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Influence of Fermentation Period on the Quality of Wild Yam (*Discorea Villosa*) Flour

Akeem Olayemi Raji[1*], Tawakalitu Eniola Aruna[1], Oluwadamilola Adeola Afolayan[1], Saheed Mayowa Sanusi[2] and Maimuna Sani[1]

[1] Department of Food Science and Technology, Kwara State University, Malete, Ilorin, Kwara State, Nigeria.
[2] Department of Food Engineering, University of Ilorin, Kwara State, Nigeria.

*Corresponding author: Akeem O.R.; E-mail: bigggi2003@yahoo.com; akeem.raji@kwasu.edu.ng

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Abstract

Greater utilization of wild yam is limited due to the presence of some anti-nutritional factors. Submerged fermentation is a simple traditional method of detoxifying food substances. Yam slices were blanched and fermented at ambient condition with intermittent changing of water at three days interval for 15 days (0, 3, 6, 9, 12, and 15 days). Six samples obtained were dried at 60°C for 8 hours. The proximate compositions, anti-nutritional factors and functional properties were determined using standard methods. Data obtained were analysed using ANOVA. The proximate compositions of the samples were moisture (6.60-10.26%), protein (13.71-23.70%), fat (5.40-7.18%), crude fibre (2.61-9.60%), ash (0.50-3.17%) and carbohydrate contents (56.73-62.60%). The saponin, tannin, oxalate contents decreased from 3.47-2.20%, 0.36-0.20% and 0.001-0.002% respectively. Bulk density and water absorption capacity decreased from 6.43-4.80g/ml and 0.40-0.19g/ml respectively. The pasting properties obtained were peak viscosity (354.08 - 88.92 RVU), trough (70.00-277.58 RVU), set back (109.42-567.17 RVU), final viscosity (231.25 - 844.75 RVU), peak time (6.87 - 7.00 mins) and pasting temperature (52.55 - 84.70°C). Fermentation improved the yam flour quality and reduced its anti-nutritional factors, but should be limited twelve days due to decreasing functional properties, most especially the bulk density.

Keywords: Wild yam, submerged fermentation, detoxification, functional properties, nutritional quality

1.0 INTRODUCTION

Yam belongs to the semi-perishable class of food based on its relatively high moisture content, and it is also a member of the *Dioscorea spp.* (Jimoh and Olatidoye, 2009). It is a widely grown tuber crop in many parts of the world (e.g. China, Korea, Japan, Ghana, America and Nigeria). Its production in sub-Saharan Africa is more than 95% of the global yam cultivation (Babajide *et al*., 2006). It is rated second after cassava as the most important tuber crop in Africa (Adejumo *et al*., 2013). The majorly grown species of yam include; *Dioscorea bulbifera* (potato yam), *Dioscorea cayenensis* (yellow yam), *Dioscorea alata* (water yam), *Dioscorea dumetorum* (bitter yam), *Dioscorea esculenta* (lesser yam), *Dioscorea opposita* (Chinese yam), *Dioscorea rotundata* (white yam) and *Dioscorea trifida* (cush-cush yam). Among these species, the commonly grown ones are *Dioscorea rotundata* and *Dioscorea cayenensis* (Adejumo *et al*., 2013). Yam mainly contains carbohydrate and provides about 110 calories per 100 grams of products. It also contains small amounts of proteins, lipids and vitamins (Babalola and Oyenuga, 2001). It has high moisture content, dry matter, starch, dietary fiber and vitamin B_6, but low in saturated fat, sodium and vitamin A content

(Adejumo *et al*., 2013). Yam contains limiting amino acids (isoleucine and sulphur containing amino acids), it also contains about 5-10 mg/100g of vitamin C (Alozie *et al*., 2009; Adejumo *et al*., 2013).

Yam possesses "diosgenin" ($C_{13}H_{19}O_2N$), a compound that can be extracted and used in the production of cortisone and hormonal drugs (Patel *et al.*, 2012). Some yam species may contain alkaloids (e.g. dioscorine) and steroid derivatives (Poornima and Ravishankar, 2009). Dioscorine, saponin and alkaloid in some species of wild yams are responsible for their toxic and bitter taste and may cause vomiting and diarrhea when large amount are ingested if eaten raw or without proper processing (Webster *et al*., 1984; Adejumo *et al*., 2013). It was reported that fatal paralysis of the nervous system could be triggered if a fragment of a tuber containing 100g of dioscorine was ingested (Akissoé, 2003; Patel *et al.*, 2012). Similarly, allergic reactions such as mild inflammation and itching are caused by histamine, which can be found in some plants belonging to the *Dioscoreceae* family (Bhandari and Kawabata, 2005; Patel *et al.*, 2012). Wild yams are the unexploited species that are found in the forests, and shortage of foods has forced rural dwellers in some part of Nigeria to source some of the wild yam species as food.

Dioscorea villosa L (common name; wild yam or atlantic yam) is a member of the *Dioscoreceae* family, which is a deciduous perennial and herbaceous twine that grows counterclockwise over small and medium-size shrubs. It grows abundantly in Mexico, the eastern and central regions of United States, south of Canada, Central America and India (Kumar *et al*., 2013; Manda *et al*., 2013; Wojcikowski *et al*., 2013). It has also been found in north central and south western parts of Nigeria. The utilization of yams can be limited by the presence of toxic anti-nutrients. The presence of enzyme inhibitors in yams could impair digestion of starch and protein, thereby limiting their utilization as food (Adejumo *et al*., 2013). Yang and Lin (2008) reported that age, cultivar, geographic locality of a plant or the storage condition after harvest could significantly affect the anti-nutritional contents of tubers. Also, the presence of enzyme inhibitors in yams could impair digestion of starch and protein thereby limiting their utilization as food. However, processing techniques influence the nutritional status of yam-based foods. In many parts of West Africa including Ghana, yam is processed into various food forms, which include pounded yam, boiled yam, roasted yam, or grilled yam, yam balls, mashed yam, yam flour, yam chips and flakes (Babalola and Oyenuga, 2001;Vernier *et al*., 2003). Therefore, value addition to wild yam is important, since literature is sparse on the effect of processing on its anti-nutritional factors.

