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QUALITY VARIABILITY OF DOUGHMEAL FROM TRADITIONAL CASSAVA STARCH AS INFLUENCED BY DIFFERENT DRYING METHODS

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ABSTRACT

The study aimed at investigating the influence of drying methods on the physicochemical properties of dried cassava starches and quality attributes of doughmeals prepared from such starches. The results revealed that there were variations in the pH (6.18-6.5), total titratable acidity (0.28-0.84 %), water absorption capacity (1.7-1.73 g/g) and bulk density (0.65-0.82 g/cm^3) of the freeze dried, oven dried, sundried and freshly-prepared starches. The colour characteristics revealed that the lightness index (L*-value) decreased due to drying operations on the starches. All the pasting factors were affected by the drying methods with variations in the pasting temperature (70.95-72.14 ^{o}C), peak viscosity (3748-4476 RVU), breakdown viscosity (2225-2711 RVU) and final viscosity (2063-2514 RVU). The drying operations caused a decrease in residual cyanide content in all the samples ranging from 26.72 mg/Kg in fresh cassava roots to 3.06 mg/Kg in doughmeal from sundried starch. There was a variation in the softness index of the doughmeals (21.24-27.43 mm) while the sensory quality rating of the doughmeal showed that the product from freshly prepared cassava starch was rated the highest in terms of aroma, colour and overall acceptability while the one from freeze dried starch was rated the highest in terms of taste and mouldability. The study has revealed that doughmeal from freshly prepared cassava starch was the most acceptable while the one prepared from freeze dried starch was rated second best.

Keywords: Doughmeal, Cassava starch, Quality, Freeze drying, Sundrying, Oven drying.

INTRODUCTION

Cassava (*Manihot esculenta Crantz*) is a crop that is widely grown and utilized in the tropics. It is an important biomass, highly recognized as food security and emerging industrial crop in Nigeria. The crop is highly useful for food, animal feed, and energy (ethanol) production. Nigeria is currently the largest producer of cassava in the world with an annual estimated output of more than 54 million tonnes of the root (FAOSTAT, 2014) and it plays a dominant role in the rural economy of the people (Timothy and Adeoti, 2006). In Nigeria, a greater percentage of cassava roots are being used for processing traditional food commodities such as *gari, fufu, lafun, pupuru*, edible starch, etc., while appreciable quantity is also being used for industrial production of high quality cassava flour, starch and ethanol.

Cassava roots are known to experience rapid postharvest deterioration and this usually prevents their storage in the fresh state for more than 72 hours (Booth, 1976; Owiti *et al*., 2011). It has been observed that the deterioration of cassava roots is related to two separate processes: physiological and microbiological deterioration (Acedo and Acedo 2013; Njoku *et al*., 2014). Owing to the poor storability characteristics of cassava root in its fresh or unprocessed state, the produce is usually processed into more storable forms, one of which is the cassava starch.

The consumption of this traditional starch, in the form of doughmeal, is predominant among the people of Delta, River, and Igbo-speaking states of Nigeria. The traditional starch, usually obtained through the wet-milling of cassava roots, also has a short shelf life as it cannot be stored for more than 4-6 days. Sundrying is one of the methods of improving the shelf life of this traditional cassava starch and this is being practiced at various household levels (Chukwuemeka, 2007). The sundrying operation itself usually takes about 3-5 days for sufficient drying depending on the shape, size and composition of the food commodity involved as well as the prevailing temperature, humidity and velocity of the air (Ihekoronye and Ngoddy, 1985).

This study was therefore designed to evaluate the effects of other drying methods such as oven-drying and freeze drying on the physicochemical properties of cassava starch as well as the quality attributes of doughmeal prepared from the starch.

MATERIALS AND METHODS

Materials

Fresh cassava roots (TMS 30572) were got from FUTA Teaching and Research Farm, Obanla, Akure, Nigeria. The variety was chosen on the basis of its high potential of product yield (Dixon *et al*., 2012).

