International Journal of Food Science and Nutrition
ISSN: 2455-4898, Impact Factor: RJIF 5.14
www.foodsciencejournal.com
Volume 2; Issue 4; July 2017; Page No. 23-28

Effects of pre-treatment and drying methods on the pasting characteristics, amylose content and colour of Aerial Yam (*Dioscorea bulbifera)* flour

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Abstract
The effects of various pre-treatments, solar and oven drying on the pasting characteristics, amylose content and colour of the aerial yam flours were evaluated. Flours were obtained from aerial yam (*D. Bulbifera)* by peeling, grating, steaming, and boiling, oven/solar drying, milling and sieving. The flours obtained were evaluated for their pasting characteristics, amylose content and colour. Between the two drying methods, the flour samples had pasting characteristics ranging from 51.55-94.80°C pasting temperature, 1.13 to 27.85 min pasting time, 6.50-57.00 peak viscosity, 0.50-46.00BU final viscosity, 6.50-57.00BU holding strength, -1.00-13.50BU breakdown and -18.00-3.00 BU setback viscosity. The yam flour samples had amylose and amylopectin contents ranging from 25.00-31.00 and 69.0-75.0 respectively. In all the pasting parameters measured, the oven dried samples obtained lower values in all the pre-treated samples except for the breakdown and setback viscosities. The high amylose content of the study sample indicates its potential for use in starch based products such as breakfast cereals. Overall pre-treatment did not improve lightness whiles steaming showed potential for inhibiting non-enzymatic browning. Oven drying showed increases in yellowness whiles solar drying increased redness indicating a high potential for non- enzymatic browning.

Keywords: amylopectin, final viscosity, peak viscosity, retrogradation, starch

1. Introduction

Yam has been recorded to have originated from Africa and Asia before spreading to other parts of the world [1] and it is an important tuber crop and staple food for millions of people in many tropical and subtropical countries. Yams are generally grown for their tubers or storage organs, which may be subterranean e.g. *D. Rotundata*, *D. Alata* or aerial e.g. *D. Bulbifera* and serve a dual agricultural function as source of food and planting material [1, 2, 3].

Dioscorea bulbifera is recorded to be an unpopular yam among the edible yam species which unlike the traditional yam produces aerial bulbis that looks like potatoes hence the name aerial/air potatoes [4]. This species of yam is consumed by a small number of communities and is generally underutilized for a number of reasons. In Ghana, the *Dioscorea bulbifera* is distributed throughout the ten regions and appear in both edible and inedible form. The inedible grows wild whiles the edible are cultivated. Predominantly, they are grown on large scale in the North, Upper West and Upper East regions and only consumed during the famine season.

However, there is a lot of potential for *D. bulbifera* in food product development, thus information about the effects of various processing methods on its quality characteristics is essential in promoting its use. The objective of this study was to investigate the effects of different processing methods on the flour quality of the aerial yam.

2. Materials and methods

Source of materials

D. bulbifera was obtained from farmers in Tamale, the Northern Region of Ghana. The samples were sent to the Crops Research Institute of the Council for Scientific and Industrial Research at Fumesua in the Ashanti region of Ghana for laboratory analysis.

Pre-treatment and preparation of dioscorea bulbifera flour

By simple randomization between ten and twenty bulbis were selected, washed, peeled and dried. About 12,000 g of the sample were washed, peeled, sliced into 2 cm thick slices and divided into four groups. Two out of the four groups were subjected to two different treatments (steaming and boiling) after which it was further divided into two groups each. One group was solar dried and the other oven dried. With the remaining two groups, one group was left fresh and further divided into two for oven drying and solar drying while the other group was grated and further divided into two for oven drying and solar drying as shown in Figure 1.