2.0 MATERIALS AND METHODS

2.1 Materials

Wild yam (*Dioscorea villosa*) tubers were purchased from a local farmer in Malete, Kwara state, Nigeria. The tubers were brought to the Food Processing Laboratory, Department of Food Science and Technology, Kwara State University for processing.

2.2 Methods

2.2.1 Sample preparation

Yam tubers (20.0 kg) were peeled, weighed, washed with distilled water, and sliced using a table knife. The yam slices were further washed and drained. The thickness of the slices was maintained at 1±0.02 cm.

2.2.2 Submerged Fermentation

The yam slices were divided into five portions (1000g each) and blanched with hot water at 100°C for 3 minutes. The blanched slices were fermented at ambient condition with intermittent changing of water at three days interval throughout the fermentation period. Fermentation periods for the five samples were designed to be 3, 6, 9, 12, and 15 days. Fermented samples were drained and subsequently dried in a cabinet drier at 60°C for 6-8 hours (Figure 1). Each sample was produced in triplicate and subjected to further analyses.

Wild yam (*Dioscorea villosa*)
↓
Peeling
↓
Washing
↓
Slicing (1cm)
↓
Blanching
↓
Steeping
↓
Draining
↓
Drying
↓
Cooling
↓
Milling
↓
Yam flour

Figure 1: Flow chart for production of flours from *Dioscorea villosa*

2.3 Chemical Analyses

The chemical analyses carried out in this study are stated below:

2.3.1 Proximate Composition

The proximate composition (moisture, protein, ash, fat, crude fibre and carbohydrate) of the samples were evaluated using AOAC (2005) methods:

2.4 Determination of Anti-nutritional Factors

2.4.1 Tannin Determination

Total tannin content of yam flour was determined by the spectrophotometric procedure described by Bainbridge (1996).

2.4.2 Oxalate determination

The oxalate content in the yam flour samples was analyzed using the calcium oxalate precipitation method as used in the Association of Official Analytical Chemists' (AOAC, 2005) method.

2.4.3 Saponin Determination

Total saponin content of yam flour was determined by the method described by Obadoni and Ochuko (2001).

2.5 Functional Properties Determination

2.5.1 Determination of Bulk Density

The bulk densities of the samples were determined using the method of Okezie and Bello (1988). A known quantity of flour sample was weighed into measuring cylinder (W_1). The weighed sample was tapped gently to eliminate spaces between the flour particles, the level was noted to be the volume of the sample and then weighed (W_2).

$$\text{Bulk density (g/cm3)} = \frac{\text{W2} - \text{W1}}{\text{Volume of sample}}$$

2.5.2 Determination of Water Absorption Capacity

The method of Onwuka (2005) was used for water absorption capacity determination. A gram of each sample was weighed into a graduated clean conical centrifuge tube. It was then was mixed thoroughly with 10 ml distilled water in a warring mixer for 30seconds. The sample was then allowed to stand for 30 minutes at room temperature, after which it was centrifuged at 5000 rpm for 30 minutes. After centrifugation, the volume of the supernatant, water was read directly from the graduated centrifuge tube. The absorbed water was converted to weight (in grams) by multiplying by the density of water (1 g/ml). The water absorption capacity was expressed as grams of water retained per gram of sample used.

2.5.3 Pasting Property Determination

IITA (2001) method was used in determination of pasting properties. The pasting characteristics of the samples were determined using a Rapid Visco Analyzer (Model RVA-4C, Newport Scientific, Warriewood, Australia) interfaced with a personal computer equipped with the Thermocline software supplied by same manufacturer. The parameters that was determined automatically by the instrument are peak viscosity(the maximum viscosity during pasting), breakdown viscosity(the difference between the peak viscosity and the minimum viscosity during pasting), setback viscosity(the difference between the maximum viscosity during cooling and the minimum viscosity during pasting), final viscosity(the viscosity at the end of the RVA run) ,pasting temperature(°C) (the temperature at which there is a sharp increase in viscosity of flour suspension after the commencement of heating) and peak time(min)(time taken for the paste to reach the peak viscosity).

2.6 Statistical analysis

All tests were replicated and the data obtained were statistically analyzed using the statistical package for social science (SPSS) version 16.0 package software. Significance was accepted at 0.05 probability level.

3.0 RESULTS AND DISCUSSION

The results obtained from various analyses carried out on the wild yam flours are shown below in Table 1-4.

3.1 Effect of fermentation on proximate composition of wild yam flours

3.1.2 Moisture

The moisture content obtained from the wild yam flour samples from 6.60-10.32% with a mean value of 7.87±0.29% (Table 1). The unfermented yam flour had the least moisture content, while the sample that was fermented for 15 days before drying had the highest moisture contents. However, the fermentation period had significant influence on the final moisture contents of the dried fermented wild yam flour. Moisture content is an index of flour storage stability, and also it is a direct estimate of the amount of water present in a sample. Flour having a moisture content of less than 14% will have a better storage stability and ability to resist microbial growth (Okonkwo and Opara. 2010). The values obtained for moisture contents in this study were far below 14%, suggesting that flour samples obtained might have better storage stability. It was observed that the final moisture content in the fermented dried yam flour increased as the fermentation period increased. However, increase in moisture content might be due to enzymatic degradation of carbohydrate and other compound, thereby making the flour to highly susceptible to moisture intake after dehydration. Also, the slight increase in the moisture content of the samples might be attributed to absorption of water from the environment (Huaning and Benheng, 2013).Similar results were observed for flours (4.02-8.17%) produced from seven commonly grown *Dioscorea spp* in Ghana (Polycarp et al., 2012).