Methods

Starch Extraction from Cassava

Twenty kilograms of the cassava roots were taken and peeled with clean kitchen knife and washed with potable water at room temperature. The washed tubers (about 15.8 Kg) were conveyed to the grating machine to obtain grated pulp. The grated pulp was put into a basket over a bowl covered with a piece of clean muslin cloth. Water was poured over the basket which facilitated the washing out of the starch which was then filtered through the cloth into the bowl. This led to the recovery of milky starch. The milky starch eventually obtained was left for 24 hours for it to settle (sediment) followed by pouring away of the supernatant to give the starch slurry which is traditionally referred to as cassava starch.

Drying of Extracted Cassava Starch

The extracted cassava starch was divided into four portions and three were subjected to different drying operations (sundrying, oven drying and freeze drying). The fourth portion was not dried but was regarded as the control representing the fresh traditional cassava starch.

Sun-drying of the extracted starch: Open air drying of starch was carried out by spreading the starch slurry in thin layer on an aluminum tray. The starch was allowed to dry under this condition until the surface cracked and touching of the cake caused it to crumble into powder and this took 3-4 days.

Oven–drying of the extracted starch: The second portion was dried mechanically, by spreading the thin starch slurry on an aluminum foil which was then placed in an oven tray and allowed to dry at 55±2 °C for 12 h.

Freeze–drying of the extracted starch: The third portion was freeze-dried using a freeze dryer (United Scientific, Virtis Bench Top freeze dryer, Gerdiner, NY) by placing the slurry in a dish and freeze dried at a temperature of -40 to -112 °C for 72 h.

The different portions of the dried starch were then milled separately by making use of a milling machine which ground it into flour which was then stored for subsequent analyses.

Evaluation of Physicochemical Characteristics of Differently Dried Cassava Starches

The physicochemical characteristics of differently dried cassava starches determined were pH, total titratable acidity (TTA), water absorption capacity (WAC) and bulk density.

The pH was determined using pH meter (model WPA CD70, India). After each determination, the pH probe was rinsed with distilled water and blotted dry (Sadler and Murphy, 2010).

The TTA was determined by taking 2g of each sample into a separate conical flask and 20ml of distilled water was added to each sample and shaked properly on addition of indicator (phenolphthalein).The mixture was further shaken properly and titrated against 0.1M NaOH and the percentage acidity was expressed as lactic acid equivalent (Sadler and Murphy, 2010).

The WAC was evaluated by the method described by (Sathe and Salunkhe, 1982). Approximately 1 g of the sample was weighed into a tarred 20 ml centrifuge tube and 10 ml of distilled water was added. The suspension was stirred for 5min. The suspension was then taken to the centrifuge at 3500g for 30 min. The supernatant was decanted and the volume of water was determined, the water absorbed by the dried

starch was calculated as the difference between the initial water used and the volume of supernatant obtained after centrifuging. The result was expressed as percentage g/g of water absorbed by the starch.

The bulk density was determined by the method described by Akpapunam and Markakis (1981). Twenty grammes of the starch samples was put into 100ml measuring cylinder. The measuring cylinder was then tapped continuously on a laboratory table until a constant volume was obtained. Bulk density (g/cm^3) was calculated using by dividing the weight of sample by the volume of sample after tapping.

Determination of Colour Characteristics of the Starch Samples

The colour of the cassava starch samples was measured using a colour measuring instrument (ColorTec-PCM, model SN 3000421, USA) and the values expressed on the L*, a*, b* tristimulus scale. The L*-value indicates lightness while the positive *a** value indicates the red direction, negative *a** value is the green direction; positive *b** value is the yellow direction, and negative *b** value is the blue direction (Wojdylo *et al.*, 2009). The instrument was first standardized (L*=93.24, a*=0.96, b*= -2.75) with a Business Xerox 90 g/m² white paper. About 3g of flour sample was put in a clean paper and the colour meter was placed on the sample by allowing the sensor to touch the sample. The reading was taken directly and the results from three replicates per sample were averaged. (McGuire, 1992).

