the fit of the model was evaluated using analysis of variance (ANOVA) with SPSS statistical package (Version 17.0). Duncan Multiple Range test and mean ± standard deviation was chosen to determine any significant difference among the samples at ($p < 0.5$).

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of Taro Species

The results of the proximate composition of the cocoyam samples are shown in Table 2. It was observed that there were significant ($P<0.05$) differences in the proximate composition of the samples. The crude fat content of BDC1 was the highest while sample BDB1 had the least ash content. The samples BDC1and BDB4 are not significantly ($P>0.05$) different. The result of the crude fat showed that the fat content ranged from 0.42-0.92%. Akpan and Umoh (2004) reported that cocoyam has an average crude fat content of 0.93% while Ndabikunze *et al.* (2011) an average of 0.43%. These results implied that taro has a low fat content and could be a preferred food crop that can contribute less to the health problems related with excess fat intake. However, Lola (2009) attributed the low fat content to incluside the heat treatment (blanching) done prior to drying that may have melted the fat into the boiling water thus causing a reduction in the fat content. This assertion may have been supported by Fennama (1996) who argued that heat could trigger polymerization reaction as well as the decomposition and oxidations of fat that would lead to losses during boiling and drying. The linear component of the variables such as boiling temperature, boiling time and drying temperature had positive effects on the samples. In contrast to the above assertions, the research showed that boiling, drying and the boiling time increased the crude fat content while the interaction effect negative influence on the crude fat content. The quadratic effects were positively correlated ($P<0.05$).

TABLE 2: Proximate composition of cocoyam flour

Runs BT_p:BT:DT	Crude fat %	Crude protein %	Ash content %	Moisture content %	Crude fiber %	Carbohydrate %
100:30:50	0.92^{a} ±0.01	7.98^{g} ± 0.01	3.61^{c} ± 0.02	5.20^{j} ± 0.01	0.56^{f} ± 0.01	81.73^{a} ± 0.01
100:30:80	0.89^{b} ±0.01	8.12^{f}±0.01	3.78^{b}±0.01	6.00^{i}± 0.01	0.53^{g}±0.01	80.68^{bc}±0.01
100:50:50	0.85^{c}±0.01	8.45^{e}±0.01	2.88^{j}±0.01	6.80^{h}±0.18	0.51^{h} ±0.01	80.51^{bc}±0.01
100:50:80	0.77^{e}±0.01	9.01^{d}±0.01	2.44^{k}±0.01	7.02^{g}±0.01	0.51^{h}±0.01	80.25^{bc}±0.01
70:50:80	0.62^{h}±0.01	7.12^{k}±0.01	3.01^{i}±0.02	7.75^{f}±0.01	0.48^{i}±0.01	81.02^{ab} ±0.01
70:50:50	0.55^{i} ±0.01	6.33l±0.01	3.11^{h}±0.01	8.90^{h}±0.01	0.55^{f}±0.01	80.56^{bc} ±0.01
70:30:80	0.66^{g}±0.01	6.12^{m}±0.01	3.17^{g}±0.01	8.95^{e}±0,01	0.67^{d}±0.01	80.43^{bc}±0.01
100:30:50	0.77^{e}±0.01	6.03^{n}±0.01	3.23^{f}±0.01	9.50^{d}±0.01	0.69^{c}±0.01	79.78^{c}±0.01
100:30:80	0.74^{f} ±0.02	10.08^{c}±0.01	3.45^{e} ±0.01	9.54^{d}±0.01	0.72^{b}±0.01	75.47^{ef}±0.01
100:50:50	0.76^{e}±0.00	10.56^{b}±0.01	3.56^{d}±0.01	9.56^{d}±0.02	0.53^{g}±0.01	75.03^{f}±0.01
100:50:80	0.77^{de}±0.01	11.04^{a}±0.01	3.78^{b}±0.01	9.58^{d}±0.01	0.51^{h}±0.01	73.32^{g}±0.73
70:50:80	0.78^{d} ±0.01	7.44^{h}±0.01	3.90^{a}±0.00	10.00^{c} ±0.00	0.60^{e}±0.00	77.28^{e}±0.01
70:50:50	0.52^{j}±0.02	7.32^{i}±0.01	2.13^{m}±0.01	11.05^{b}±0.01	0.77^{a}±0.01	78.03^{d}±0.01
70:30:80	0.42^{k}±0.01	7.14^{j}±0.01	2.33^{l}±0.01	12.07^{a}±0.01	0.43^{j}±0.01	77.61^{d}±0.01

Results are Mean ± SD of triplicate determinations. Results with different superscript along the same column are significantly different (P<0.05). BTp= Boiling Temperature (ºC); BT: Boiling Time (min); DT: Drying Temperature (ºC).

The crude protein ranged from 6.03-11.04%. The sample BDB4 had the highest crude protein content while sample BDC5 had the least. The results also showed that all the samples were significantly ($P<0.05$) different from each other. The values determined by this study were higher than the mean protein (4.47%) of taro reported from Tanzania, Uganda and Nigeria by Ndabikunze *et al*. (2011). Higher mean crude protein contents of taro as observed in this study may be associated with the inclusion of cormels in the flour. The present study were in agreement with a review conducted by Shewry (2003) who reported that plant tuber contain protein up to 10%. The regression analysis showed that the linear variables had positive effect on the crude protein content of the samples while the interactive effect had negative correlation on the crude protein content. However, the quadratic factors had positive effect on the crude protein content. The high protein content in taro flours is important for improved nutrition (Otekunrin *et al.,* 2021). Cocoyam, especially taro is one of the tuberous crops with the highest protein content and is thus recommended for sustainable food security in the developing countries, especially to countries with huge humanitarian crises, as obtained in the Northeastern Nigeria.

There were significant difference ($P<0.05$) in the ash content of the samples which ranged from 2.13-3.90%. The increased ash content of the samples is indicative of the high mineral content in taro. These values were higher than the ash content of cocoyam from southern Nigeria which ranged from 0.88-1.15% (Ndon *et al*., 2003). The differences could be due to the influence of the environmental condition in which the cocoyam was grown. Some of the values were within the range of total ash contents of cocoyam (3.51%) grown along the lake Victoria Basin in Tanzania and Uganda (Ndabikunze *et al*., 2011). The regression analysis showed that the linear variables positively influence the ash content which implied that increased boiling, drying and length of boiling led to increased ash content of the samples. Conversely, the interactive effects had negative correlation effect ($P =.05$) on the ash content of the samples. Therefore, increased association of any two of the treatment effect led to decrease in ash content in taro. The quadratic factors had positive effect ($P<0.05$) on the ash content.

The Moisture content analysis of the samples ranged from 5.20-12.07%. The result showed that sample BDB7 was the highest while sample BDC1 was the least. Some of the samples such as sample BDC1, BDC2, BDC3 and BDC4 were not significantly different ($P>0.05$) from each other. When a food is placed on the a hot oven, a moisture vapor pressure gradient which causes moisture at the surface of the food to evaporate and the turn creates movement from the interior of the food to the surface (Tekle, 2009). The result of the regression analysis showed that the linear variables positively influenced the crude fat content of the cocoyam samples while the interactive effects had negative correlation effect on the moisture content of the samples. More so, the quadratic factors had positive effect on both the moisture and crude fat of the samples.