Table 1: Effect of fermentation on proximate composition of wild yam flours

Parameter	**0 days**	**3 days**	**6 days**	**9days**	**12 days**	**15 days**
Moisture (%)	6.60±0.21^{c}	8.34±0.40^{b}	9.86±0.29^{a}	10.15±0.23^{a}	10.32±0.25^{a}	10.26±0.37^{a}
Protein (%)	23.70±0.03^{a}	16.81±0.02^{b}	13.28±0.10^{e}	12.70±0.10^{f}	14.21±0.25^{c}	13.71±0.03^{d}
Crude fat (%)	7.18±0.20^{c}	7.72±0.03^{b}	8.42±0.02^{a}	5.85±0.06^{e}	5.70±0.00^{e}	6.40±0.00^{d}
Crude fiber (%)	2.61±0.03^{f}	6.20±0.02^{e}	6.67±0.03^{d}	9.60±0.09^{b}	9.49±0.04^{c}	9.90±0.05^{a}
Crude ash (%)	3.17±0.06^{a}	0.68±0.03^{b}	1.20±0.02^{c}	1.11±0.01^{d}	0.50±0.01^{f}	0.59±0.02^{e}
Carbohydrate (%)	56.73±0.10^{d}	60.24±0.40^{ab}	60.57±0.40^{a}	60.60±0.20^{a}	59.78±0.30^{b}	59.15±0.44^{c}

Data was reported as Mean±SD. Values followed by the same superscripts in columns are not significantly different at $P < 0.05$.

3.1.3 Carbohydrate

The result of chemical analysis shows that the carbohydrate content ranged from 56.73-60.60% with a mean value of 59.51±0.31% (Table 1). It was observed that the carbohydrate contents of the flour increased up till 9 days of fermentation and decreased thereafter. Increase in carbohydrate during fermentation might be due to separation of carbohydrate from their complexes with non-nutritive components of the wild yam. Similar findings was reported by Cemaluk *et al*. (2014) who worked on effect of soaking prior to oven-drying on some nutrient and anti-nutrient properties of bitter yam. The findings also suggested that fermented wild yam flour obtained at the optimum fermentation period (9 days) could serve as a good dietary energy source. Slight decrease in the value of carbohydrate after 9 days of fermentation implied that there might be degradative changes in the carbohydrate content of the flour. However, the values for the carbohydrate obtained in this were below the values reported by Polycarp et al. (2012) on flours produced from seven commonly grown yam species in Ghana, but slightly fell within the 60-90% dry matter range reported by Jacques et al. (2016) for roots and tubers.

3.1.4 Crude fat

The fat contents obtained in this study ranged from 5.70-8.42% with a mean value of 6.88±0.05% (Table 1). It was noticed that the fat contents of the flour increased up till 6 days of fermentation and decreased thereafter. Increase in fat contents during 6 days fermentation suggested that there was an enhanced fat formation and preservation during the period. Similar findings was reported by Cemaluk *et al.* (2014) who researched on the effect of soaking prior to oven-drying on some nutrient and anti-nutrient properties of bitter yam (Dioscorea dumetorum). The reduction in fat content after 6 days of fermentation indicates an increase in lipid oxidation. The increase in the lipid oxidation might by due to the release of oxidative enzymes and prooxidants from various rupture cellular organelles (Boonsumrej *et al*., 2007).
The fat contents obtained was higher than the values reported for *D. alata* (Udensi *et al*., 2008); *D. oppositifolia, D. pentaphylla, D. hispida, D bulbifera,* (Rajyalakshmi and Geervani, 1994) *and D. rotundata* (Akissoe *et al*., 2001). It was also higher than the values of fat in *D. calicola, D. daunea, D.wallichi, D. stemonoides* and *D. glabra* (Maneenoon *et al*., 2008). However, moderately high fat content observed in the flours might increase their chance for rancid off flavour development, thereby limiting their storage stability.

3.1.5 Protein

The protein contents of the samples ranged from 12.70-23.70% with a mean value of 15.74±0.08% (Table 1). It was discovered that the protein contents of the flour decreased up till 9 days of fermentation and slightly increased thereafter. The unfermented flour contains the highest protein content (23.70%). However, decrease protein contents during fermentation might be attributed to loss of free amino acids as result of leaching into water (Azene and Molla, 2017). It might also be as result of formation of an insoluble complex by the reaction between tannin and protein, which was catalyzed by replacement of soaking water with hot water (100^{o}C) at three days interval to avoid slimming (Cemaluk et al., 2014). Slight increase in protein content after 9 days of fermentation could due to enzyme mediated synthesis of amino acid during fermentation process (Adane *et al*., 2013). The protein contents observed in this study was higher than 6.43 -6.98% reported for taro flour (Adane *et al*., 2013), 8.12% for *Dioscorea bulbifera* flour (Jacques et al., 2016), 5.15% for white yam and 3.64% for sweet potato (Alaise and Linden, 1999). Thus, higher protein contents in villosa flour, suggested that its inclusion in diet could contribute to amino acid balance.

3.1.6 Ash

The ash contents obtained from this study ranged from 0.50-3.17% with a mean value of 1.20±0.07% (Table 1). It was observed that as the fermentation period increased the ash contents reduced. The reliable indicator of mineral contents in biota is the ash content (Akubugwo *et al*., 2007). The quantity of ash present in a sample is a direct estimate of the amount of mineral present in the sample (Cemaluk *et al.*, 2014). Highest ash content (3.17%) was observed in the unfermented samples, while the sample that was fermented for 12 days had the lowest of value (0.50%). Reduction in the ash content might be linked to leaching of minerals during fermentation process. Similar findings was observed by Cemaluk *et al.* (2014) who researched on the effect of soaking prior to oven-drying on some nutrient and anti-nutrient properties of bitter yam (Dioscorea dumetorum). Thus, decrease in the ash content suggests a reduction in the mineral contents on the villosa yam flour during fermentation. However, the ash contents obtained in this study fell within the range of values reported for *Dioscorea species*. Assa *et al.* (2014) reported 3.44 and 4.64% % for *Dioscorea bulbifera and Dioscorea alata respectively*. Polycarp *et al.* (2012) reported 1.29 and 8.56% % for *Dioscorea rotundata* (Pona) and *Dioscorea esculenta* (Large) respectively.