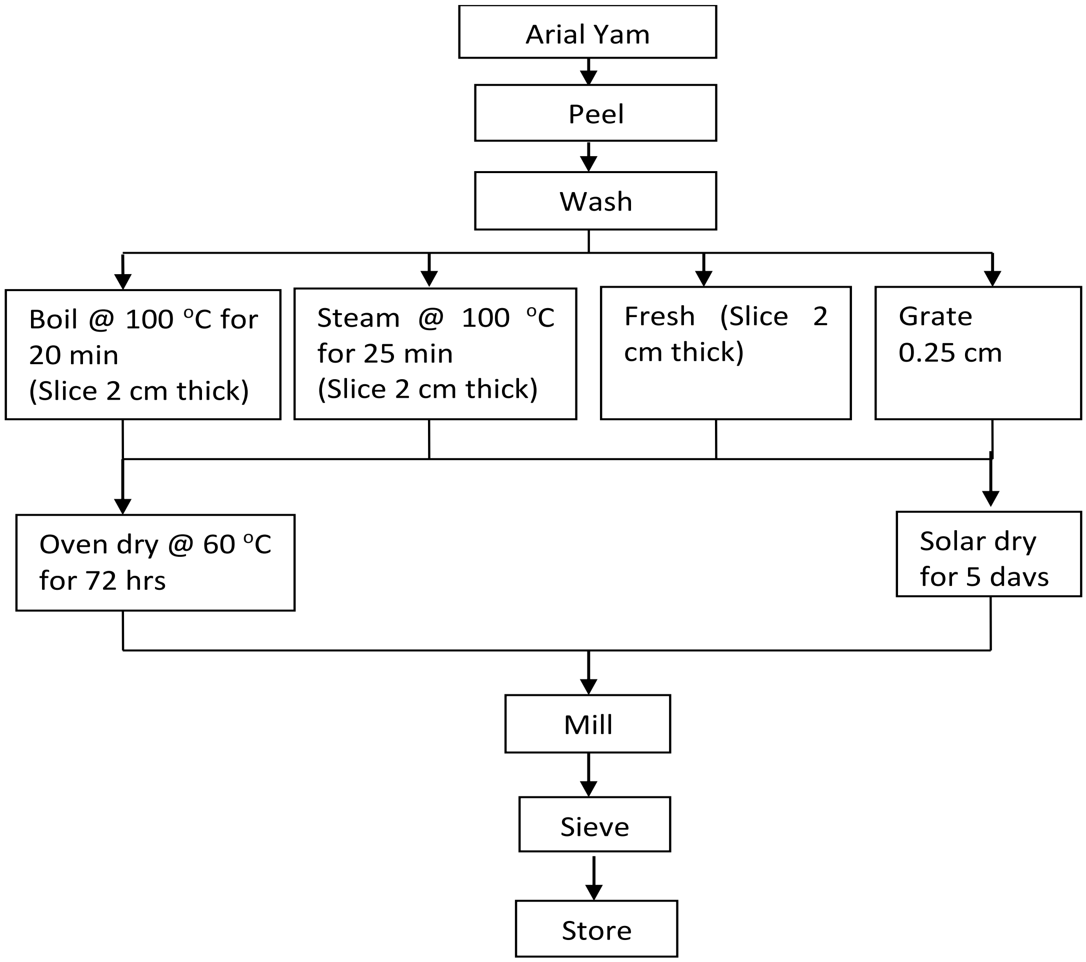

Fig 1: Flow chart for flour preparation for solar and oven drying

Boiling: where the yam slices were placed in a rice cooker of boiling water and boiled at 100ºC for 20 min. Steaming: The slices were placed in a colander over boiling water and steamed at 100ºC for 25 min. Grating: The slices were grated with a local grater into 0.25 cm thin strips. Samples to be oven dried were dried at 60ºC for three days, milled and sieved with a 0.25 µm sieve and stored in a polyethylene bag for further analysis. Samples to be solar dried were dried between 4 and 5 days (Plate 1), milled with a hammer mill

Fig 1: Yam samples in solar dryer

(Retsch Adda Antriebstechnik, GMBH 63322 Rodermark), sieved and stored in a polyethylene bag for further analysis.