Determination of Pasting Properties of the Starch Samples

Pasting properties of the starch samples was carried out using a Rapid Visco Analyser, RVA (Newport-Scientific, 1996). The moisture content of all starch samples was determined and 3g of each of the starch sample was weighed into the canister at different time. Series of operational procedures were followed and a programmed heating and cooling cycle was then used, where the slurry was held at 50^{o}C for 1 min, heated to 95^{o}C at 6^{o}C/min, held at 95^{o}C for 5 min, finally cooled from 95 to 50^{o}C at 6^{o}C/min, and held at 50^{o}C for 2 min. The parameters recorded from the pasting curve include the pasting temperature, peak viscosity, time to peak, breakdown, holding strength or trough, setback, and final viscosity. All measurements were replicated thrice.

Preparation of Doughmeal from Starch Samples

Doughmeal was prepared from each cassava starch sample. Each starch sample was reconstituted with boiling water in the ratio of 1:4 (starch/water, w/v) to form a thick paste. This was carried out by pouring some quantity of starch into boiling water and then stirred using a wooden paddle. This was continued until the whole starch poured has formed a thick paste and there was no lump. Some quantity of palm oil was added to the already formed thick paste to give it a yellowish colouration followed by proper stirring and was then left to heat up for about 3 minutes for proper cooking. Depending on the texture, more water or

starch may be added to form a smooth thick paste after thorough stirring. This food product eventually obtained is called starch doughmeal which was then kept hot in a cooler.

Residual Cyanide Determination of the Starch Samples

Determination of residual cyanogenic glycoside content of the samples was done by the alkaline titration method of the AOAC (1990). In this method, 200 cm^3 of distilled water was added to 1.0 g of each of the sample flour in triplicate in an 800 cm^3 capacity distillation flask. The flask was fitted for distillation and allowed to stand for 2 hours, for autolysis to take place. An antifoaming agent (silicon oil) was then added. Steam distillation was carried out and 150 cm^3 of the distillate collected into 250 cm^3 capacity conical flask containing 20 cm^3 of 2.5% sodium hydroxide and then diluted to the mark with distilled water. To 100 cm^3 of diluted distillate containing the cyanogenic glycoside, 8.0cm^3 of 6N NH_4OH solution and 2.0 cm^3 of 5% potassium iodide were added. This was titrated against 0.02N silver nitrate ($AgN0_3$) solution using a 10 cm^3 microburette. The end-point was noted as a permanent turbidity against a black background. Titre values were obtained and used to calculate residual cyanide contents.

Determination of Softness Index of Doughmeal Prepared from Different Cassava Starches

The softness index of starch doughmeal prepared from starches were evaluated using Cone Penetrometer (Benchtop model, Pioden Controls Ltd., UK). Some quantity of freshly prepared starch doughmeal sample was scooped into the standard cup attached to the penetrometer. Upon cooling, the centre of the cup was positioned perpendicularly to the falling probe of the penetrometer. The probe was finally released to fall freely from a standard distance to penetrate into the product in the cup. The total depth of penetration of the probe was then read on the penetrometer scale and the reading, expressed in millimetre (mm), was taken as an index of the product softness.

Sensory Evaluation of Doughmeal Prepared from Different Cassava Starches

This was carried out to evaluate the level of acceptability and best sample that was preferred by the panelists. A 30-member panelist consisting of staff and students who were familiar with starch doughmeal were involved in the evaluation. Each of the panelists was asked to rate the samples on the basis of colour, taste, aroma, mouldability and overall acceptability using a nine-point hedonic scale (i.e. 9=like extremely; 8= like very much; 7= like moderately; 6= like slightly; 5= neither like nor dislike; 4= dislike slightly; 3= dislike moderately; 2= dislike very much; 1= dislike extremely) (Lawless and Heymann, 2010).

Statistical analysis

All determinations reported in this study were carried out in triplicates. In each case, a mean value and standard deviation were calculated. Analysis of variance (ANOVA) was also performed and separation of the mean values was by Duncan's Multiple Range Test at $p<0.05$.