3.1.7 Crude Fibre

The crude contents of the samples varied from 2.61-9.90% with a mean value of 7.41±0.04% (Table 1). It was noticed that there was a significant increase in the crude fiber contents of the fermented yam flour as the fermentation period increased. Samples fermented for 15 days with intermittent changing of water had the highest crude fibre content (9.90%). Increase in crude fibre contents indicates that the crude fibre in villosa yam was well preserved during fermentation and this also suggests that the fermented villosa yam flour might have better digestibility than the unfermented sample. The values obtained in the study for the fermented flours were higher than the values earlier researchers found in *D. bulbifera* (Pramila *et al*., 1991; Mohan *et al*., 2011); *D. oppositifolia, D. pentaphylla* (Murugesan and Ananthalakshmi, 1991; Mohan *et al*., 2011); *D. alata* (Udensi *et al*., 2008); *D. bulbifera*, D. *deltoidea, D. versicolor* and *D. triphylla* (Bhandari *et al*., 2003).

3.2 Effect of fermentation on the anti-nutritional factors in wild yam flours

3.2.1 Saponin

The saponin contents obtained in this study ranged from 2.20-3.47% with a mean value of 2.66±0.04% (Table 2), with a significant reduction in the saponin content which may be attributed to the effect of fermentation and drying processes of the flour. It was observed that as the fermentation period increased the saponin contents reduced. The decrease in the saponin content corroborates with the findings of Osagie (1998) who reported that simple soaking of bitter yam in water could reduce its anti-nutrients contents. It also corroborates with the findings of Cemaluk *et al.* (2014) who researched on the effect of soaking prior to oven-drying on some nutrient and anti-nutrient properties of bitter yam (Dioscorea dumetorum).

3.2.2 Tannin

The tannin contents of the samples varied from 0.20-0.36% with a mean value of 0.25±0.00% (Table 2). It was observed that there was an inverse relationship between the fermentation period and the tannin content of the flour. Increase in the fermentation period resulted into a decrease in the tannin content of the yam flour. Tannin is a high molecular weight compound which is soluble in water. Due to its ability to precipitate alkaloids, gelatins and proteins, food substances possessing high tannin content are considered to be low nutritional values (Azene and Molla, 2017). It also inhibits digestive enzymes and affects utilization of vitamins and minerals from meals (Tinkílíç and Uyaník, 2001). The result obtained in this study revealed that submerged fermentation with intermittent changing of soaking water resulted in significant decrease in tannin content of the wild yam. Similar findings were reported by some researchers who worked on influence of processing on anti-nutritional factors in yam (Onu and Madubuike, 2006; Akpan and Umoh, 2004; Azene and Molla, 2017). However, the tannin reduction in the samples was as a result of the enzymes produced by the micro organisms that are involved in fermentation process **(**Alcantara *et al.*, 2013)

Table 2: Effect of fermentation on anti-nutritional factors of wild yam flours

Parameter	**0 days**	**3 days**	**6 days**	**9 days**	**12 days**	**15days**
Saponin (%)	3.47±0.03[a]	2.40±0.02[d]	2.65±0.06[b]	2.57±0.04[c]	2.20±0.02e	2.66±0.07[b]
Tannin(%)	0.36±0.01[a]	0.22±0.01[d]	0.26±0.00[b]	0.24±0.01[c]	0.21±0.01[e]	0.20±0.01[f]
Oxalate (%)	0.001±0.00[b]	0.002±0.00[b]	0.002±0.00[b]	0.001±0.00[b]	0.001±0.001[a]	0.001±0.00[b]

Data was reported as Mean±SD. Values followed by the same superscripts in columns are not significantly different at $P < 0.05$.

3.2.3 Oxalate

The oxalate content ranged between 0.001-0.002% with a mean value of 0.001±0.001% (Table 2), according to the result obtained it was observed that the oxalate content present in wild yam was relatively low. Oxalate presence in yam gives them acrid taste and causes irritation if consumed. High oxalate content in food reduces calcium absorption and aids kidney stone formation (Noonan and Savage, 1999). The result obtained showed that submerged fermentation with intermittent changing of soaking hot water decreased the oxalate content of the wild yam. The report was similar to the findings of Oke and Bolarinwa (2012) who discovered that 48 hours fermentation resulted in 65% reduction of oxalates of taro. Similarly, Cemaluk et al. (2014) reported that soaking prior to oven drying reduced the oxalate content of bitter yam (*Dioscorea dumetorum*). However, the oxalate levels in the fermented flours were far below the recommended allowable limit of 71 mg/100g (Egbuonu *et al*., 2014). This implies that the flours obtained are at safe levels.

3.3 Effect of fermentation on functional properties of wild yam flours

3.3.1 Bulk Density

The result for functional properties of wild yam flour is presented in Table 3. The bulk density of the sample ranged from 0.19-0.40 (g/ml). An inverse relationship was observed between the fermentation period and the bulk density, increase in the fermentation period resulted in a decrease in the bulk density of the fermented yam flour. The result obtained was in agreement with the findings of Adams *et al.* (2017) who researched on the influence of fermentation sweet potato and wheat flours` functional properties. Functional properties of the food materials play significant role in determining the suitability of a diet particularly for growing children (Omueti *et al*., 2009; Obadina *et al*., 2016). However, diet having lower bulk density is required by infants for easy swallow without experiencing choking or suffocation (Victor *et al.*, 2013). This implies that the fermented flour obtained can be consumed by both infants and adults. The bulk density also serves as an indication of food product porosity that influences packaging design and the choice of packaging materials (Iwe and Onadipe, 2001). Therefore, the results obtained would provide an insight into better packaging of fermented D. villosa yam flour.

Table 3: Effect of fermentation on the functional properties of wild yam flours

Parameter	0days	3days	6days	9days	12days	15days
Bulk Density (g/ml)	0.40±0.01[a]	0.20±0.01 [b]	0.20 ±0.01[b]	0.19±0.03 [b]	0.20±0.01 [b]	0.20 ±0.01[b]
WAC (%)	180.45± 1.35[d]	190.63±2.25[b]	201.50±0.60[a]	186.65±0.10[c]	170.67±3.56 [e]	150.60±3.00[f]

Data was reported as Mean±SD. Values followed by the same superscripts in columns are not significantly different at $P < 0.05$.