Determination of pasting characteristics

The pasting characteristic of the flour samples were determined using Brabender Viscograph instrument (802526 versions 2.3.16). The moisture content of each flour sample was determined with an electronic moisture analyser (Sartorius MA 45). The moisture value obtained was inputted into the software of the Brabender Viscograph, which automatically indicates the weight of flour sample to use and the amount of distilled water to be added to form slurry. About 40 g of flour (10% moisture level) was mixed with 420 ml of distilled water in a sample canister. The sample was thoroughly mixed and the slurry set into a stainless steel canister of the instrument and heated at a rate of 1.5ºC/min by means of a thermo-regulator at a speed of 75rpm. The initial temperature was 50ºC and when the suspension attained 95ºC, the suspension was held constant for 15 min (first holding period) as stirring continued. The paste was then cooled to 50ºC at a rate of 1.5ºC/ min and held for another 15 min (second holding period). The process lasted for 90 min and the following parameters were read from the print out of the Brabender Viscograph. Corresponding values for Pasting temperature, Pasting time, Peak viscosity (Brabender Units-BU), Peak temperature, Peak time, Viscosity at 95ºC (BU), Viscosity after 15 min at 95ºC (BU), Viscosity at 50ºC (BU), Viscosity after 15 min at 50ºC (BU), Paste stability at 50ºC (BU), Paste stability at 95ºC (BU) Setback viscosity (BU) and

Breakdown viscosity (BU). Paste stability at 95ºC and paste stability at 50ºC were calculated as the difference between viscosity at 95ºC and viscosity after 15 min at 95ºC and the difference between viscosity at 50ºC and viscosity after 15 min at 50ºC respectively.

Determination of amylose content

The methods of (5, 6) were used.

Colour measurement

The colour of the flours was measured using a Minolta portable chroma-metre. The hunter lab colour coordinates system L* a* and b* values were recorded and the Light index was calculated as (100/0).

Statistical analysis

Data was analysed using Minitab (14th version). Analysis of variance (ANOVA) was used to test for significant differences between the means.

3. Results and Discussion

Effect of pre-treatment and drying on pasting properties of aerial yam flour

The results of the effect of pre-treatment and drying on the pasting properties of aerial yam flour is presented in Table 1.

Table 1: Effect of pre-treatment and drying on pasting properties of *D.* bulbifera

Samples	Pasting Temperature (ºC)	Pasting Time (min)	Peak Viscosity (BU)	Final Viscosity (BU)	Holding Strength (BU)	Break down Viscosity (BU)	Setback Viscosity (BU)
DBBO	86.20^{a}	25.33^{cd}	25.00^{bc}	0.50^{a}	11.50^{b}	13.50^{b}	-11.00^{ab}
DBFO	85.50^{a}	24.30^{c}	57.00^{d}	46.00^{c}	57.00^{e}	0.00^{ab}	-11.00^{ab}
DBGO	91.25^{a}	28.25^{cd}	46.50^{de}	41.00^{bc}	46.50^{d}	0.00^{ab}	-5.50b^{c}
DBSO	94.80^{a}	32.00^{d}	13.00^{ab}	1.00^{a}	14.00^{b}	-1.00^{a}	-13.00^{ab}
DBBS	53.0^{b}	2.20^{b}	6.50^{a}	9.50^{a}	6.50^{a}	0.00^{ab}	3.00^{c}
DBFS	90.90^{a}	27.85^{cd}	45.50^{de}	44.50^{c}	45.50^{d}	0.00^{ab}	-1.00^{bc}
DBGS	89.50^{a}	27.05^{cd}	43.00^{de}	32.00^{b}	43.00^{d}	0.00^{ab}	-11.00^{ab}
DBSS	74.80^{c}	17.10^{a}	35.00^{cd}	5.00^{a}	23.00^{c}	12.00^{ab}	-18.00^{a}

Means on the same column sharing the same superscript are not significantly different (P<0.05) BU- Brabender Unit
Samples with same letters are not significantly different (p<0.05) DBGS = *Dioscorea bulbifera* grated solar dried, DBBS= boiled solar dried, DBSS, = steamed solar dried, DBFS= fresh (control) solar dried, DBGO= grated oven dried, DBBO= boiled oven dried, DBSO= steamed oven dried and DBFO= fresh oven (control) dried.

Pasting properties of flour are reported to be essential indices in predicting the pasting behaviour during and after cooking [7 in 8]. They are the most commonly assessed set of quality characteristic possibly because the methods are well established and have been proven to be a reliable predictor of flour quality [9].