RESULTS

The results for the pH, total titratable acidity (TTA), water absorption capacity (WAC) and bulk density are presented in Table 1. The pH of the starches ranged between 6.18 and 6.5 with freshly-prepared cassava starch (control) having the highest value while the sun-dried sample had the lowest. The pH of fresh cassava root was 6.5. The pH of the samples was generally acidic with significant differences at $p<0.05$ but drying operations significantly lowered the pH values.

The total titratable acidity of the starch samples ranged between 0.38 and 0.84% with oven-dried sample having the lowest value while fresh cassava root gave the highest. The water absorption capacity of the dried starch samples ranged between 1.7 and 1.73 g/g with no significant differences ($p<0.05$). The sundried sample however gave a slightly higher value than others. The bulk density of the starch samples ranged between 0.65 and 0.82 g/cm^3 with the sundried sample having the highest value while the freeze dried sample had the lowest.

Table 1: Physicochemical characteristics of differently dried cassava starches.

Source of sample	**Physicochemical characteristics[1]**			
	pH	**Total titratable acidity (TTA, %)**	**Water absorption capacity (g/g)**	**Bulk density (g/cm^3)**
Freeze-dried starch	6.30±0.17^{ab}	0.59±0.04^{b}	1.70±0.10^{a}	0.65±0.01^{b}
Oven-dried starch	6.42±0.09^{a}	0.38±0.01^{c}	1.70±0.10^{a}	0.78±0.03^{a}
Sun- dried starch	6.18±0.06^{b}	0.52±0.05^{b}	1.73±0.04^{a}	0.82±0.02^{a}
Freshly-prepared cassava starch (control)	6.50±0.10^{a}	0.82±0.03^{a}	NEV[2]	NEV
Fresh cassava root	6.50±0.05^{a}	0.84±0.12^{a}	NEV	NEV

[1]Mean value within the same column having the same letter are not significantly different at $p< 0.05$.
[2]NEV= Not Evaluated.

The colour characteristics of differently dried cassava starches are shown in Table 2. The lightness index (L*-value) of the starch samples were 92.44, 90.23, 89.87 and 94.85 for freeze-dried, oven-dried, sundried and freshly-prepared starch samples respectively; with significant differences at $p<0.05$. The effect of drying methods on the pasting properties of cassava starch samples is presented in Table 3. The pasting temperature of cassava starch from freeze-dried sample was the lowest (70.95^{o}C) while that from freshly-prepared cassava starch was the highest (72.14^{o}C). The peak viscosity of the cassava starches ranged between 3748 and 4476 RVU with sundried and freshly prepared starches having the lowest and highest values respectively

with significant differences ($p<0.05$). The breakdown viscosity of the cassava starches ranged between 2225 and 2711 RVU with sundried and freshly prepared starches having the lowest and highest values respectively. The final viscosity of freeze dried, oven dried, sundried and freshly-prepared cassava starches were 2154, 2514, 2063 and 2294 RVU respectively. The setback viscosity values obtained were 625, 783, 540 and 529 RVU for freeze dried, oven dried, sundried and freshly-prepared cassava starches respectively with significant differences ($p<0.05$).

Table 4 shows the residual cyanide content in different cassava starches and doughmeals prepared from them. The cyanide content of fresh cassava root was 26.72 mg/Kg while those of cassava starches were 3.79, 3.25, 3.26 and 4.55 mg/Kg for freeze-dried, oven-dried, sundried and freshly-prepared starch samples respectively. Further reduction in the cyanide content (3.06-3.44 mg/Kg) was similarly observed in the doughmeals prepared from the respective starches. The softness index of doughmeals prepared from differently dried cassava starches is presented in Fig. 1. The softness index of doughmeal samples ranged between 21.24 and 27.43 mm with oven dried and freshly prepared doughmeal sample having the lowest and highest values respectively.

