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Effect of processing on the nutritional contents of yam and cocoyam tubers

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ABSTRACT
Objective: To evaluate the effect of processing on the nutrient content of yam and cocoyam (*Colocasia esculentum)* tubers.
Methodology and results: Two species of water yam (*Dioscorea alata*) and white yam (*Dioscorea rotundata*) were subjected to various processing methods, i.e. boiling, sun-drying and roasting. The proximate, chemical and pasting properties of the processed yams were determined. The results showed that the moisture content (flour) ranged from 5.01 to 15.71%; ash content from 1.88 to 5.50%; fat content d from 0.24 to 0.75%; protein content from 0.03 to 5.02%; amylose from 23.35 to 33.28%; sugar content 2.13 to 7. 59% and starch content from 62.94 to 93.67%. The Tannin content ranged from 0 to 1.10%, swelling power from 5.63 to 9.95%; soluble content from 4.10 to 11.30% and trough set point from 18.75 to 189.71°C. The break down set point ranged from 4.63°C to 97.46°C ; final viscosity from 47.79 to 366.38 RVU; set back from 24.33 to 213.96 RVU; peak time from 4.6 to 7 min and the pasting temperature from 61.84 to 62.40°C. There exists significant difference ($P < 0.005$) among the samples analyzed.
Conclusion: Apart from establishing the nutritional contents of these commonly consumed yams that are semi-perishable, the effects of the common traditional methods of processing on the nutrient contents are established. It was found that fresh- oven-dried and fresh -sun dried were better processing methods.
Key words: Yam, Cocoyam, processing, proximate analysis, boiling, roasting.

INTRODUCTION

Yam belongs to the genus Dioscorea. It is a major staple food for an estimated 60 million people in the region stretching from Ivory Coast to Cameroon, an area commonly referred to as “Yam Zone” of West Africa (Akissoe, et al., 2003; Jimoh, 2009,). Nigeria alone produces well over half of the world’s yams (Onwueme,1978; Coursey,1976). Yams are high in starch and also contain the enzyme alpha amylase which converts starch to sugars as the tuber matures in storage (Ravindran and Wanasundera, 1992). Yams are commonly consumed with sauces after boiling, roasting, or frying. It is mashed or pounded into dough after boiling (Ferede et al., 2010; Omonigho and Ikenebomeh, 2000). There are indications that yam has great prospect of contributing to closing the projected food deficit in Africa in the 21st century, if efforts are made to identify and overcome the constraints to its production (FAOSTAT, 2005).
Cocoyam (genus *Colocasia)* is another tuber crop used mainly for human food in Nigeria. It is commonly grown amongst small scale farmers

who operate within the subsistence economy. In the past, it is regarded as a lowly important crop which cultivation and consumption lay within the less privileged farmers. Cocoyam, like yam suffers from extensive post harvest losses since it is also stored mostly as fresh corms. Unfortunately, cocoyam corms do not store well, thus most of the produce is consumed within a couple of months after harvest. Therefore, annual supply and price of cocoyam experience tremendous fluctuation (Onwueme, 1978) Yam belongs to the semi-perishable class of food due to its relatively high moisture content and vulnerability to gradual physiological deterioration after harvesting.

However, yams can be processed into less perishable products such as yam flour through a drying process (Jimoh and Olatidoye, 2009). Tubers of yam and cocoyam require air drying in the sun before they can be stored. It is hypothesized that the processing method could affect the nutritional contents of these crops. Hence, a study was carried out to assess the nutrient contents of yam and cocoyam tubers before and after processing.

MATERIALS AND METHODS

Tuber: Tubers of water yam *(D. alata*), white yam *(D. rotundata*), and cocoyam *(Colocasia esculentum*) were obtained from Kuto market in Abeokuta and new market at Ijebu-ode, both in Western part of Nigeria. The yam tubers were collected fresh and were used for the processing study.

Processing methods

Sun-drying: The yam tubers were peeled, washed in water, sliced and sun dried for 2 to 3 days.

Boiling method: The yam tubers were peeled, sliced, washed and boiled in water for 15 minutes at 60^{o}C.
After boiling, the boiled yam tuber samples were dried in an oven at 60^{o}C .

Roasting method: The yam tubers were washed and roasted using locally fabricated manual roaster. After roasting, it was peeled, sliced and oven dried at 60^{o}C.
All the dried samples were milled to 0.50mm sieve size with Perten Laboratory Hammer Mill 3102 for further laboratory analysis.