Effect of pre-treatment on pasting properties of aerial yam flour

The pasting temperature is the temperature at which the viscosity starts to rise [10, 11]. The pasting temperatures of pre-treated yam flours in this study varied significantly at p<0.05, and ranged between 53.0 to 86.20°C, 89.50 to 91.25°C and 74.80 to 94.80°C with boiling having the lowest range and steaming the highest.

Pasting time provides an indication of the minimum time required to cook a given food sample. All the study samples needed a little more time to cook with exception of the boiled solar dried sample which took 2 min 20 sec to cook. Pasting time values ranging between 2.20 to 25.33 min, 27.05 to 28.25 min and 17.10 to 32.00 min were observed for boiling, grating and steaming respectively. The boiled flours had the lowest pasting time (2.20 to 25.33 min) and pasting temperature (53.0 to 86.20°C); this implies it would be most suitable for the production of foods that require shorter processing time.

Peak viscosity indicates the water binding capacity of starch [12, 13 in 14], that is its ability to form a paste. It is measured as the highest value of viscosity attained by the paste during the heating cycle (25-95°C). The peak temperatures of yam flours showed significant difference at p<0.05. Boiling, steaming and grating had 6.50 to 25.00, 13.00 to 35.00 and 43.00 to 46.50°C respectively. The values observed in this study were lower than the values of 112.38 to 284.82°C for fresh and cooked trifoliate yam flour as recorded by Abiodun *et al.* (2013) and 79.58 for *Dioscorea dumetorum* as recorded by [9]. Peak viscosity observed for the fresh yam flour in this study ranged between 45.50 to 57.00°C. Increase in viscosity of gelatinised food is said to be more dependent on the starch content of the product [15]. The differences observed between the study samples and reports by other authors could be due to differences in variety. Aerial yam, a known bulbis, even though a *dioscoreacea* is neither a root nor tuber and so may not exhibit the same characteristics as a typical root and tuber. The low starch content of the study samples indicates that they may not be suitable for product requiring high gel strength and elasticity as high viscosity is an indicator that a sample is suitable for high gel strength products [16].

Final viscosity indicates the ability of the flour to form a firm, visco- elastic paste or gel after cooking and cooling due to re-association of starch molecules [17]. It is the common parameter used to determine the quality of starch-based samples and is the viscosity after cooling cooked paste to 50°C. Grating had the least effect on the final viscosity of the flour (32.00 to 41.00 BU), followed by steaming (1.00 to 5.00 BU) and boiling (0.50 to 9.50 BU). The low final viscosities recorded for the study samples indicate their low resistance to shear stress during cooking and cooling.

Holding strength measures the ability of starch to remain undisrupted when yam paste is subjected to a long duration of high constant temperature during the process of cooking [18]. Lower holding strength was observed in the boiled (6.50 to 11.50 BU) and steamed (14.00 to 23.00 BU) flours indicating high cooking loss and inferior eating quality whiles higher values were observed for the grated (3.00 to 46.50 BU) and fresh (46.50 to 57.00 BU) samples indicating low cooking loss and good eating quality [19]. Values observed in this study agree with [20], who reported lower holding strength in boiled white trifoliate yam. Samples were subjected to a period of constant high temperature and mechanical shear stress during the holding period which disrupted the starch granules. It has been reported that the capacity of flour samples to withstand heating and shear stress is an important factor for many processes [17]. Significant differences ($p<0.05$) were observed between the pre-treated yam flour in relation to the fresh yam flour. Boiling and steaming resulted in lower holding strength of the flour.

Breakdown is a measure of susceptibility of cooked starch granules to disintegration and affects the stability of flour product. This means that, it is able to measure the ability of starch to break down during cooling. The flour samples in this study exhibited lower breakdown in viscosity. Significant differences existed in breakdown viscosities of all the pre-treated flours. Grating had the lowest (0.00 to 0.00 BU) and boiling the highest (0.00 to 13.50 BU) and were found to be within the range of 5.85 -78.10 RVU reported for pre-cooked white trifoliate yam flour (21). However, the values observed in this study for fresh flour samples were lower than values of 21.64 RVU and 69.17- 257.36 RVU reported by [21, 22] for fresh white trifoliate yam. Low breakdown values in the samples indicate high stability of the yam flour under hot conditions. It was reported by [16] that the higher the breakdown in viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking. This is an important factor for most food processing operations and a factor in describing the quality of starch gels.