3.3.2 Water Absorption Capacity

The water absorption capacity value ranged from 150.60 - 201.50% (Table 3). It was observed that the water absorption capacity increased at the initial stages of fermentation and decreased thereafter. Sample that was fermented for six days with three days intermittent changing of soaking hot water had the highest water absorption capacity. Decrease in the value of water absorption capacity after 6 days of fermentation implied that there might be enzyme mediated degradative changes in the carbohydrate and protein contents of the flour resulting into leaching of amino acids and glucose into the soaking water (Azene and Molla, 2017). Increase in water absorption capacity might be as a result of increase in the number of hydrophilic group of the protein in the flour, caused by degradation of the peptide bonds in protein during fermentation (Adams *et al.*, 2017). Water absorption capacity is the measure of the amount of water that an insoluble starch is able to hold in relation to its weight. Higher water absorption capacities observed in this study is an indication that the flour will perform better in aqueous food formulation, most especially operations that involve dough handling.

3.3.3 Pasting properties

The pasting properties are shown in Table 4. The peak viscosity value ranged from 354.08 to 88.92 RVU. The highest value was recorded in the sample that was fermented for 12days, while the lowest value was recorded in the sample that was fermented for 6 days. Peak viscosity has been reported to be the ability of starch to swell freely before their physical breakdown, and it is an indication of viscous load likely to be encountered during mixing (Sanni *et al*., 2004). High peak viscosity connotes high starch content and it is related to the water binding capacity of starch (Osungbaro, 1990; Adebowale *et al*., 2005). The peak viscosities obtained in this study are in line with the values (195.17-399.58 RVU) reported by Ezeocha and Okafor (2016) for D. *dumentorum*, and also similar to the values (325-398 RVU) reported by Aviara *et al.* (2010) for starch extracted from sorghum. However, the values were lower than the peak viscosity values (639-726 RVU) reported for yam starches by Amoo *et al*. (2014). The high peak viscosity observed in sample that was fermented for 12days implies that it might be a suitable candidate for products which requires high gel strength, thick paste and elasticity.

The trough values ranged from 70.00 to 277.58 RVU. The highest value was found in the sample that was fermented for 12days, while the sample that was fermented for 6 days had the lowest value. The trough is the minimum viscosity value in the constant temperature phase of the RVU profile and measures the ability of paste to withstand breakdown during cooling (Sanni *et al*., 2004). The values obtained in this study fell within the range of values (46.67 to 221.67 RVU) reported by Harijono *et al*. (2013), who researched on effect of blanching on properties of water yam (*Dioscorea alata*) flour. High through value noticed in sample that was fermented for 12days implies that its paste might possess strong ability to withstand breakdown during cooling.

Table 4: Pasting properties of wild yam flours

Days	Peak viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Setback (RVU)	Peak Time (min)	Pasting Temp (°C)
0	151.83±2.00 [d]	143.50±2.00[c]	8.33±0.40[f]	252.92±2.00[e]	109.42±2.00[f]	6.87±0.50[a]	79.80±0.80[b]
3	259.50±2.50[c]	231.17±0.50[b]	28.33±0.25[d]	495.67±1.50[c]	264.50±1.50[d]	7.00±0.30[a]	52.55±1.40[f]
6	88.92±1.00[f]	70.00±0.70 [e]	18.92±1.50[e]	231.25±2.30[f]	161.25±0.90[e]	6.93±1.00[a]	61.90±1.60[d]
9	137.33±3.10[e]	96.83±0.90 [d]	40.50±0.60 [c]	422.08±1.80[d]	325.25±1.40[c]	7.00±0.20[a]	68.55±2.50[c]
12	354.08±1.50[a]	277.58±1.00[a]	76.50±2.10 [a]	844.75±2.40[a]	567.17±2.80[a]	7.00±0.33[a]	58.40±1.10[e]
15	300.33±2.60 [b]	229.92±2.50[b]	70.42±1.90[b]	767.83±1.50[b]	537.92±3.40[b]	7.00±0.20 [a]	84.70±1.30[a]

Data was reported as Mean ± SD. Values followed by the same superscripts in columns are not significantly different at $P < 0.05$.

Breakdown viscosity ranged from 8.33-76.50, with the sample that was fermented for 12days having the highest value, while the lowest value was recorded in the un-fermented sample. It was observed that the breakdown viscosity was lower in the un-fermented flour than in the fermented flours. The period of fermentation has a significant influence on the breakdown viscosity of the samples at 95% confidence level. The low breakdown viscosity of the un-fermented flour suggested that it might have hot paste stability advantage over others. Breakdown is a measure of the ability of flour or starch to withstand collapse during cooling, it is also a good index that can be used to determine the degree of disintegration or paste stability (Jimoh *et al*., 2009; Ezeocha and Okafor, 2016). However, it was reported that the higher the breakdown viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking (Adebowale *et al*., (2005). Values obtained in this study were within the range of values (15-385) reported by Amoo *et al*. (2014) for yam starches, except for the un-fermented yam sample (8.33).

Set back viscosity values varied from 109.42 to 567.17 RVU. Sample that was fermented for 12 days had the highest value, while the unfermented sample had the lowest value. The fermentation period significantly influenced the set back viscosity of the samples at 95% confidence level. Setback viscosity measures the re-association starch and it is associated with paste cohesiveness (Jimoh *et al*., 2009; Ezeocha and Okafor, 2016). However, the relatively low setback observed in the unfermented sample, suggesting low tendency of the flour to retrograde. This indicate that the flour might be useful in the food processing and allied industries, as staling of bread or starchy dough, quick precipitation of sols and loss of viscosity in sauce are caused by high retrogradation (Ikegwu *et al*., 2010; Sanful and Engmann, 2016). High set back viscosities of the samples fermented for 12 and 15 days make them suitable for the production of gluten free pastas, weaning food and pounded yam (Oduro *et al*., 2001; Sanful and Engmann, 2016 ; Ezeocha and Okafor, 2016). The result derived from this study is in agreement with the findings of Aviara *et al*. (2010) who researched on sorghum (104-140 RVU), and it is also similar to the report of Amoo *et al*., (2014) who researched on yam flours (79-339 RVU).