The result of crude fiber ranged from 0.43-0.77%. It showed that the sample BDB6 (70: 50: 50) had the highest crude fiber content while BDB7 was the lowest. The samples BDC2 (100:30:80) and BDB3 (100:50:50) are not significantly different ($P>0.05$) from each other. The samples BDC4, BDC3 and BDB4 were not significantly different from each other while sample BDC5 and BDB7 were significantly ($P<0.05$) different from other samples. The crude fiber were in the range of (0.6-1.90%) was reported by Akpan and Umoh (2004) and was in contrast to the range of crude fiber content (1.11-3.00%) of cocoyam as reported by sefa-Dedeh and Kofi-Agyir (2004). The differences in the fiber content could be attributed to the genotype differences and probably difference in the species of taro as well as environmental conditions. Analysis of the results obtained showed that the linear variables had positive influence on the crude fiber content while the interactive effects had negative correlation effect on the crude fiber content of the samples. Furthermore, the quadratic factors had positive effect on the crude fiber content.

The carbohydrate content of the sample BDC1 was the highest while the sample BDB4 had the least. The result of the carbohydrate content of taro species ranged from 73.32-81.73% and it was observed that sample BDC1and BDC5 are not significantly ($P>0.05$) different from each other. These results were similar to the total carbohydrate content of released taro variety from Ethiopia which was 85.65% (Boloso *et al.,* 2013).This indicates that cocoyam grown in the eastern part of Nigeria had high energy content. The results of the regression analysis showed the influence of processing conditions on the carbohydrate content of the samples. It was observed that the linear factors had positive influence ($P<0.05$) on the carbohydrate content of the samples while the interactive effects had negative (*P* = *.05*) on the carbohydrate content. In the same vein, the quadratic effects positively influenced the content of the samples.

3.2 Anti-Nutrients in cocoyam samples

The results of the anti-nutrient composition of the samples showed that oxalate, saponin, phytate, alkaloid, and flavonoids ranged from 0.01-0.99 mg/g, 0.01-0.82 mg/g, 0.01-1.90 mg/g, 0.11-0.67 mg/g and 0.01-0.04 mg/g respectively while the tannin was negligible and those detected was at 0.01 mg/g (Table 3). The observation from the results indicates that Cross-river cocoyam had less of these phyto-chemicals compared to Bendel cocoyam. Additionally, processing conditions affected the content of these compounds in the two cocoyam samples leading to significant variations (*P* = *.05*) in the samples. However, Cross-river cocoyam had more flavonoids compared to Bendel cocoyam.

The reduction in oxalate content may be due to different treatments done to the raw taro prior to drying like peeling, dicing, boiling at different temperature and time. Washing, according to the studies of Huang *et al.* (2007), reduced the concentration of oxalate by 92% while Akpan and Umoh (2004) stated in their study that the peel of tubers contained more oxalate than the peeled tubers. Buntha *et al.* (2008) also reported that high oxalate acidity cultivars of taro can be reduced by peeling, grating, soaking and fermentation during processing. Cocoyam should be properly processed to reduce the oxalate level to a tolerable level to avoid irritation and scratching sensation in the mouth and throat when consumed. Proper cooking before consumption significantly reduces the total oxalate of leaves and vegetables (Awkaowo *et al*., 2000). The regression analysis showed the effect of boiling temperature; boiling time and drying temperature on the cocoyam sample indicate a positive effect (increases) on the oxalate content. The interactive effect on the boiling temperature and boiling time, boiling time and drying temperature had a negative correlation on the oxalate content of the samples while the boiling temperature versus drying temperature had a positive correlation on the oxalate content of the samples. Furthermore, the quadratic factors had a negative effect on the oxalate content.

TABLE 3: Anti-Nutrients of cocoyam samples

Runs BT_p:BT:DT	Oxalate (mg/g)	Saponin (mg/g)	Phytate (mg/g)	Alkaloid (mg/g)	Flavonoid (mg/g)	Tannin (mg/g)
100:30:50	$0.01^{g}\pm0.00$	$0.77^{c}\pm0.01$	$0.99^{c}\pm0.00$	$0.13^{l}\pm0.02$	$0.04^{b}\pm0.01$	ND
100:30:80	$0.57^{fg}\pm0.12$	$0.01^{f}\pm0.00$	$0.79^{e}\pm0.00$	$0.20^{fg}\pm0.01$	$0.03^{c}\pm0.00$	ND
100:50:50	$0.60^{c}\pm0.01$	$0.83^{b}\pm0.01$	$0.07^{g}\pm0.00$	$0.14^{hi}\pm0.04$	$0.04^{a}\pm0.00$	ND
100:50:80	$0.41^{c}\pm0.01$	$0.75^{c}\pm0.01$	$0.03^{g}\pm0.00$	$0.18^{fg}\pm0.01$	$0.02^{d}\pm0.00$	ND
70:50:80	$0.38^{c}\pm0.12$	$0.02^{f}\pm0.00$	$0.03^{g}\pm0.01$	$0.18^{gh}\pm0.01$	$0.01^{f}\pm0.00$	ND
70:50:50	$0.27^{fg}\pm0.01$	$0.03^{f}\pm0.01$	$0.19^{f}\pm0.01$	$0.22^{f}\pm0.01$	$0.01^{e}\pm0.00$	ND
70:30:80	$0.17^{de}\pm0.00$	$0.02^{f}\pm0.01$	$0.89^{d}\pm0.01$	$0.12^{i}\pm0.01$	$0.02^{j}\pm0.00$	ND
100:30:50	$0.21^{d}\pm0.69$	$0.09^{a}\pm0.00$	$0.01^{g}\pm0.00$	$0.73^{a}\pm0.58$	ND	ND
100:30:80	$0.99^{a}\pm0.01$	$0.07^{d}\pm0.00$	$0.06^{g}\pm0.00$	$0.67^{b}\pm0.00$	ND	ND
100:50:50	$0.41^{c}\pm0.01$	$0.08^{c}\pm0.00$	$0.07^{g}\pm0.00$	$0.44^{c}\pm0.01$	ND	ND
100:50:80	$0.35^{c}\pm0.01$	$0.82^{b}\pm0.00$	$0.90^{d}\pm0.00$	$0.39^{d}\pm0.00$	ND	$0.01^{a}\pm0.00$
70:50:80	$0.11^{ef}\pm0.0$	ND	$1.90^{a}\pm0.10$	$0.30^{e}\pm0.00$	ND	ND
7050:50	$0.57^{b}\pm0.12$	$0.05^{e}\pm0.00$	$0.03^{g}\pm0.10$	$0.17^{gh}\pm0.00$	$0.01^{g}\pm0.00$	ND
70:30:80	$0.17^{de}\pm0.12$	ND	$1.10^{b}\pm0.10$	$0.11^{b}\pm0.00$	$0.01^{gh}\pm0.00$	ND

Results are Mean±SD of triplicate determinations. Results with different superscript along the same column are significantly different (P<0.05).BTp = Boiling Temperature (0C); BT: Boiling Time(mins); DT: Dehydration Temperature (◦C). **ND**: Not detected.