Setback is an index of the tendency of the cooked flour to harden on cooling due to amylose retrogradation [23]. It measures the re-association of starch. The higher the setback value, the higher the retrogradation during cooling. The flour samples in this study exhibited lower setback in viscosity with the least observed in the steamed yam flour.

Higher values of setback have been reported by other researchers [9, 22]. Low setback values observed in the study samples indicate minimal amylose retrogradation as the paste is cooled and indicates its flour is more stable when cooked. The low set back values obtained for *D. bulbifera* may not make it suitable for pounded fufu that require high cohesive pastes. Conversely, the flours *may* be useful for products like complimentary foods, which require low viscosity and paste stability at low temperatures [24], it has been reported that pre-cooked flours have lower tendency to retrograde than fresh yam flours [22].

Steaming had the least effect on pasting temperature and pasting time and the highest effect on the final viscosity, breakdown and setback while grating had the least effect on peak viscosity, final viscosity and holding strength. Boiling on the other hand had the least effect on breakdown and setback and the highest effect on pasting temperature, pasting time, peak viscosity and holding strength.

Effect of drying on pasting properties of aerial yam flour

The two drying methods, oven and solar had varying effects on the pasting properties of the yam flours. With the exception of setback viscosity (-13.00 to 5.50 BU), oven drying was observed to have the least effect on temperature (85.50 to 94.80°C) and pasting time (24.30 to 32.00 min), holding strength (11.50 to 57.00 BU), peak (13.00 to 57.00 BU), final (0.50 to 46.00 BU) and breakdown (-1.00 to 13.50 BU) viscosities Conversely, solar drying had the least effect on temperature (53.0 to 90.90°C) and pasting time (17.10 to 27.85 min), holding strength (6.50 to 45.50 BU), peak (6.50 to 45.00 Bu), final (5.00 to 44.5 BU) and breakdown (0.00 to 12.00 BU) viscosities and the highest effect on setback viscosity (-18.00 to 3.00 BU). Solar drying exhibited lower pasting time and enabled the yam flour to swell faster**.** Overall solar dried samples required lower temperature and time to cook compared to the oven dried samples. This implies it would be most suitable for the production of foods that require shorter processing time. In all the pasting parameters measured, the solar drying had lower values for all the pre-treated samples except for the breakdown and setback viscosities.

Effect of pre-treatment and drying on amylose content of aerial yam flour

The results of the effect of pre-treatment on amylose content of aerial yam flour are presented in Table 2.

Table 2: Amylose and amylopectin content (%) of flours from *D. bulbifera*

Sample	Amylose (%)	Amylopectin %	Amylose/Amylopectin Ratio
DBFO	30.0	70.0	0.43
DBGO	31.0	69.0	0.45
DBBO	26.5	73.5	0.36
DBSO	28.5	71.5	0.40
DBFS	29.5	70.5	0.42
DBGS	28.5	71.5	0.40
DBBS	28.0	72.0	0.39
DBSS	25.0	75.0	0.33

DBGS= *Dioscorea Bulbifera* grated solar dried, DBBS= boiled solar dried, DBSS, = steamed solar dried, DBFS= fresh(control) solar dried, DBGO= grated oven dried, DBBO= boiled oven dried, DBSO= steamed oven dried and DBFO= fresh oven (control) dried.

The pre-treatment methods had different effect on the amylose and amylopectin contents of the yam flour. While grating had the least effect on the amylose content, steaming had the highest effect. Grated yam had the highest amylose content followed by the boiled and steamed yam samples in that order. The range of amylose fraction in the order grating, boiling and steaming was between 28.5 – 31.10%, 26.5 – 28.0 and 25.0% respectively. These results did not agree with findings of [25] who observed significantly higher amylose content in blanched cocoyam flour. However, the results agreed with observation by [26] in water yam, that blanched yam had lower amylose content than the unblanched. This may be attributed to the different drying method of sun drying used by [25] as against oven and solar for the present study. Blanching in tuber processing in general, is reported to decrease water soluble content such as starch due to leaching [26]. The amylopectin content ranged from 61.0 to 71.5%, 72.0 to 73.5% and 71.5 to 75.0% for the grated, boiled and steamed yam samples respectively.