The final viscosity values varied from 231.25 to 844.75 RVU, with the sample that was fermented for 12days having the highest value, while the lowest value was recorded in the sample was fermented for 6 days. The period of fermentation significantly influenced the final viscosity of the samples at 95% confidence level. The final viscosity is the most commonly used parameter to define starch and flour quality as it is used to indicate paste stability (Martin *et al*, 1972; Bashiru et al., 2010). Babajide *et al*. (2007) reported that yam flour with high final viscosity would possess high pasting quality. High final viscosities observed in the studied fermented samples affirm that they might possess good pasting quality, leading to the production good yam pastes (*Amala*).

The peak time value ranged from 6.87 to 7.00 min and the pasting temperature value ranged from 52.55 to 84.70°C. Sample that was fermented for 15days had the highest value for the pasting temperature while the sample that was fermented for 3 days had the lowest value. A slight change was noticed in their peak time values, where many samples had an average peak time of 7.00 min. The pasting temperature is a true predictor of the likely gelatinization time during processing (Odedeji and Adeleke, 2010), and it is also an indication of the least temperature needed for cooking, estimation of energy cost and the stability of other components (Ikegwu *et al*., 2009; Sanful and Engmann, 2016). The pasting time is an indicator of the minimum time needed to cook a given food sample (Odedeji and Adeleke, 2010; Sanful and Engmann, 2016). It was observed that samples that were fermented for 3 and 12 days had the lower pasting time (52.55 and 58.40 min), making them suitable for the production of foods where shorter processing time is required. The values reported for the peak time were below the values established for aerial yam flour and starch (24.30 and 19.25 min) as reported by Sanful and Engmann (2016), but fell within the range reported by Addy *et al.(*2014). The pasting temperature values observed in this study were slightly- moderately lower than the value Sanful and Engmann (2016) reported for aerial yam flour (85.50°C), but in line with the findings of Amoo *et al*., (2014) who researched on yam flours (75.1 to 77.3°C).

4.0 CONCLUSION

Fermentation improved the nutrients qualities and reduced the anti-nutritional factors in the wild yam flour. The fermentation period should not be less than six days in as in the case of anti-nutritional factors reduction, and should not be extended beyond twelve days due to decreasing functional properties. The pasting properties study suggest that the unfermented flour might be used for food products where require thick paste, high gel strength and elasticity are required, while the fermented flour samples are more suitable for the production of gluten free pastas, weaning food and amala (yam paste).

REFERENCES

A.O.A.C. (2005). Official Methods of Analysis of the Association of Official Analytical Chemistry, A.O.A.C.: Washington D.C.

Adams, O. K., Adams, I. M. and Orungbemi, O.O. (2017). The effect of fermentation on functional properties of sweet potato and wheat flour. *African Journal of Food Science and Technology*. 8(2):14-18

Adane, T., Shimelis, A., Negussie, R., Tilahun, B. and Haki, G. D. (2013). Effect of processing method on the Proximate composition, mineral content and antinutritional factors of Taro (Colocasia esculenta, L.) growth in Ethiopia. *African Journal of Food, Agriculture, Nutrition and Development*.13(2): 7383-7398

Addy, R. N. A., Wireko-Manu, F. D. and Oduro, I. (2014). Physicochemical and Pasting Properties of Starch Extracted from Four Yam Varieties. *Journal of Food and Nutrition Sciences*; 2(6): 262-269.

Adebowale, A. A., Sanni, L. O. and Awonorin, S. O. (2005). Effect of texture modifiers on the physicochemical and sensory properties of dried fufu. *Food Science and Technology International*. 11(5): 373-382.

Adejumo, B. A., Okundare, R. O., Afolayan, O. I., & Balogun, S. A. (2013). Quality attributes of yam flour (Elubo) as affected by blanching water temperature and soaking time. *Int J. Eng Sci*. *2*(1): 216-221.

Akissoe, H.N, Hounhouigan, D.J, Bricas, N, Vernier, P, Nago C.M, and Olorunda, O.A. (2001). Physical, chemical and sensory evaluation of dried yam *(Dioscorea rotundata)* tubers, flour and 'amala', a flour- derived product. *Tropical Science*. 41:151-155.

Akissoé, N., Hounhouigan, J., Mestres, C. and Nago, M. (2003). How blanching and drying affect the colour and functional characteristics of yam (Dioscorea cayenensis-rotundata) flour. *Food Chemistry*. 82(2): 257-264.

Akpan, E. J. and Umoh, I. B. (2004). Effect of heat and tetracycline treatments on the food quality and acridity factors in cocoyam [Xanthosoma sagittifolium (L) Schott]. *Pakistan Journal of Nutrition*. 3(4): 240-243.

Akubugwo, I.E.,Obasi, N.A., Chinyere, G.C. and Ugbogu A.E. (2007). Nutritional and chemical value of Amaranthus hybridus L. leaves from Afikpo, *Nigeria. African Journal of Biotechnolog*y 6(24): 2833-2839.

Alaise, C. and Linden, G. (1999). Food Biochemistry. Chapman and Hall, Food Science Book. Aspen Publishers Inc. Maryland. 15-121.

Alcantara, M. R, Hurtada, A.W., and Dizon, I. (2013). The nutritional value and phytochemical components of taro [Colocasia esculenta (L.) Schott] powder and its selected processed foods. *Nutrition & Food Sciences*. . 3(3):207.

Alozie, Y., Akpanabiatu, M. I., Eyong, E. U., Umoh, I. B. and Alozie, G. (2009). Amino acid composition of Dioscorea dumetorum varieties. *Pakistan Journal of Nutrition*, *8*(2): 103-105.