Table 2: Colour characteristics of differently dried cassava starches

Source of sample	**Colour index[1]**		
	L*	**a***	**b***
Freeze-dried starch	92.44±0.08[b]	85.44±0.01[a]	7.56±0.01[d]
Oven-dried starch	90.23±0.01[c]	87.86±0.01[b]	9.77±0.01[c]
Sun-dried starch	89.87±0.01[d]	85.67±0.01[a]	10.13±0.01[b]
Freshly-prepared cassava starch (control)	94.85±0.02[a]	83.86±0.01[d]	5.15±0.02[c]

[1]Mean value within the same column having the same letter are not significantly different at $p< 0.05$.

Table 3: Pasting properties of differently dried cassava starches.

Source of sample	**Pasting factor[1]**						
	Pasting temp (°C)	**Peak viscosity (RVU)[2]**	**Trough (RVU)**	**Breakdown (RVU)**	**Final viscosity (RVU)**	**Setback (RVU)**	**Peak Time (min)**
Freeze-dried starch	70.95[b]	3885.0[c]	1529.0[c]	2356.0[c]	2154.0[c]	625.0[b]	4.07[a]
Oven-dried starch	71.85[a]	4429.0[b]	1731.0[b]	2698.0[b]	2514.0[a]	783.0[a]	4.00[a]
Sun-dried starch	71.95[a]	3748.0[d]	1523.0[c]	2225.0[d]	2063.0[d]	540.0[c]	4.00[a]

Freshly-prepared cassava starch (control)	72.14[a]	4476.0[a]	1765.0[a]	2711.0[a]	2294.0[b]	529.0[d]	4.09[a]

[1]Mean value within the same column having the same letter are not significantly different at $p< 0.05$.
[2] RVU = Rapid Visco Unit.

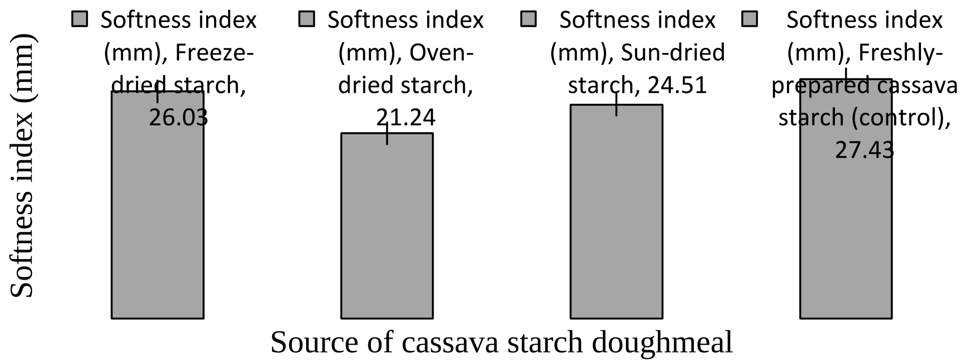

Figure 1: Softness index of doughmeals prepared from differently dried cassava starches.

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Table 4: Residual cyanide content in differently dried cassava starches and doughmeals prepared from them.

Sample source	Residual cyanide content (mg/Kg)[1]
Freeze-dried starch	3.79±0.54 [c]
Oven- dried starch	3.25±0.18 [c]
Sun-dried starch	3.26±0.16 [c]
Freshly-prepared cassava starch (control)	4.55±0.14[b]

Fresh cassava root	26.72±0.11[a]
Doughmeal from freeze- dried starch	3.13±0.01 [d]
Doughmeal from oven-dried starch	3.15±0.02 [d]
Doughmeal from sun-dried starch	3.06±0.05 [d]
Doughmeal from freshly-prepared cassava starch	3.44±0.07[c]

[1]Mean value within the same column having the same letter are not significantly different at $p < 0.05$.

Table 5: Sensory quality rating of doughmeals prepared from differently dried cassava starches.