Effect of drying on amylose content of aerial yam flour

Among the two drying methods, oven drying had the least effect on the amylose content of the yam samples while solar drying had the highest. In view of this, the yam samples dried in the oven had the highest amylose content (26.5 – 31.0%) followed by the solar dried yam samples (25.0 – 29.5%). The range of amylose content 25.0 – 29.5% and 26.5 – 31.0% were observed for oven dried and solar dried yam samples respectively.

On the other hand the opposite was observed with the amylopectin content. Yam flours generally have higher amylose contents than those from other root and tuber crops [27]. Amylose values of between 27.6 and 39.4% for *D. alata* have been reported by other researchers [28, 29, 30]. Obtained amylose content of 2.32 and more than 25% for wild yam species.

Amylose content of starch affects its swelling and hot paste viscosities [31]. As the amylose content increases, the swelling tends to be restricted and hot paste viscosity stabilizes [32]. Ikegwu *et al.* [33] reported that amylose content of flour and other component present has a bearing on pasting properties. Amylose content of yam starch is reported to be between 14-30% depending on the species. Moorthy [12] reported amylose content of 21.25% for *D. rotundata*, 21-25% for *D. cayenensis*, and 21-30% for *D. alata.* The amylose content of the study samples compared favourably with values reported by other authors. The study has shown that the drying methods affected the chemical composition of the dried yam due to the transformation that takes place. The disruption of the cellular/granular structure within the amorphous and crystalline domain by the different drying methods might have caused the differences in amylose content of the yam samples. This effect might have enhanced strong bond formation and increased the interaction between the water molecules thus facilitating the release of amylose.

Effect of pre-treatment and drying on the colour of the *Dioscorea bulbifera* flour

Colour is an important standard for starch quality especially for utilisation in the textile industries. It is one of the most important criteria of food and brightness, an essential indicator for many powders. Brightness of powder may be an indicator of its freshness or purity [34]. The development of colour due to enzymatic and non-enzymatic browning is one of the major problems that occur during processing of food materials.

The results of the colour parameters obtained from the oven and solar drying processes of various pre-treatments are presented in Table 3.

Table 3: Effect of pre-treatment and drying on the colour of the *Dioscorea bulbifera* flour

Oven	L*	a*	b*	Solar	L*	a*	b*
Fresh	77.69 ΔL= 1.82	-0.45 ΔL= 0.16	+19.14 ΔL=-17.24	Fresh	75.71 ΔL=+2.18	+1.22 ΔL=-0.93	+18.30 ΔL=-16.4
Grated	74.35 ΔL=+23.16	+0.49 ΔL=-0.2	-19.62 ΔL=-17.72	Grated	65.64 ΔL=+31.87	+2.78 ΔL=-2.49	+13.85 ΔL=-11.95
Boiled	76.78 ΔL=+20.73	-2.71 ΔL=2.42	+20.14 ΔL=-18.24	Boiled	66.67 ΔL=+30.84	+1.75 ΔL=-1.46	+16.45 ΔL=-14.55
Steamed	73.10 ΔL=+24.41	-1.38 ΔL=1.09	+17.91 ΔL=-16.01	Steamed	70.85 ΔL=+26.66	+1.01 ΔL=-0.72	+17.08 ΔL=-15.18

L axis indicates Lightness/darkness on a scale of 100/0, a axis indicates Red (+values)/green (-values), b axis indicates Yellow (+values)/blue (-values) -ΔL: standard is lighter than sample +Δa: sample is redder than standard +Δb: sample is yellower than standard. Calibration (standards): L=97.51, a=+0.29 and b=+1.90.

The pre-treatments had varying effects on the colour of the flour. Boiling and steaming significantly affected the brightness of the flour as indicated by the high L* values. Steaming had the least effect maintaining a more whitish colour of the flour while boiling had the highest effect. This implies that, steamed yam flour had a higher white intensity compared to the other samples with the exception of the fresh yam flour which showed a higher L* value than all the samples. The range of colour (L) values in the order of fresh, boiling, grating and steaming were, 75.71 – 77.69, 66.67 – 76.78, 65.64 – 74.35 and 70.85 – 73.10.