Amoo, A.R.N., Wireko-Manu, F.D. and Oduro, I. (2014). Physicochemical and pasting properties of starch extracted from four yam varieties. Journal of Food and Nutrition Sciences; 2(6): 262-269.

Assa Cyrile D., Hubert Konan K., Martin Djè K and Lucien Kouamé P. (2014). Effect of boiling time on some biochemical parameters of yam specie (*Dioscorea alata variety "Bètè-Bètè"*) tubers. *International Journal of Advanced Research*. 2(11): 40-50.

Aviara, N.A., Igbeka, J. C. and Nwokocha, L. M. (2010). Physicochemical Properties of Sorghum (Sorghum Bicolor L. Moench) Starch as Affected by Drying Temperature. . Agricultural Engineering International: the CIGR Ejournal. Vol. XII.

Azene, H. and Molla, T. (2017). Nutritional Composition and Effects of Cultural Processing on Anti-nutritional Factors and Mineral Bioavailability of Colocasia Esculenta (Godere) Grown in Wolaita Zone, Ethiopia. *Journal of Food and Nutrition Sciences*. *5*(4): 147-154.

Babajide, J. M., Oyewole, O. B. and Obadina, O. A. (2006). An assessment of the microbiological safety of dry yam (gbodo) processed in South West Nigeria. *African Journal of Biotechnology*. *5*(2): 157-161.

Babalola, M. and Oyenuga, V. A. (2001). Value of yam Dioscorea speiceis. *Nigerian food and feeding stuffs. Ibadan, University Press, Ibadan, Nigeria*, 110-114.

Bainbridge, Z., Tomlins, K., Wellings, K. and Westby, A. (1996). Methods for Assessing Quality Characteristics of Non-Grain Starch Staples. Part 3 Laboratory Methods. Chatham UK: Natural Resources Institute.

Bhandari, M. R. and Kawabata, J. (2005). Bitterness and toxicity in wild yam (Dioscorea spp.) tubers of Nepal. *Plant Foods for Human Nutrition*, *60*(3), 129-135.

Bhandari, M.R., Kasai, T. and Kawabata, J. (2003). Nutritional evaluation of wild yam (*Dioscorea* spp.) tubers of Nepal. Food Chemistry. 82: 619-623.

Boonsumrej, S., S. Chaiwanichsiri, and S. Tantratian. Effect of freezing and thawing on the quality changes of tiger shrimp (*Penaeus monodon*) frozen by air-blast and cryogenic freezing. *J. Food Eng*. 80:292–299.

Cemaluk, E. A. C., Daniel, N. C. and Nkiru, E. O. C. (2007). Effect of soaking prior to oven-drying on some nutrient and anti-nutrient properties of bitter yam (Dioscorea dumetorum). *J Nutr Food Sci*. *4*:(3): 1-5 (2014).

Coursey, D. G. (1967). Yam storage—I: a review of yam storage practices and of information on storage losses. *Journal of Stored Products Research*. *2*(3): 229-244.

Ezeocha, C. V. and Okafor, J. C. (2016). Evaluation of the chemical, functional and pasting properties of starch from trifoliate yam (Dioscorea dumetorum) landraces. *European Journal of Advanced Research in Biological and Life Sciences*, *4: 53-62*.

Harijono, T. E., Saputri, D. S. and Kusnadi, J. (2013). Effect of blanching on properties of water yam (Dioscorea alata) flour. *Advance Journal of Food Science and Technology*. *5*(10): 1342-1350.

Huaning, Y. and Benheng, G. (2013). Storage stability of freeze-dried colostral whey powders with different additives. *International Journal of Agricultural and Biological Engineering*, 6(2): 95-106.

IITA. (2001). Operation manual for the series 3 Rapid Visco Analysis using thermocline for windows. Newport Scientific pty. Ltd.

Ikegwu, O. J., Okechukwu, P. E. and Ekumankana, E. O. (2010). Physico-chemical and pasting characteristics of flour and starch from achi Brachystegia eurycoma seed. *Journal of Food Technology*. *8*(2): 58-66.

Iwe, M. O., & Onalope, O. O. (2001). Effect of extruded full-fat soy flour into sweet potato flour on functional properties of the mixture. *Journal of Sustainable Agriculture and Environment*. 3: 109-117.

Jimoh, K. O. and Olatidoye, O. P. (2009). Evaluation of physicochemical and rheological characteristics of soybean fortified yam flour. *Journal of Applied Biosciences*. 13: 703-706.

Jimoh, K.O., Olurin, T. O. and Aina. J. O. (2009). Effect of drying methods on the rheological characteristics and colour of yam flours. *African Journal of Biotechnology*. 8 (10): 2325-2328.

Kumar, S., Parida, A. K. and Jena, P. K. (2013). Ethno-Medico-Biology of Bān-Aālu (Dioscorea species): A neglected tuber crops of Odisha, India. *International Journal of Pharmacy & Life Sciences*. 4(12): 3143-3150.

Manda, V. K., Avula, B., Ali, Z., Wong, Y. H., Smillie, T. J., Khan, I. A. and Khan, S. I. (2013). Characterization of in vitro ADME properties of diosgenin and dioscin from Dioscorea villosa. *Planta medica*. 79(15): 1421.

Maneenoon, K., Sirirugsa, P. and Sridith, K. (2008). Ethnobotany of Dioscorea L.(Dioscoreaceae), a major food plant of the Sakai tribe at Banthad Range, Peninsular Thailand. *Ethnobotany Research and Applications*. 6: 385-394.

Mohan, V. R., Shajeela, P. S., Jesudas, L. L. and Soris, P. T. (2011). Nutritional and antinutritional evaluation of wild yam (Dioscorea spp.). *Tropical and subtropical Agroecosystems*. 14(2): 723-730.

Murugesan P.T. and Ananthalakshmi, A. (1991). Dietary practices of the Palliyar tribal group and the nutrient content of unconventional foods consumed. Indian Journal of Nutrition and Dietetis. 28: 297-301.