The Saponin content of the samples ranged from 0.01-0.82 mg/g. Sample BDB1 (100:30:50) had the highest value 0.9 (mg/g and saponin was not detected in the sample BDB5. It was also observed that sample BDC3 and BDB4 are not significantly different (*P = .05*) from each other. The samples BDC1, BDC4 and BDB3 are not significantly different (*P = .05*) from each other. Also, samples BDC5, BDC6, BDC7, BDB2, BDB5 are not significantly different (*P = .05*) from each other while samples BDB1 and BDB5 differed significantly (*P = .05*) from the other samples. Saponin has a bitter taste and has reduced palatability as well as cause depression in feed intake. It is however, noted that most of these toxicants are eliminated during processing/boiling.

The Phytate content ranged from 0.01-1.90 mg/g. The sample BDB5 had the highest value of 0.90 mg/g while sample BDC5 and BDB6 had the lowest value 0.03 mg/g. The results showed that sample BDC3, BDC4, BDC5, BDB1, BDB2, BDB3and BDB6 are not significantly different (*P = .05*) from each other while samples BDC1, BDC2, BDC6, BDB4, BDB5andBDB7 are significantly different (*P = .05*) from the other samples. This value falls within the range gotten from the studies conducted by Abdulrashid and Agwunobi (2012). High content of phytate in foods is of nutritional significance because phytate binds phosphorus and makes it unavailable to human but its presence lowers the availability of many other dietary minerals such as iron and zinc (Siddhuraju and Becker, 2001). The level of phytate in cocoyam in this work appeared less than most of the plant leaves and therefore might be safer. Kaala (2010) indicated that phytate causes more calcium binding than oxalate (Kaala, 2010). Phytates are the leading cause of anaemia and impaired immune system function (Kaala, 2010). The regression analysis showed that the boiling temperature had a negative effect on the linear factors and the boiling time and drying temperature had a positive effect on the linear factors. The interactive effect of boiling temperature and boiling time and boiling time, and drying temperature had a positive correlation on the phytate content while the boiling temperature and drying temperature had a negative correlation on the phytate content. The quadratic factors had a positive effect on the phytate content.
The alkaloid content ranged from 0.11-0.73 mg/g. The result showed that sample BDB1 had the highest value 0.73 mg/g while sample BDB7 was the lowest value of 0.11 mg/g. It was also observed that the sample BDC2, BDC4, BDC5 and BDC6 are not significantly different (*P<0.05)* from each other while samples BDC3, BDC5 andBDB6 are not also significantly different from each other. The regression analysis showed that the boiling temperature and the drying temperature had a positive effect on the alkaloids content while linear the boiling time had a negative effect on the alkaloid content. The interaction of the boiling temperature and boiling time as well as boiling temperature and drying temperature had negative interactive effect while the boiling time versus drying temperature had a positive interactive effect on the alkaloid contents. The quadratic factors had negative effect on the alkaloids contents.

The flavonoid content of the samples ranged from 0.01 mg/g to 0.04 mg/g. The result showed that samples BDC1 and BDC3 had the highest value 0.04 mg/g while the least value was 0.01 mg/g. Flavonoids were not detected in samples BDB1, BDB2, BDB3, BDB4 and BDB5 that could be attributed to the level of instrumentation used for analysis as processing conditions reduced the level of flavonoids in the cocoyam varieties and due to the low level of flavonoids in Cross-river cocoyam, they were highly reduced during processing. According to Tagodoe and Nip (1994), heat processing has effect of decreasing the functional properties of taro. Flavonoids are group of phenolic compounds which influence the radical scavenging, inhibition of hydrolytic and oxidative enzymes and also act as anti-inflammatory agent (Frankel, 1994). The biological properties of flavonoid, apart from its antioxidant properties include protection against aggregation, microbes, ulcers, hepatoxins, viruses and tumors (Barakat *et al*., 1993). The regression analysis showed that the boiling temperature and drying temperature had a negative effect on the flavonoids content while the boiling time had a positive effect on the flavonoids contents of cocoyam. The interactive effects of boiling temperature and boiling time and; boiling time versus drying temperature had negative correlation on the flavonoid content of the cocoyam samples while the interactive effect of the boiling temperature and drying temperature had a positive correlation. The quadratic factors had positive effects on the flavonoid contents(*P = .05*).

The tannin content was negligible and was only found in some of the samples as 0.01 mg/g. Tannins have been reported to have anti-helminthic properties and anti-carcinogenic effects (Ocheja *et al., 2013*). However, reports had revealed that higher intake of tannic acid has been associated with poor protein utilization, liver and kidney toxicity. The levels of tannins in cocoyam in this work appeared relatively low when compared to its high levels in some common vegetables being consumed as delicacies. Boiling, cooking and washing reduce the tannin content of vegetable since tannin is soluble in water. The results of the regression analysis showed that the linear variables positively influenced the tannin content of the samples. The interactive effect on the boiling temperature and boiling time as well as boiling time and drying temperature had a positive correlation of the tannin content of the cocoyam samples while the interactive effect of the boiling temperature versus drying temperature had a negative correlation on the tannin content of the samples. The quadratic factors had positive effect on the tannin content of the samples.

3.3 Functional Properties of Taro Species

The results of the functional properties of cocoyam samples are as shown in Table 4. The results showed that water absorption capacity, bulk density, swelling index, oil absorption capacity and porosity ranged from 1.56-0.82%, 0.58- 2.98%, 1.60-3.35%, 1.30-1.67% and 0.30-0.76%, respectively. There was significant differences ($P = .05$) in the functional properties of the samples as evaluated which were the different processing treatments given to the samples. Also, the water absorption capacityof Cross-river cocoyam were lower compared to Bendel cocoyam which received similar treatments. It was evident from the results obtained that increases in the processing variables led to increase in the water absorption capacities of the cocoyam samples. The bulk density of the samples differed significantly ($P = .05$) among the samples.