The grated flour samples had the highest redness indicated by a* value while the boiled yam flour exhibited the highest yellowness as indicated by the b* value (16.45 – 20.14). The pre-treatment methods had a significant effect ($P < 0.05$) on the L* values of all the yam flour samples. The a* and b* values varied significantly ($P < 0.05$) among the samples under the different pre-treatment methods. The light/white colour or appearance of the yam flour samples may be due to the effect of the pre-treatment methods on enzymatic/microbial activity. The various pre-treatment methods significantly ($p < 0.05$) affected the colour of the yam flour samples. The oven dried flours showed high L* and b* values than the solar dried flours while it had low b* values relative to the solar dried flours.

None of the flour samples had L* values comparable to commercial flours (L* value of 92.5). However it is worth noting that the aerial yam has a characteristic yellow colour and any reduction in its b* value (yellow intensity) could be attributed to bleaching as in the case of the steamed and boiled yam flour samples.

4. Conclusion

Data obtained on the pasting characteristics indicated that the different processing methods affected the yam flour quality.

On the whole, flours produced by solar drying after pre-treatment gave relatively lower values for all the pasting indicators measured except for breakdown and setback viscosities.

Pre-treated aerial yam flour could be explored in complimentary foods while a composite with wheat flour could also be utilised in bakery products.

5. References

1. Hahn SK. Yams *Dioscorea* species (Dioscoreacea) in Kambaska, K., Sahoo, S., and Prusti, A. Effect of plant growth regulator on in vitro micro propagation of 'bitter yam' (*Dioscorea hispida* Dennst). International Journal of Integrative Biology. 1995; 4(1):50-56.
2. Coursey DG. Yams An Account of the Nature, Cultivation and Utilization of the Useful Members of *Dioscoreacea.* Longmans: London, 1967.
3. Ile EI, Craufurd PQ, Battey NH, Asiedu R. Phases of dormancy in yam tubers (Dioscorea Rotundata). Annals of Botany. 2006; (1)97:497-504.
4. Igyor MA, Ikyo SM, Gernah DI. The food potential of potato yam (*Dioscorea Bulbifera*). Nigerian Food Journal. 2004; 22:209-215.
5. Williams VR, Wu WT, Tsai HY, Bates HG. Varietal difference in amylose contents of rice starch. Journal of Agriculture and Food Chemistry. 1985; 8:47-48.