Moisture content determination: 5grammes of sample was weighed into a Petri-dish of known weight. The weighed sample was put into an oven pre-set at 110 ^{o}C for 3hrs. The sample was removed and cooled in a dessicator to room temperature and the weight was determined after which it was returned into the oven at 110^{o}C for 30 minutes until constant weight was obtained: AOAC (2004).

Ash content determination: 5grammes of sample was weighed into a previously ignited and cooled silica dish. The dish was ignited gently first and then at 600^{o}C for 3 hours in a muffle furnace. The dish and its content were cooled in a dessicator and reweighed, the .weight of the residue was recorded as ash content

Crude fat determination: Crude fat was determined by the method of AOAC (2004). This was determined using a Soxtec System HT2 fat extractor. Crude fat was extracted from the sample with hexane, and the solvent evaporated off to get the fat. The difference between the initial and final weight of the extraction cup was recorded as the crude fat content.

Crude protein determination: Crude protein was determined by Kjeldahl method using Kjeltec^{TM} model 2300, as described in Foss Analytical manual, AB, (2003). The method involved digestion of the sample at 420^{o}C for 1hr to liberate the organically bound nitrogen in the form of ammonium sulphate. The ammonia in the digest ammonium sulphate was then distilled off into a boric and receiver solution, and then titrated with standard hydrochloric acid. A conversion factor of 6.25 was used to convert from total nitrogen to percentage crude protein (AOAC, 2004).

Determination of pasting properties; Pasting properties were determined with a Rapid Visco Analyzer (RVA) (Newport Scientific RVA Super 3). An aliquot3grammes of sample was weighed in a vessel; 25ml of distilled water was dispensed into a new test canister. The sample was then transferred into the water surface in the canister. The paddle was placed into the canister and the blade vigorously jogged through the sample up and down ten times. The test proceeded and terminated automatically.

Determination of Tannin (Polyphenols): Tannin content was determined by the Folins-Dennis colorimetric method described by Joslyn (1970) with modifications. Five grams sample was dispersed in 50ml of distilled water and shaken. The mixture was allowed to stand for 30 min at 28^{o}C before it was filtered through Whatman No. 42 filter paper. 2 millitres of the extract was dispensed into a 50ml volumetric flask. 2 millitres standard tannin solution (tannin acid) and 2ml of distilled water were put in separate volumetric flasks to serve as standard and Folins reagent was added to each of the flasks and 2.5ml of saturated Na_2CO_3 solution added. The content of each flask was made up to 50ml with distilled water and incubated at 28°C for 90 min. Their respective absorbance was measured in a spectrophotometer at 260nm using the reagent blank to calibrate the instrument at zero.

Determination of Apparent Amylose content: The apparent amylose was determined by the method of Williams et al (1985). Starch (500.0mg) was defatted by standard AOAC (2004) method using hexane. The defatted starch (100.0mg) was dispersed in ethanol (1.0ml) and 1m NaCl (9.0ml). The volume was made up to 100.0ml with distilled water and a 5.0ml aliquot transferred to a volumetric flask containing water 25.0ml. 1M Acetic acid (0.5ml) and 1.0ml iodine solution (0.2% iodine in 2% potassium iodide) were added and the volume made up to 50.0ml with water and absorbance recorded at 620 nm.

Determination of starch and sugar contents: The starch and total sugars content were determined using a colorimetric method described earlier (Onitilo et al., 2007). This involved weighing 0.02g of the sample into a centrifuge tube with 1ml cold ethanol, 2ml distilled water, and 10ml hot ethanol. The mixture was vortexed and centrifuged at 2000rpm for 10 min. The supernatant was decanted and used for determining the sugar content while the sediment was hydrolyzed with perchloric acid and used to estimate starch content. Phenol- sulfuric reagent was used for colour development and glucose standards were used for estimation of sugar. The absorbance was read with a spectrophotometer (Milton Roy Spectronic 601, USA) at 490nm.

Statistical Analysis: The means of the data obtained were subjected to analysis of variance (ANOVA) using Statistical Analysis System software (SAS, version 8e) and separated using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSIONS

Moisture and dry matter content: The moisture contents for both fresh and dried tubers are shown in Table 1. The fresh moisture content ranged from 57.55 to 62.76% and was highest in water yam and least in cocoyam. The dry matter content ranged from 37.24 to 42.45%, being highest in cocoyam and lowest in white yam.