TABLE 4: Functional properties

Runs BT_p:BT:DT	Water absorption capacity (mg/g)	Bulk density (mg/g)	Swelling index (mg/g)	Oil absorption capacity (mg/g)	Porosity (mg/g)
100:30:50	$2.91^{c} \pm 0.01$	$0.79^{bc} \pm 0.01$	$1.90^{h} \pm 0.01$	$1.33^{j} \pm 0.01$	$0.76^{a} \pm 0.01$
100:30:80	$1.89^{k} \pm 0.00$	$0.71^{g} \pm 0.00$	$2.30^{e} \pm 0.10$	$1.67^{a} \pm 0.01$	$0.64^{d} \pm 0.01$
100:50:50	$2.01^{h} \pm 0.00$	$0.73^{f} \pm 0.00$	$2.10^{f} \pm 0.00$	$1.58^{b} \pm 0.01$	$0.60^{e} \pm 0.01$
100:50:80	$1.68^{m} \pm 0.01$	$0.72^{g} \pm 0.00$	$1.78^{i} \pm 0.00$	$1.54^{c} \pm 0.01$	$0.57^{f} \pm 0.01$
70:50:80	$1.98^{i} \pm 0.01$	$0.73^{f} \pm 0.00$	$3.35^{a} \pm 0.00$	$1.51^{d} \pm 0.01$	$0.54^{g} \pm 0.01$
70:50:50	$2.77^{d} \pm 0.01$	$0.77^{d} \pm 0.01$	$2.91^{b} \pm 0.00$	$1.47^{e} \pm 0.01$	$0.75^{a} \pm 0.01$
70:30:80	$1.56^{n} \pm 0.01$	$0.67^{j} \pm 0.01$	$1.86^{h} \pm 0.01$	$1.44^{f} \pm 0.01$	$0.72^{b} \pm 0.01$
100:30:50	$2.19^{g} \pm 0.01$	$0.69^{h} \pm 0.01$	$1.97^{g} \pm 0.01$	$1.40^{g} \pm 0.01$	$0.68^{c} \pm 0.01$
100:30:80	$2.45^{f} \pm 0.02$	$0.58^{k} \pm 0.02$	$2.37^{d} \pm 0.01$	$1.35^{i} \pm 0.01$	$0.56^{f} \pm 0.01$
100:50:50	$3.01^{a} \pm 0.01$	$0.78^{bcd} \pm 0.00$	$1.66^{j} \pm 0.00$	$1.32^{j} \pm 0.01$	$0.44^{h} \pm 0.01$
100:50:80	$2.98^{b} \pm 0.01$	$0.75^{e} \pm 0.00$	$1.54^{l} \pm 0.00$	$1.30^{k} \pm 0.01$	$0.35^{j} \pm 0.01$
70:50:80	$2.66^{e} \pm 0.01$	$0.77^{cd} \pm 0.00$	$1.60^{l} \pm 0.01$	$1.50^{d} \pm 0.01$	$0.33^{k} \pm 0.01$
70:50:50	$1.78^{l} \pm 0.01$	$0.82^{a} \pm 0.01$	$1.78^{i} \pm 0.01$	$1.48^{e} \pm 0.01$	$0.30^{l} \pm 0.01$
70:30:80	$1.93^{j} \pm 0.01$	$0.74^{b} \pm -0.06$	$2.53^{c} \pm 0.00$	$1.38^{h} \pm 0.01$	$0.37^{i} \pm 0.01$

Results with different superscript along the same column are significantly different Results are Mean±SD of triplicate determinations

It was observed that all the samples are significantly (*P<0.05*) different from each other. Increased drying increased the absorption capacity of flour (Hayata *et al*., 2006). Niba *et al*. (2001) also stated that water absorption capacity is important in bulking and consistency of products as well as baking applications. The water absorption capacity is important in the development of ready to eat foods and high absorption capacity may assure product cohesiveness (Houson and Ayenor, 2002).

The bulk ranged from 0.58 mg/g-0.82 mg/g. The result from this study showed that sample BDB6 had the highest value 0.82 mg/g while sample BDB2had the lowest value 0.58 mg/g. BDC1 and BDB5 are not significantly different (*P<0.05*) from each other. Sample BDC1 and BDB3 are not significantly different from each other. Sample BDB3and BDC5 are not significantly (*P<0.05*) different from each other. Bulk density is an important factor for packaging considerations.
The swelling index analysis ranged from 1.54 to3.3 mg/g. The sample BDC5 had the highest content of the swelling index value 3.35% while sample BDB4 had the least value of 1.54%. It was observed that sample BDC1 and BDC7 are not significantly (*P>0.05*) different from each other. According to Oyinaka *et al*. (2009) cocoyam samples shows good swelling power when compared to other root crops as a result of the type of granules cocoyam starch has and it is highly digestible in nature. The results of the regression analysis showed that negative effect on the boiling temperature and boiling time had negative effects on the swelling index of the cocoyam samples while drying temperature had a positive effect (*P<0.05*)on the swelling index. The interactive effect of the boiling temperature and drying temperature as well as boiling time and drying temperature had a negative correlation while the interactive effect of the boiling temperature and boiling time had positive correlation. The quadratic factors had positive effects on the cocoyam samples. The results of the regression analysis showed that negative effect on the boiling temperature and boiling time had negative effects on the swelling index of the cocoyam samples while drying temperature had a positive effect (*P<0.05*)on the swelling index. The interactive effect of the boiling temperature and drying temperature as well as boiling time and drying temperature had a negative correlation.

The oil absorption capacity of the cocoyam samples ranges from 1.33-1.67 mg/g. The results showed that sample BDC2 had the highest value 1.67 mg/g while sample BDC1 had the least value 1.33 mg/g. The samples BDC5 and BDB5 are not significantly different (*P = .05*) from each other and sample BDC1and BDB3 are not significantly (*P<0.05*) different from each other. There were significant differences (*P = .05*) in samples BDC2, BDC3, BDC4, BDC7, BDBI, BDB2**,** BDB4 andBDB7. Oil absorption capacity reflects the emulsifying capacity and the amount of oil that can be picked up by a sample. The major chemical component affecting oil absorption capacity is protein, which is composed of both hydrophilic and hydrophobic parts. Oil gives soft texture and good flavour to food. Therefore, the interactive effect of the boiling temperature and drying temperature and; boiling time and drying temperature had negative correlation effect (*P = .05*) while the interactive effect of the boiling temperature and boiling time had a positive correlation on the oil absorption capacity of the samples. The quadratic factors had positive effect on the oil absorption capacity cocoyam samples.
The porosity of the samples ranged from 0.30-0.76 mg/g. The result showed that sample BDC1 had the highest of value 0.76 mg/g while sample BDB5 had the least value of 0.30 mg/g. From this research, sample BDC1 and BDC6 were not significantly (*P<0.05*) different from each other and Sample BDC4 and BDB2 are not significantly different from each other (*P = .05*). Sample BDC2, BDC3, BDC5, BDC7, BDB1, BDB3, BDB4, BDB5 and BDB7 are significantly different from the other samples (*P<0.05*). Porosity is the reverse of bulk density. The regression analysis on the boiling temperature and drying temperature on the samples had a positive effect on the linear factors while the boiling time has a negative effect on the on the linear factors. The interactive effect had negative correlation on the cocoyam samples. Also, the quadratic factors had a positive effect on the cocoyam samples.

3.4 Thermal Diffusivity

The result of thermal diffusivity in Table 5 of the cocoyam samples ranged from 0.20 m^2/s to 0.99 m^2/s. The result showed that sample BDB1 had the highest value while sample BDC2 had the lowest value. Sample BDC1, BDC2, BDC3, BDC4, BDC5 and BDC6 are not significantly (*P<0.05*) different from each other while the samples BDC7, BDB1, BDB2, BDB3, BDB4 and BDB7 are not significantly different (*P = .05*) from each other. The sample BDB6 is significantly (*P<0.05*) different from other samples of taro. The ease to which heat is transferred in food is important in the design of food storage, drying and refrigeration equipment and the calculation of process times in this equipment through the use of mathematical models that integrates chemical composition and temperature of the process.