Obadina, A., Ashimolowo, H. and Olotu, I. (2016). Quality changes in cocoyam flours during storage. *Food science & nutrition*, *4*(6), 818-827.

Obadoni, B.O. and Ochuko, P.O. (2001). Phytochemical studies and comparative efficacy of the crude extracts of some homeostatic plants in Edo and Delta States of Nig. Glo. J. Pure Appl. Sci. 8: 203-208.

Odedeji, J. O. and Adeleke, R. O. (2010). Pasting characteristics of wheat and sweet potato flour blends. *Pakistan Journal of Nutrition.* 9(6): 555-557.

Oduro, I., Ellis, W. O., Nyarko, L., Koomson, G. and Otoo, J. A. (2001). Physicochemical and pasting properties of flour from four sweet potato varieties in Ghana. In *Proc. of the 8th ISTRC-AB, Symp. Ibadan, Nigeria*. 142-145.

Oke, M. O. and Bolarinwa, I. F. (2012). Effect of Fermentation on Physicochemical Properties and Oxalate Content of Cocoyam (Colocasia esculenta) Flour. *ISRN Agronomy*.1-4.

Okezie, B. O. and Bello, A. B. (1988). Physicochemical and functional properties of winged bean flour and isolate compared with soy isolate. *Journal of Food science*. *53*(2): 450-454

Okonkwo, S. I. and Opara, M. F. (2010). The analysis of bambara nut (Voandzeia subterranea (L) Thouars) for sustainability in Africa. *Research Journal of Applied Science*. *5*(6): 394-396.

Omueti, O., Otegbayo, B., Jaiyeola, O. and Afolabi, O. (2009). Functional properties of complementary diets developed from soybean (Glycine Max), groundnut (Arachis Hypogea) and crayfish (Macrobrachium Spp). *Electronic Journal of Environmental, Agricultural & Food Chemistry*. 8(8): 563-573.

Onu, P. N. and Madubuike, F. N. (2006). Effect of raw and cooked wild cocoyam (Caladium bicolor) on the performance of broiler chicks. *Agricultura Trop. Et Subtropica*. 39: 268-272.

Onwuka, G. I., and Onwuka, N. D. (2005). The effects of ripening on the functional properties of plantain and plantain based cake. *International Journal of Food Properties, 8*(2), 347-353.

Osagie, A.U. (1998). Antinutritional Factors. In: Nutritional Quality of Plant Foods. Ambik Press Ltd, Benin City, Nigeria. 1-40; 221-244.

Osungbaro, T. O. (1990). Effect of differences in variety and dry milling of maize on textural characteristics of ogi (fermented maize porridge) and agidi (fermented maize meal). *Journal of the Science of Food and Agriculture*. 52(1): 1-11.

Patel, K., Gadewar, M., Tahilyani, V. and Patel, D. K. (2012). A review on pharmacological and analytical aspects of diosgenin: a concise report. *Natural Products and Bioprospecting*. 2(2): 46-52.

Polycarp, D., Afoakwa, E. O., Budu, A. S. and Otoo, E. (2012). Characterization of chemical composition and anti-nutritional factors in seven species within the Ghanaian yam (Dioscorea) germplasm. *International Food Research Journal.* 19 (3): 985-992.

Poornima, G. N. and Ravishankar, R. V. (2009). Evaluation of phytonutrients and vitamin contents in a wild yam, Dioscorea belophylla (Prain) Haines. *African Journal of Biotechnology*. *8*(6): 971-973.

Pramila, S. S., Kumar, A. and Raghuvanshi, R. (1991). Nutrient composition of some uncommon foods consumed by Kumaon and Garhwal hill subjects. *Journal of food science and technology*, *28*(4), 237-238.

Rajyalakshmi, P. and Geervani, P. (1994). Nutritive value of the foods cultivated and consumed by the tribals of South India. *Plant Foods for Human Nutrition*. *46*(1): 53-61.

Sanful, R. E. and Engmann, F. N. (2016). Physico-chemical and pasting characteristics of flour and starch from Aerial Yam. *American Journal of Food Science and Nutrition*. *3*(1): 1-7.

Sanni, L. O., Kosoko, S. B., Adebowale, A. A. and Adeoye, R. J. (2004). The influence of palm oil and chemical modification on the pasting and sensory properties of fufu flour. *International Journal of Food Properties*. *7*(2): 229-237.

Tinkílíç, A. Uyaník, N. (2001). Spectrophotometric determination of the tannin contents of various Turkish black tea, beer and wine samples. *International journal of food sciences and nutrition*. *52*(3): 289-294.

Udensi, E. A., Oselebe, H. O. and Iweala, O. O. (2008). The investigation of chemical composition and functional properties of water yam (Dioscorea alata): Effect of varietal differences. *Pakistan Journal of Nutrition*. *7*(2): 342-344.

Vernier, P., Orkwor, G. C. and Dossou, A. R. (2003). Studies on yam domestication and farmers' practices in Benin and Nigeria. *Outlook on Agriculture*. *32*(1): 35-41.

Victor, I. A., Oguntuase, S. O. and Vincent, O. S. (2013). Physico-chemical properties of complementary food from malted quality protein maize (Zea mays L.) and defatted fluted pumpkin flour (Telfairia occidentalis Hook, F). *Food and public Health*. *3*(6): 323-328.

Webster, J., Beck, W. and Ternai, B. (1984). Toxicity and bitterness in Australian Dioscorea bulbifera L. and Dioscorea hispida Dennst. from Thailand. *Journal of Agricultural and Food Chemistry*. *32*(5): 1087-1090.

Wojcikowski, K., Wohlmuth, H., Johnson, D. W. and Gobe, G. (2008). Dioscorea villosa (wild yam) induces chronic kidney injury via pro-fibrotic pathways. *Food and chemical toxicology*, *46*(9): 3122-3131.

Yang, D. J., & Lin, J. T. (2008). Effects of different storage conditions on steroidal saponinsin yam (Dioscorea pseudojaponica Yamamoto) tubers. *Food Chemistry*. *110*(3): 670-677.