Proximate and chemical composition: The proximate and chemical compositions are shown in Table 2. The moisture content of the processed samples (flour) ranged from 5.01 to 15.71% and was highest in fresh sun-dried white yam and lowest in fresh oven-dried white yam. The ash content ranged from 1.88% in boiled oven-dried water yam to 5.50% in fresh sun-dried cocoyam . Fat content ranged from 0.24% in boiled oven-dried cocoyam to 0.75% in roasted cocoyam. Protein content ranged from 3.03% in fresh oven-dried water yam to 5.02% in fresh sun-dried cocoyam. Amylose content ranged from 23.35 to 33.28% being highest in boiled oven-dried water yam and lowest in fresh sun-dried cocoyam. The sugar content ranged from 2.13 to 7.59% in fresh sun-dried cocoyam and in roasted oven-dried water yam, respectively. . Starch content ranges from 62.94% in fresh sun-dried water yam to 93.67% in fresh oven-dried cocoyam.

Functional properties of yam tubers: The functional properties of yam tubers are shown in Table 3. Swelling power ranged from 5.63% in fresh oven-dried cocoyam to 9.98% in fresh sun-dried white yam. The soluble content ranged from 4.10 to 11.30% with highest value in boiled oven-dried water yam and the lowest in fresh sun-dried white yam. Water Absorption Capacity (dWAC) ranged from 88.87 to 372.18% in fresh cocoyam and in boiled oven dried cocoyam, respectively. .

Table 1: Moisture and Dry Matter content of fresh oven dried yam tubers.

Yam Varieties	Moisture Content	Dry Matter
White yam	59.83[b]	37.24[c]
Water yam	62.76[a]	40.17[b]
Cocoyam	57.55[c]	42.45[a]

Each value is a mean of two replicates; Means followed by the same alphabet within column are not significantly different at 5% confidence level; *** - Significant at P< = 0.001, ** - Significant at P< = 0.01

Table 2: Proximate and chemical properties of yam tubers.

Processing method	Yam variety	Moisture content %	Ash %	Fat %	Protein %	Amylose %	Sugar %	Starch %
Fresh Sun-dried	White yam	15.71^{a}	1.99^{gh}	0.73^{a}	3.35^{ef}	32.93^{ab}	2.97^{d}	72.40^{b}
	Water yam	15.15^{b}	2.68^{cd}	0.30^{h}	4.59^{b}	26.67^{f}	3.38^{cd}	62.94^{b}
	Cocoyam	13.49^{c}	5.50^{a}	0.66^{b}	5.02^{a}	23.35^{h}	2.13^{d}	65.33^{b}
Boiled Oven-dried	White yam	10.35^{e}	1.99^{gh}	0.58^{d}	3.91^{d}	33,15^{ab}	4.84^{bc}	71.71^{b}
	Water yam	10.46^{e}	1.88^{h}	0.50^{e}	3.41^{e}	33.28^{a}	5.30^{b}	73.74^{b}
	Cocoyam	11.66^{d}	3.30^{b}	0.24^{i}	4.56^{b}	23.54^{h}	3.47	68.37^{b}
Roasted oven-dried	White yam	7.89^{g}	2.76^{c}	0.59^{cd}	3.86^{d}	32.77^{b}	7.58^{a}	73.20^{b}
	Water yam	7.98^{g}	2.50^{de}	0.46^{f}	3.18^{fg}	29.80^{d}	7.59^{a}	68.90^{b}
	Cocoyam	9.60^{f}	2.31^{f}	0.75^{a}	4.24^{c}	27.14^{e}	3.50^{cd}	77.27^{b}
Fresh oven-dried	White yam	5.01^{i}	2.77^{c}	0.63^{bc}	4.76^{b}	26.73^{ef}	5.66^{b}	69.56^{b}
	Water yam	5.21^{i}	2.02^{gh}	0.39^{g}	3.03^{g}	31.58^{c}	5.72^{b}	74.37^{b}
	Cocoyam	6.26^{h}	2.18^{fg}	0.50^{e}	4.63^{b}	25.51^{g}	5.33^{b}	93.67^{a}
Pr.>F		***	***	***	***	***	***	***

Each value is a mean of two replicates; Means followed by the same alphabet within columns are not significantly different at 5% confidence level; *** - Significant at P> = 0.001; ** - Significant at P> = 0.01.

Pasting properties of yam tubers: The pasting properties are shown in Table 4. The peak viscosity value ranged from 24.38 to 267.79 RVU. The highest value was recorded in fresh cocoyam while the lowest value was recorded in roasted water yam. Peak viscosity is the maximum viscosity attained during or soon after the heating portion of the test in RVU. The trough 1 and value ranged from 18.75^{o}C to 189.71^{o}C in roasted water yam and in fresh sun-dried white yam, respectively. . Break down set point ranged from 4.63^{o}C in fresh sun-dried cocoyam to 97.46^{o}C in fresh white yam. . Final viscosity value ranged from 47.79 to 366.38 RVU being highest in fresh white yam and lowest in roasted water yam. Set back value ranged from 24.33 to 213.96 RVU in fresh sun-dried water yam and in fresh white yam respectively. Peak time value ranged from 4.6 min to 7 min. The highest time was recorded in boiled white yam, water yam, roasted white yam and water yam while the lowest was recorded in fresh sun-dried white yam.Pasting temperature value ranged from 61.85^{o}C to 62.40^{o}C being highest in fresh water yam and tubers under varying processing methods.