3.5 Pasting Properties of Cocoyam Samples

It was observed in Table 6 that taro grown in Cross-river had more pasting temperatures compared to the variety grown in Bendel locality. The significance (*P<0.05*) difference in the pasting temperatures could be attributed to changes in the variety, growing conditions as well as the changes in the processing conditions. The same trend was observed in all the pasting properties considered.

Peak viscosity of cocoyam cultivars varied significantly (*P<0.05*) from 15.81to 10.88N/$m^{2.}$ The result showed that sample BDC1 had the highest value while the sample BDB7 had the least value. Peak viscosity, which shows the maximum swelling of the starch granule prior to disintegration, had also been described as the equilibrium point between swelling and breakdown of the granules (Liu *et al*., 2006). Hoover (2001) stated that granules with high peak viscosity have weaker cohesive forces within the granules than those with lower values and would disintegrate more easily. Falade and Okafor (2013) showed that the peak viscosity and other physicochemical parameters, including amylose, amylopectin and granule sizes of the starches of the cocoyam cultivars varied significantly (*P = .05*). The pasting properties are greatly influenced by plant source, starch content, interaction among the components, and testing conditions (Liu *et al*., 2006). Breakdown viscosity measures the resistance to heat and shear.

TABLE 5: Thermal property of cocoyam samples

Runs BT_p:BT:DT	Thermal diffusivity (m^2s^{-1})
100:30:50	$0.99^{a} \pm 0.01$
100:30:80	$0.98^{a} \pm 0.01$
100:50:50	$0.96^{a} \pm 0.01$
100:50:80	$0.95^{a} \pm 0.01$
70:50:80	$0.94^{a} \pm 0.01$
70:50:50	$0.90^{a} \pm 0.01$
70:30:80	$0.80^{ab} \pm 0.01$
100:30:50	$0.70^{abc} \pm 0.01$
100:30:80	$0.60^{bcd} \pm 0.01$
100:50:50	$0.50^{cde} \pm 0.01$
100:50:80	$0.40^{def} \pm 0.01$
70:50:80	$0.30^{ef} \pm 0.01$
70:50:50	$0.20^{f} \pm 0.01$
70:30:80	$0.43^{cdef} \pm 0.57$

Results are Mean± SD of triplicate determinations. Results with different superscript along the same column are significantly different (P<0.05). BTp = Boiling Temperature (0C); BT: Boiling Time (mins); DT: Dehydration Temperature (0C)

TABLE 6: Pasting properties of cocoyam

Runs	Pasting temp. (°C)	Peak viscosity (N/m²)	Peak time (mins)	Viscosity (N/m²)	Final viscosity (N/m²)	breakdown (N/m²)	Setback from peak (N/m²)	Setback after holding (N/m²)
BDC1	95[a]±0.00	15.81[a]±0.01	20.87[a]±0.01	9.97[a]±0.01	17.90[a]±0.00	7.5[a]±0.00	3.80[a]±0.00	9.5[a]±0.00
BDC2	90[b]±0.00	14.91[b]±0.01	19.89[b]±0.01	9.13[b]±0.01	17.80[b]±0.00	7.4[b]±0.00	3.70[b]±0.00	9.4[b]±0.00
BDC3	85[c]±0.00	13.81[c]±0.01	18.77[c]±0.01	9.08[c]±0.01	17.77[c]±0.00	7.3[c]±0.00	3.60[c]±0.00	9.3[c]±0.00
BDC4	80[d]±0.00	12.91[d]±0.01	17.45[d]±0.01	9.07[cd]±0.01	16.65[d]±0.00	7.2[d]±0.00	3.50[d]±0.00	9.2[d]±0.00
BDC5	75[e]±0.00	11.77[e]±0.01	16.57[e]±0.01	9.05[cde]±0.00	17.45[e]±0.00	7.1[e]±0.00	3.40[e]±0.00	9.0[e]±0.00
BDC6	70[f]±0.00	10.71[f]±0.01	15.34[f]±0.01	9.04[de]±0.00	17.40[f]±0.00	7.0[f]±0.00	3.30[f]±0.00	8.8[f]±0.00
BDC7	65[g]±0.00	9.33[g]±0.01	14.27[g]±0.01	9.03[e]±0.00	17.30[g]±0.00	6.9[g]±0.00	3.20[g]±0.00	8.7[g]±0.00
BDB1	60[h]±0.00	12.88[h]±0.01	13.22[h]±0.01	9.02[e]±0.00	17.10[h]±0.00	6.8[h]±0.00	3.10[h]±0.00	8.6[h]±0.00
BDB2	55[i]±0.00	13.71[i]±0.01	12.34[i]±0.01	8.05[f]±0.00	17.00[i]±0.00	6.7i±0.00	3.00[i]±0.00	8.5[i]±0.00
BDB3	50[j]±0.00	12.31[j]±0.01	11.23[j]±0.01	8.04[fg]±0.00	16.90[j]±0.00	6.6[j]±0.00	2.70[j]±0.00	8.4[j]±0.00
BDB4	45[k]±0.00	11.70[k]±0.01	10.67[k]±0.01	8.03[fg]±0.00	16.80[k]±0.00	6.5[k]±0.00	2.60[k]±0.00	8.3[k]±0.00
BDB5	40[l]±0.00	12.59[l]±0.01	9.57[l]±0.01	8.02[fg]±0.00	16.70[l]±0.00	6.4[l]±0.00	2.50[l]±0.00	8.2[l]±0.00
BDB6	35[m]±0.00	11.78[m]±0.01	8.67[m]±0.01	8.01[fg]±0.00	16.50[m]±0.00	6.3[m]±0.00	2.40[m]±0.00	8.1[m]±0.00
BDB7	30[n]±0.00	10.88[n]±0.01	7.87[n]±0.01	8.00[g]±0.00	15.10[n]±0.00	6.0[n]±0.00	2.30[n]±0.00	7.0[n]±0.00

Results are Mean ±SD of triplicate determinations. Results with different superscript along the column are significantly different (P<0.05). BTp = Boiling Temperature (0C); BT: Boiling Time (mins); DT: Dehydration Temperature.

Therefore, lower breakdown viscosity showed greater resistance which would be expected of flours with lower peak viscosities (Liu *et al*., 2006).

Setback defines the difference between the breakdown viscosity and the viscosity at 50°C, determines the tendency of starch to retrogradation. The setback values differed significantly ($P<0.05$) from 2.3 N/m^2 to 3.8 N/m^2. The higher the setback value, the lower the retrogradation during cooling and the lower the staling rate of the products made from the flour.

Final viscosity of the flours ranged from 15.10-17.90 N/m^2. This increase in the final viscosity could be due to the alignment of the chains of amylose in the starch (Flores-Farias *et al*., 2000).

Pasting temperatures of the flours ranged from 30-95^{o}C. Pasting temperature depends on the size of the starch granules in the flour; small starch granules are more resistant to rupture and loss of molecular order (Zeng *et al.,* 2013). Therefore, sample BDC1 with higher pasting temperature was found to have smaller granular size.