6. Juliano BO, Hicks PA. Rice functional properties and rice food products. Food Reviews International. 1996; 12:71-103.
7. Richard J. Quality aspects of Tropical Root Crop Starches. In; proceeding of 9th symposium International Soc. Tropical Root Crops. 1991, 89-93.
8. Ogunlakin GO, Oke MO, Babarinde GO, Olatunbosun DG. Effect of drying methods on proximate composition and physico-chemical properties of cocoyam flour. American Journal of Food Technology. 2012; 7(4):245-250.
9. Eke-Ejiofor J. Owuno F. Functional and Pasting Properties of Wheat/ Three leaved Yam (*Dioscorea dumetorum*) composite flour blend. Global Research Journal of Agricultural and Biological Sciences. 2012; 3(4):330-335.
10. Swinkels JJM. Sources of Starch, its Chemistry and Physics. In: Starch conversion. G. M. A. Van Beynum, J. A. Roels, (Ed). Marcel Dekker: Orlando, FL, USA. 1985, 15-46.
11. Liang X, King JM. Pasting and crystalline property differences of commercial and isolated rice starch with added amino acids. Journal of Food Science. 2003; 68 (3):832-838.
12. Moorthy SN. Physicochemical and functional properties of tropical tuber starches. 2002; 54:559-592.
13. Mahasukhonthachat K, Sopade PA, Gidley MJ. Kinetics of starch digestion in sorghum as affected by particle size. Journal of Food Engineering. 2010; 96:18-28.
14. Oduro I, Ellis WO, Argeetaoy SK, Ahenkora K, Otoo JA. Pasting characteristics of starch from new varieties of sweet potato. Trop. Sci. 2000; 40:25-28.
15. Adeyemi IA, Beckley O. Effect of period of maize fermentation and souring on chemical properties and amylograph pasting viscosities of ogi. Cereal Science. 1986; 4:353-360
16. Adebowale A.A, Sanni LO, Awonorin SO. Effects of texture modifiers on the physicochemical and sensory properties of dried fufu. Food Sci. and Tech. Inte. 2005; 11(5):373-382.
17. Newport Scientific. Applications manual for the Rapid visco^{TM} analyzer Using thermocline for windows. Newport Scientific Pty Ltd. Australia. 1998, 2-26.
18. Jimoh KO, Olurin TO, Aina JO. Effect of drying methods on the rheological characteristics and colour of yam flours. African Journal of Biotechnology. 2010; 8(10):2325-2328.
19. Bhattacharya M, Zee SY, Corke rs H. Physicochemical properties related to quality of rice noodles. Cereal Chemistry.1999; 76:861-867
20. Adebowale AA, Sanni LO, Awonorin SO. Effects of texture modifiers on the physicochemical and sensory properties of dried fufu. Food Science and Technology International. 2005; 11(5):373-382.
21. Abiodun OA, Adegbite JA. Oladipo TS. Effect of soaking time on the pasting properties of two cultivars of trifoliate yam (*Dioscorea dumetorum*) flours. Pakistan Journal of Nutrition. 2009; 8(10):1537-1539.
22. Abiodun OA, Akinoso R, Oladapo AS, Adepeju AB Influence of soaking method on the chemical and functional properties of trifoliate yam (Dioscorea dumetorum) flours. Journal of Root Crops. 2013; 39(1):84-87.
23. Aribisala OA, Olorunfemi BN. Proceedings of the first meeting of the Action Committee on raw materials Research and Development Council, Lagos: Nigeria. 1989, 131-138.
24. Oduro I, Ellis WO, Nyarko L, Koomson, G, Otoo JA. Physicochemical and pasting properties of flour from four sweet potato varieties in Ghana. Proceedings of the Eigth Triennial Symposium of the International Society for Tropical Root Crops (ISTRC-AB), Ibadan, Nigeria. 2001, 12-16.
25. Ejoh SI, Obagtolu VA, Olanipekun OT, Farinde EO. Extending the use of an underutilized I: Physico chemical and Pasting Properties of cocoyam (*Xanthosoma sagittifolium*) flour and its suitability for making biscuits. African Journal of Food Science. 2013; 7(9):264-273.
26. Harijono TE, Saputri DS. Kusnadi J. Effect of Blanching on properties of water yam (*Dioscorea Alata*) flour. Advance Journal of Food Science and Technology. 2013; 5(10):1342-1350.
27. Baah FD, Maziya-Dixon B, Asiedu R, Oduro I. and Ellis, W. O. Physicochemical and pasting characteristics of water yam (*Dioscorea spp*) and relationship of eating quality of pounded yam. Journal of Food, Agriculture and Environment. 2009; **7**(2):107-112.
28. Hoover R. Composition, molecular structure, and physicochemical properties of tuber and root starches: a review. Carbohydrates Polymers. 2001; 45:253-267.
29. Peroni FHG, Rocha TS, Franco CML. Some structural and physicochemical characteristics of tuber of root starches. Journal of Food Science and Technology. 2006; 12(6):505-513.
30. Sahore DA, NG. Amani Composition of wild yams of Cote d'Ivoire, Tropical Science. 2005; 45(3):110-113.
31. Shimelis E, Meaza M, Rakshit S. Physico-chemical properties, pasting behaviour and functional characteristics of flour and starches from improved bean (*Phaseolus vulgaris* L.) varieties grown in East Africa. E.J. Agric. Eng. Int. 2006; 8:1-18.
32. Schoch TJ, Maywald EC. Preparation and properties of various legume starches. Cereal Chemistry. 1968; 45:564-573.
33. Ikegwu OJ, Okechukwu PE, Ekumankana EO. Physico-chemical and pasting characteristics of flour and starch from Achi Brachystegia eurycoma seed. Journal of Food Technology. 2010; 8(2):58-66.
34. Abano EE, Ma H, Qu W. Effects of pre-treatment on the drying characteristics and chemical composition of garlic slices in a convective hot air dryer. Journal of Agriculture and Food Technology. 2011; 1(5):50-58.