Table 3: The functional properties of yam tubers.

Processing method	Yam Variety	Swelling Power %	Soluble %	WAC %
Fresh Sun-dried	White yam	9.98^{a}	4.10^{d}	115.29^{e}
	Water yam	8.55^{b}	8.09^{bc}	116.05^{e}
	Cocoyam	6.04^{fg}	6.70^{c}	129.81^{e}
Boiled Oven-dried	White yam	7.05^{d}	8.53^{bc}	210.40^{c}
	Water yam	7.63^{c}	8.22^{bc}	210.98^{c}
	Cocoyam	8.32^{b}	11.30^{a}	373.18^{a}
Roasted oven-dried	White yam	7.80^{c}	9.88^{ab}	233.02^{b}
	Water yam	6.74^{de}	11.06^{a}	204.93^{c}
	Cocoyam	8.51^{b}	7.13^{c}	184.59^{d}
Fresh oven-dried	White yam	7.00^{d}	6.10^{cd}	122.58^{e}
	Water yam	6.39^{ef}	6.92^{c}	96.10^{f}
	Cocoyam	5.63	6.31^{cd}	88.87^{f}
Pr.>F	***	***	***	***

Each value is a mean of two replicates. Means followed by the same alphabet within columns are not significantly different at 5% confidence level. *** - Significant at P> = 0.001; ** - Significant at P> = 0.01

TABLE 4: Pasting properties of yam tubers under varying processing methods.

Processing method	Yam variety	Peak Viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Set back (RVU)	Peak time (minute)	Pasting Temp (°C)
Fresh sun-	White yam	261.54	189.71^{a}	71.83^{b}	269.13^{c}	76.42^{c}	4.60^{e}	62.40^{a}
	Water yam	161.17^{d}	156.25	4.92^{d}	180.58	24.33^{f}	5.90^{c}	61.85^{b}
	Cocoyam	134.58^{e}	129.96^{e}	4.63^{d}	188.79^{ef}	58.83^{d}	5.87^{c}	62.35^{ab}
Boiled Oven-	White yam	86.00^{g}	72.88^{f}	13.13^{cd}	132.58^{f}	59.71^{d}	7.00^{a}	61.90^{ab}
	Water yam	91.50^{g}	77.58^{f}	13.92^{cd}	136.83^{f}	59.25^{d}	7.00^{a}	62.00^{ab}
	Cocoyam	105.46^{f}	92.58^{f}	12.88^{cd}	129.88^{gh}	37.29^{ef}	6.23^{b}	62.85^{b}
Roasted oven-dried	White yam	86.79^{g}	76.08^{f}	10.71^{d}	121.04^{h}	44.96^{de}	7.00^{a}	61.95^{ab}
	Water yam	24.38^{h}	18.75^{g}	5.63^{d}	47.79^{i}	29.04^{ef}	7.00^{a}	61.95^{ab}
	Cocoyam	148.25^{d}	135.46^{de}	12.79^{cd}	193.04^{e}	57.58^{d}	6.20^{b}	61.93^{ab}
Fresh oven-dried	White yam	249.88^{b}	152.42^{cd}	97.46^{a}	366.38^{a}	213.96^{a}	4.90^{d}	61.88^{ab}
	Water yam	199.08^{c}	173.88^{ab}	25.21^{c}	232.29^{d}	58.42^{d}	5.70^{d}	61.85^{b}
	Cocoyam	267.79^{a}	185.54^{a}	82.25^{b}	292.13	106.58^{b}	4.90^{e}	61.98^{ab}
Pr.>F		***	***	***	***	***	***	ns

Each value is a mean of two replicates; Mean values followed by the same alphabet within columns are not significantly different at 5% confidence level; *** - Significant at P< = 0.001; ** - Significant at P<= 0.01; ns – Not significant at P<= 0.05.

Tannin content: The tannin contents ranged from 0 to 1.10mg /100g. The highest was recorded in fresh oven-dried water yam while the lowest was recorded in boiled oven-dried water yam (table 5).

TABLE 5: Tannin acids content (mg/100g) of yam tubers under varying processing methods.