The ability of starch to imbibe water and swell is primarily dependent on the pasting temperature. Pasting properties indicate the tendency to form paste, the higher the pasting temperature, the faster the tendency for paste to be formed. Starch granules swell and form paste by imbibing water in the presence of water and heat (Rincon and Padilla, 2004).

Peak time of the of cocoyam flour samples ranged from 7.87-20.87 mins. This is to be expected as high peak times characterize low swelling starch granules in the flour. After peak paste viscosity, the samples showed differences in their patterns of pasting properties which can be grouped to predict the cooking and other food utilization properties of the cultivars (Falade and Okafor, 2013). However, pasting behaviours that result from interactions between starch and non-starch components (e.g. as in sorghum) or high-amylose starches may not change by increasing starch concentrations (Waramboi *et al*., 2011). Also, surface lipids and proteins, rehydration time, method of sample preparation (e.g. milling and particle size), presence of impurities, pH, type of cultivar, and presence of endogenous enzymes can affect starch swelling, pasting and gelatinization properties (Chen *et al*. 2003; Mahasukhonthachat *et al.,* 2010).

3.6 Moisture-Sorption Characteristics of Taro Species

The result of moisture-sorption characteristics of cocoyam in Fig. 2 and Fig. 3 showed the adsorption and desorption isotherms of taro flour at 18, 25 and 35^{o}C respectively. The data points for each adsorption and desorption curve were generated by the ease with which water is imbibed after rehydration during the measurement of sorption isotherms. The moisture contents of taro flour (% dry basis) measured before the isotherm testing were 7.82 ± 0.10, 6.01± 0.12 and 5.63±0.03% for 18, 25 and 35^{o}C, respectively. The moisture-sorption isotherms had sigmoid-shape profiles for all of the three temperatures which were similar with yam flour (Oyelade *et al., 2008*). The hysteresis effect at the three temperatures was distinctly expressed. The increasing temperatures resulted in less hysteresis effect on taro flour which meant the adsorption and desorption curves were closer. The behavior reflects that of a non- Newtonian behavior, there is therefore the tendency for the different flour samples to rehydrate at varying temperatures and thus exhibited different moisture-sorption characteristics.

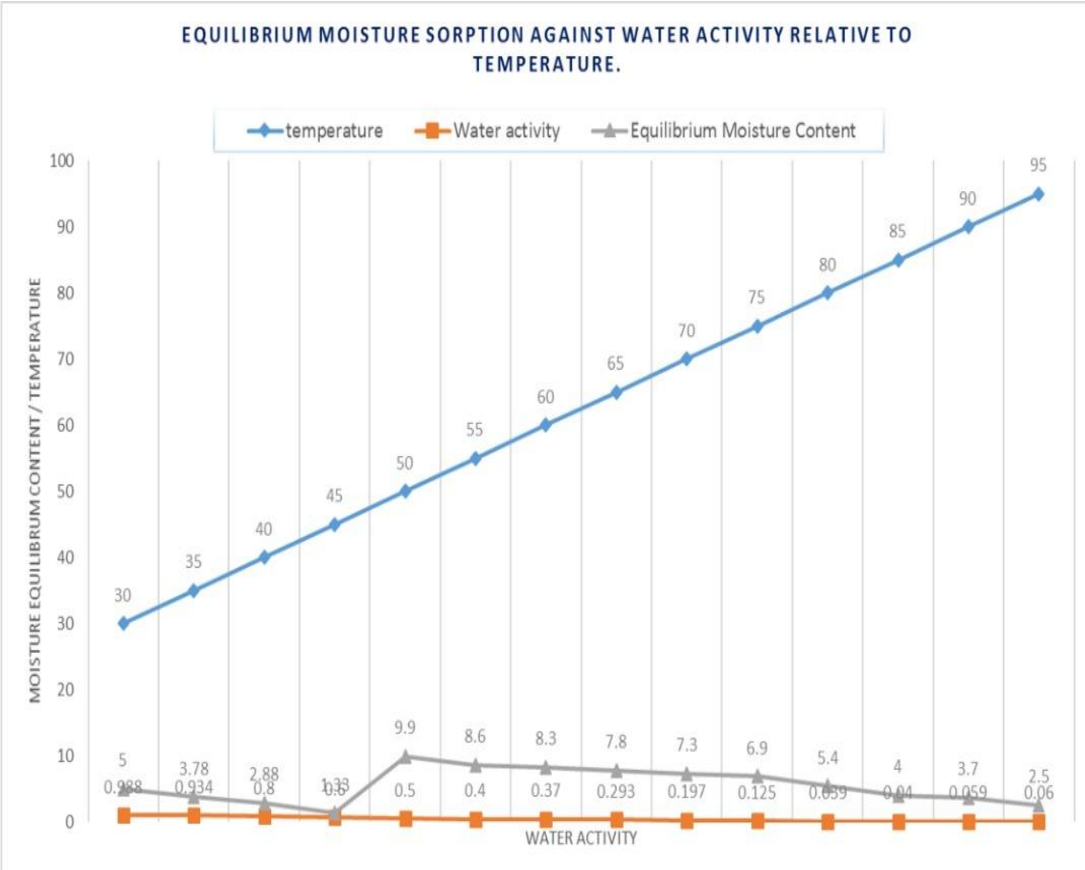

Figure 2: Equilibrium moisture-sorption content at different temperatures.