Processing method	Yam Variety	Tannin
Fresh sun- dried	White yam	0.13^{g}
	Water yam	0.58^{c}
	Cocoyam	0.32^{e}
Boiled oven-dried	White yam	0.01^{h}
	Water yam	0.00^{h}
	Cocoyam	0.19^{f}
Roasted oven-dried	White yam	0.08^{h}
	Water yam	0.43^{d}
	Cocoyam	0.22^{f}
Fresh oven-dried	White yam	0.22^{f}
	Water yam	1.10^{a}
	Cocoyam	0.66^{b}
Pr.>F		***

Each value represent mean of two replicate; Mean value having the same alphabet within column are not significantly different at 5% confidence level; *** - Significant at P< = 0.001.

DISCUSSION

The result shows the physical, chemical, functional and pasting properties of the varieties of yam tubers (3 species) collected from Nigerian markets and subjected to varying processing methods. The moisture content of the yam tuber is usually high hence the water yam and white yam have higher value of moisture content. Our results support the report of Riley et al. (2006). It is believed that materials such as flour and starch containing more than 12% moisture have less storage stability than those with lower moisture content. For is this reason, a water content of 10% is generally specified for flours and other related products. It should be pointed out that when these products are allowed to equilibrate for periods of more than one week at 60% relative humidity and at room temperature (25 to27 °C), moisture content might increase. Tubers from the water yam and white yam are known for their high nutritional content. The results of this study agree with those of Osagie (1992) Udensi and Okaka (2000).).

Water absorption capacity for the different varieties was significantly different at (P<0.01). The value obtained is similar to the value reported for *D. rotundata* (Udensi et al., 2000). Water absorption capacity WAC is an important functional property required in food formulations especially those involving dough handling such as yam fufu.

It has been reported that starches with high amylose/low amylopectin contents tends to be of the type B structure, while those with low amylose/high amylopectin content are of either the type A or the intermediate type C form (Rickard et al., 1991). The results are in correlation to these findings as all the starches studied were of the type B form and had high amylose content. Previous reports (Riley et al., 2004) have shown that type C and type A starches are more digestible than type B starches.

The apparent amylose content also varied significantly among the starches studied (P<0.01). Previous reports (Riley et al., 2004) has shown that the amylose content plays a key role in the digestion of starches, as starches with low amylose contents are more digestible than starches with high amylose content.

Physical properties of starch pastes and gels depend on the concentration of the granules and the amount of amylose and amylopectin leached from the granules during heating. Viscosity also depends on the shape and swelling power of the granule and amylopectin granules interaction (Ring et al, 1987). Peak viscosity is the maximum viscosity attained during or soon after the heating portion of the test in RVU. Peak viscosity indicates the water binding capacity of the starch or mixture and it occurs at the equilibrium point between swelling causing an increase in viscosity rupture and alignment causing its decrease. Break- down is peak viscosity minus trough viscosity in RVU. Final viscosity indicates the ability of the material to form a viscous paste or gel after cooking and cooling. Peak time was also higher for starch samples in this work and ranged from 4.60 to 7.00.

Set back has been correlated with texture of various products. High set back is also associated with syneresis, or weeping, during freeze-thaw cycles for example, and substituted starches are commonly used where this presents a quality defect. There is a relationship between amylose content and set back; high amylose indicates high leaching hence high set back.

Pasting temperature gives an indication of the gelatinization time during processing. It is the temperature at which the first detectable viscosity is measured and an index characterized by initial change due to the swelling of starch. Pasting temperature has been reported to relate to water binding capacity, a higher pasting temperature implies higher water binding capacity property of starch due to high degree of association between starch granules (Kulkarni et al., 1991).

Tannins are phenolic compounds and they usually interfere with iron absorption through a complex formation with iron when it is in the gastrointestinal lumen which decreases the bio-availability of iron. Tannins are effective in protecting the kidney, for immediate relief of sore throat, diarrhea, dysentery, hemorrhage, fatigue, skin ulcer and as a cicatrizing on gangrenous wounds.. The lowest value was recorded in boiled oven dried water yam while the highest value was recorded in fresh water yam .This method reduced the tannin content tremendously.. Phytates and tannins bind with protein and minerals to form a soluble complex, thereby reducing protein and mineral bio-availability (Liener, 1980).

CONCLUSION

The results of this study revealed that the processing (Sun drying, boiling, roasting and oven-drying)yam tubers has significant effect on the nutrient content as well as swelling power, water binding capacity and solubility index Fresh oven drying method been found to be a good method to produce flour with better retention and functional properties.

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