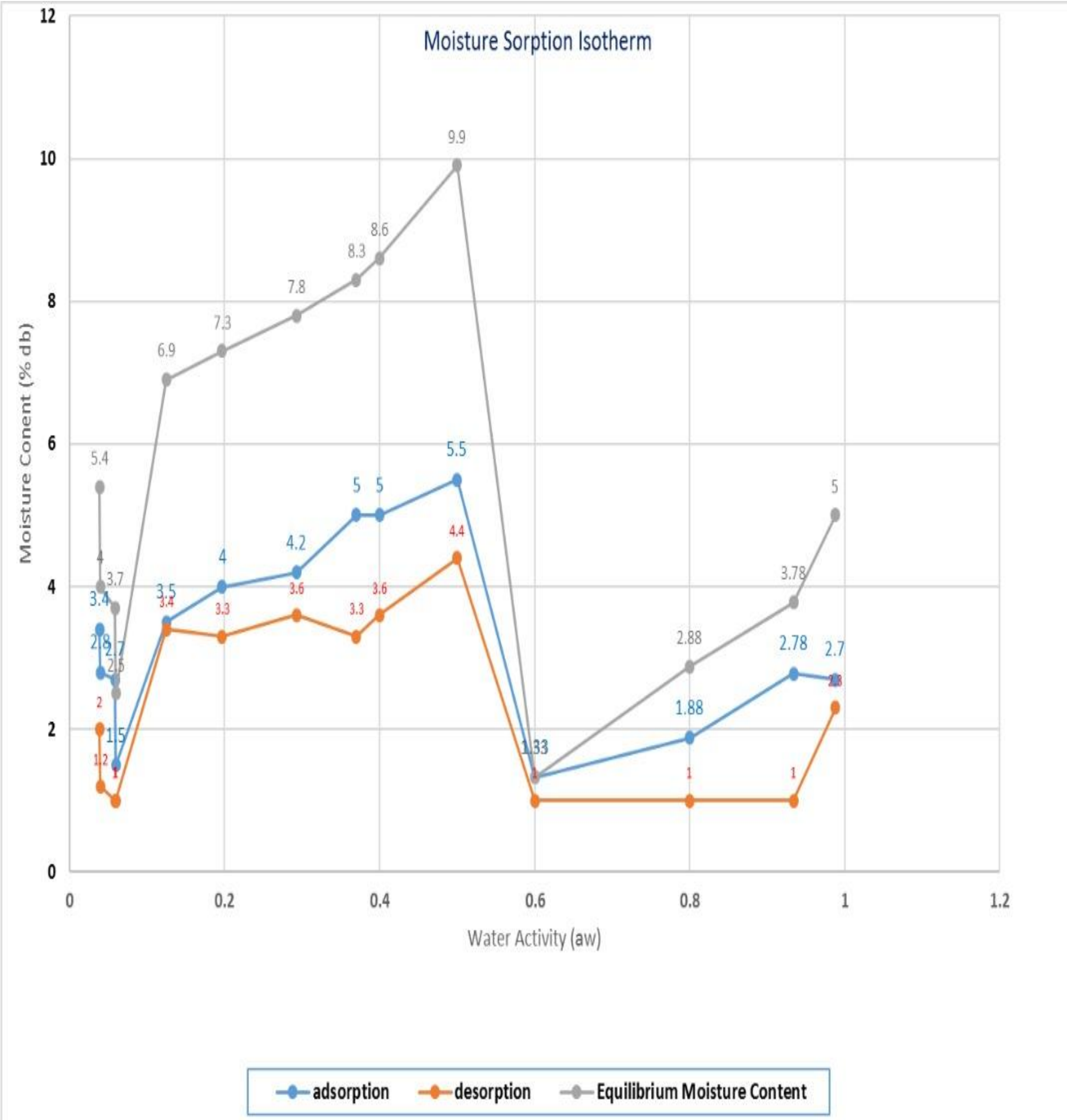

Figure 3: Moisture-sorption isotherm characteristics of cocoyam flour.

4. CONCLUSION

This study has shown the comparison of proximate, antinutrients, functional, pasting, thermal diffusivity and moisture sorption characteristics of taro varieties bought in Eke Awka market, Anambra state which was produced in Bende state (Bendel variety) and one bought in Ogbete market, Enugu State (Cross-River cocoyam). All the samples indicated low levels of crude fiber which ranged from 0.43-0.77% and low crude fat that ranged from o.42-0.92%. Bendel cocoyam has the highest crude protein, ash content and moisture content while cross river cocoyam had the highest carbohydrate. The anti-nutrients found in the taro species were relatively low. The results obtained showed that the two varieties had different thickening capabilities at different temperatures. The cross-river cocoyams were found to have higher pasting temperatures and time compared to Bendel cocoyam variety. Furthermore, the Bendel cocoyam (taro) with the 100:50:50 (BDB3) processing treatment had the best acceptable properties due to the fact that food processors expects a thickner that would absorb more water and had low oil absorption capacity. The sample was also moderately dense; can swell moderately and had no observable tannin and flavonoids. It can be concluded that the processing techniques used in the production of cocoyam flour had a significant (*P<0.05*) effect on the proximate characteristics as well as the anti-nutritional factors particularly, oxalate content. We can conclude that Bendel cocoyam had the most soup thickening effect than Cross River cocoyam.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

REFERENCES

Abdulrashid M, Agwunobi LN.Tannia (Xanthosoma sagittifolium) cocoyam as a dietary substitute for maize in broiler chicken*.* Greener J Agric Sci. 2012(2):167-171. DOI: 10.15580/GJAS.2012.5.08181244.

Achilonu **M, Shale K, Arthur, G, Naidoo K, Mbatha M. Phytochemical Benefits of Agroresidues as Alternative Nutritive Dietary Resource for Pig and Poultry Farming. J of Chem.2018 (2018): 15. https://doi.org/10.1155/2018/1035071.**

Grosvenor MB , Smolin LA. Nutrition: from science to life. New York: Harcourt college pub.2002 (12): 288-371. https://www.worldcat.org/title/nutrition-from-science-to-life/oclc/48550192.

AkpanEJ,Umoh IB. Effect of heat and tetracycline treatments on the food quality and acridity factors in cocoyam (Xanthosoma sagittifolium .L.). Pak J of Nutrition 2004 (3):240-243. DOI: 10.3923/pjn.2004.240.243.

Awkaowo EU, NdonBA,Etuk EU. Mineral and antinutrients in flutted pumpkin (Telfaria occidentalis Hook f.). J of food Chem.2000 (70): 235-740. Https://doi.org/10.1016/S0308-8146(99)00207-1.

Amandikwa C. Proximate and functional properties of open air, solar and oven dried Cocoyam flour. International J of Agric and Rural Dev. 2012:15(2): 988-994. Https://www.presentica.com/doc/10923031/proximate-and-functional-properties-of-open-air-solar-and-oven.

AOAC. Official Methods of food analysis. Association of Official Analytical Chemists (18th Edition), Washington DC, USA; 2005.

AOAC. Official Methods of Food Analysis. Association of Official Analytical Chemists.18th Edition.Washington DC, U. S. A; 2010

Awolu OO. Optimization of the functional characteristics, pasting and rheological properties of pearl millet-based composite flour. Heliyon 2017(3): e00240. https://doi.org/10.1016/j.heliyon.2017.e00240.

Barakat MZ, Shahab SK, Darwin N,Zahemy EI. Determination of ascorbic acid from plants. Annals of Biochem.1993(53):225-245.

BellLN, Labuza TP. Moisture sorption practical: Aspects of Isotherm Measurement and use, 2nd Edn. American Asso.of Cereal Chem.2000(56):49-52. https://www.amazon.com/Moisture-Sorption-Practical-Isotherm-Measurement/dp/1891127187.

Bohm BA, Koupai-Abayzani R. Flavonoids and condensed Tannins from leaves of Hawaiian Vaccinium Reticulatum and V. Calycinum (Ericaceae). Pacific Sci.1994:48(4): 458-463. https://scholarspace.manoa.hawaii.edu/bitstream/10125/2298/v48n4-458-463.pdf.

Boloso I, Adane T, Shimelis A, Negussie R,Haki G. Effect of processing method on the proximate content and anti-nutritional factors of taro (Colocasia esculenta L.) Schott grown in Ethiopia. African J of Food, Agric, Nutri and Dev.2013(13):7383-7398. https://www.ajol.info/index.php/ajfand/article/download/87463/77154.

Buntha P, Borin K, Preston T, Ogle B. Survey of taro varieties and their use in selected areas of Cambodia. Livestock Res for Rural Dev. 2008(20):2314-2320. http://www.lrrd.org/lrrd20/supplement/bunt1.htm.

Aqua Sorp Isotherm Generator. Moisture Sorption Isotherm Generator: Operators Manual, Version 3.0. Pullman, Washington, USA: 2007(77):8-84. http://publications.metergroup.com/Manuals/13480_AquaSorp_Web.pdf.

Eddy NO, Essien E, EbensoEE,Ukpe RA. Industrial potential of two varieties of cocoyam in bread making. J of Chem.2003(9):451-461. https://doi.org/10.1155/2012/635894.

Ejoh SI, Obatolu VA, Olanipekun OT,Farinde EO. Extending the use of an underutilised tuber I: Physicochemical and pasting properties of cocoyam (Xanthosoma sagittifolium) flour and its suitability for making biscuits. Africa J of Food Sci.2013(7):264-273. DOI: 10.5897/AJFS12.111.

Food and Agricultural Organization Database Results.www.fao.org.; 2006.

Fennama O. Principles of food science. Marcel Dekkel marcel, Inc; New York. https://doi.org/10.1002/ange.19760882121, 1976.

Frankel EN. Nutritional Benefits of Flavonoids. In: Ohigashi, H., Osawa, T., Terao, J., Watanabe, S., Yoshikawa, T. (eds) Food Factors for Cancer Prevention. Springer, Tokyo. 1997. https://doi.org/10.1007/978-4-431-67017-9_121.
Hayta M, Alpasian M, Baysar AD. Effect of drying on functional properties of Tarhana: A **wheat flour-yogurt mixture**. J of Food Sci.2002(67):740-744. DOI: 10.1111/j.1365-2621.2002.tb10669.x.

Houson P, Ayenor GS. Appropriate processing and food functional properties of maize flour. Africa J of Sci. and Technol.2002(3):121-126. https://agris.fao.org/agris-search/search.do?recordID=AJ2013000019.

Huang CC, Chen WC, Wang CCR. Comparison of Taiwan paddy and upland cultivated taro (Colocasiaesculenta L) cultivars for nutritive values. Food Chem 2007(102):250-256. https://doi.org/10.1016/j.foodchem.2006.04.044.

Humphrey GC. Evaluation of biological activity of alkaloids and flavanoids in Zanthoxylum gilletii (de wild waterman) extracts from different geographical regions in Kenya. A thesis submitted in partial fulfillment of the requirements for the award of the degree of masters of science (biotechnology) in the School of Pure and Applied Sciences, Kenyatta University, 2011. https://ir-library.ku.ac.ke/bitstream/handle/123456789/3401/Humphrey%20Gaya%20Cyprian%20.pdf;sequence=3.

Kaala TDE. Plants bite back: Natural anti-nutrients in plant foods. J of Nutri. 2010 (17):497-501.

Lola A. The effect of boiling on the nutrients and antinutrients in two non conventional vegetables. Pak. J of Nut.2009(8):1430-1433. DOI: 10.3923/pjn.2009.1430.1433.

Ndabikunze HL, Talwana RJ. Proximate and mineral composition of cocoyam (Colocasia esculenta L.) Schott grown along the lake Victoria Basin in Tanzania and Uganda. Afri.J of Food Sci.2011(5)4:248-254. http://erepo.usiu.ac.ke/bitstream/handle/11732/4515/Proximate%20and%20mineral%20composition%20of%20cocoyam.pdf?sequence=1&isAllowed=y.

Ndon BA, Ndulaka NH, Ndaeyo NU. Stabilization of yield parameters and some nutrient components in cocoyam cultivars in Uyo, southern Nigeria. Global J of Agric. Sci. 2003(2)2:74-78. https://www.ajol.info/index.php/gjass/article/download/2209/10984.

Niba LL, Bokanga M, Jackson FI,Schlimme DS, Li BW. Physiochemical properties and starch granular characteristics flour from various Manihot esculenta (Cassava) genotypes. J of Food Sci.2006(67)5:1701-1705. https://doi.org/10.1111/j.1365-2621.2002.tb08709.x.

Nkama I, Gbenyi DI. The effects of malting of millets and sorghum on the residue phytate and polyphenols in "dakura" a Nigerian cereal/legume snack food. Nigeria Tropical J of Agric. 2001(3):270-271.

Obadoni BO, Ochuko PO. Phytochemical studies and comparative efficacy of the crude extracts of some homoestatic plants in Edo and delta state of Nigeria. Global J of Pure and Applied Sci.2001(86):2003-2008. https://www.scienceopen.com/document?vid=bbcaec5f-28ca-4327-9801-920ec3e0a275.

Ocheja JO, Aduku AO, Ayoade JA,Lalab BC. Effects of steaming and soaking on chemical composition of cashew nutshell: implication for ruminant animal nutrition. Pak.J of Nut. 2013(12)7:683-687. DOI: 10.3923/pjn.2013.683.687.

Okoye BC, Okoye AC, Dimelu MU, Agbaeze CC, Okoroafor ON, AmaefulaAB.Adoption scale analysis of improved cocoyam production, production and storage technologies across gender in Enugu North agricultural zone of Enugu State Nigeria.MPRA Paper No. 17432; 2009. http://mpra.ub.uni-muenchen.de/17432/1/MPRA_paper_17432.

Onwuka GI.Food Analysis and Instrumentation: Theory and practice. Naphthali Prints, Lagos, Nigeria, 2005:133-137. https://books.google.com.ng/books/about/Food_Analysis_and_Instrumentation.html?id=jh_iuQEACAAJ&redir_esc=y

Onwuka GI. Food analysis and instrumentation, theory and practice 2nd Edn. Naphtali prints, Umuahia, Nigeria. 2018:179- 381. https://www.amazon.com/Food-Analysis-Theory-Practice-4Ed/dp/9386800667.

Safe-Dedeh, Kofi-Agyir. Chemical composition and the effect of processing on the oxalate content of cocoyam Xanthosoma sagittifolium and Colocasia esculenta cormels. Food Chem. 2014(85)4:479-487. https://doi.org/10.1016/S0308-8146(02)00244-3.

Shewry PR. Tuber storage proteins. Ann Bot. 2003; 91(7): 755–769. doi: 10.1093/aob/mcg084.

Shi J, Arunasalam K, Yeung D, Kakuda Y, Mittal G, Jiang Y. Saponins from edible legumes chemistry, processing and health benefit. J Med Food, 2004;7(1):67-78. doi: 10.1089/109662004322984734.

Siddhuraju P, Becker K. Effect of various domestic processing methods on antinutrients, in vitro-protein and starch digestibility of two varieties of Indian pulses, mucuna pruries varieties Var. Utilis. J of Agric. and Food Chem. 2001(49):3058-3067. doi: 10.1021/jf001453q.

Sidhu JO, Oakenful DG. A Mechanism for the hypocholesterolemic activity of saponin. Br J. of Nutri.1996 (7): 643-647. DOI: 10.1079/bjn19860070.

Tekle A. The effect of blend proportion and baking condition on the quality of cookies made from Taro and wheat flour blend. A thesis submitted to the School of Graduate studies of Addis Ababa University in partial fulfillment of the requirement for the Degree of Master of Science in Food Science and Nutrition 2009(23): 389-393. http://213.55.95.56/bitstream/handle/123456789/8452/Abinet%20Tekle.pdf?sequence=1&isAllowed=y