Source of doughmeal samples	**Sensory factor[1]**				
	Aroma	**Colour**	**Taste**	**Mouldability**	**Overall acceptability**
Freeze-dried starch	6.8[a]	7.3[a]	6.4[a]	7.4[a]	7.3[b]
Oven- dried starch	6.4[b]	6.9[b]	6.1[a]	6.3[c]	6.6[c]
Sun-dried starch	6.3[b]	4.5[c]	5.6[b]	6.5[c]	5.9[d]
Freshly-prepared cassava starch (control)	7.1[a]	7.6[a]	6.3[a]	6.9[b]	8.3[a]

[1]Mean value within the same column having the same letter are not significantly different at $p < 0.05$.

The sensory quality rating of doughmeals from differently dried cassava starches is presented in Table 5. Doughmeal produced from freshly prepared cassava starch was rated the highest in terms of aroma, colour and overall acceptability while the one from freeze dried starch was rated the highest in terms of taste and mouldability. Doughmeal prepared from sun dried starch was rated the lowest in terms of aroma, colour, taste and overall acceptability.

DISCUSSION

The general decrease in the pH level as observed in all categories of dried cassava starch samples may be due to slight fermentation that might have occurred in the starch in the course of drying (Mestres and Rouau, 1997). The pH of a food material is usually regarded as a measure of hydronium ion (H_3O^+) concentration in such material. Therefore, pH is essentially a means of quantifying the hydronium ion (H_3O^+) concentration in a food material while the ability of a microorganism to grow in a specific food is dependent on the concentration of the ions (Sadler and Murphy, 2010).

The significant decrease in total titratable acidity (TTA) in all categories of dried starch might be attributed to the conversion of cassava root to starch which essentially involved diverse unit operations of processing including dilution with water. TTA is regarded as a measure of total acid concentration contained within a food material and its significance lies in its ability to be used as a good predictor of acid's impact on food flavour (Sadler and Murphy, 2010).

The absence of significant difference ($p<0.05$) in the water absorption capacity (WAC) of the dried starch samples implies that their starch granules have equal ability to retain water within their structures after being hydrated and filtered (Kiatkamjornwong *et al*., 2000). It had earlier been observed that one major factor that could enhance WAC of flour or dried starch is the degree of damaged starch (Tulyathan *et al*., 2002).

The significant difference ($p<0.05$) in the bulk density of dried starch samples indicates that the type of drying method adopted could affect the bulk density of a sample. An earlier observation had revealed that bulk density usually plays a role in the packaging weight of flour or dried starch as less weight would be packaged in a specific volume of container with flour/dried starch of lower bulk density (Fagbemi, 1999).

The results on the colour characteristics of differently dried cassava starches as shown in Table 2 indicate that subjecting the starch to drying operation could lower the lightness index (L*-value) of the samples while the sundried sample seemed to exhibit the most severe effect. Colour as a sensory quality factor had been observed to play an important role in food acceptability (Wrolstad and Smith, 2010). However, the a* and b* of the colour coordinate seem not to be a useful indicators for describing the colour change in white cassava starch as red-yellow-green colour indices are seldom applicable (Bolade *et al.*, 2009).

The results in Table 3 showed that subjecting cassava starch to different drying methods could lead to significant differences ($p<0.05$) in the pasting variables. The lowest and highest pasting temperature of freeze-dried and freshly-prepared cassava starch samples respectively indicate that the freeze-dried sample would gelatinize faster than others. This is most probably because the seeming mild drying effect of freeze drying on the cassava starch granules might have given rise to higher bulk porosity in the starch (Karathanos *et al*., 1996) which could facilitate greater water penetration thereby leading to free granule swelling and faster gelatinization. The significant differences ($p<0.05$) observed in the peak viscosities of the cassava starches may be attributed to different rates of water absorption and swelling of starch granules of these starches during heating (Ragaee and Abdel-Aal, 2006). The breakdown viscosity is regarded as a measure of the degree of disintegration of starch granules or paste stability during heating (Dengate, 1984). This implies that the sundried sample with the lowest breakdown value was more resistant to heat and shear force during heating and that there was less starch granule rupture which could therefore guarantee a more stable cooked paste (Farhat *et al.*, 1999). Higher value of final viscosity as observed in the oven dried cassava starch may be attributed to the aggregation of the amylose molecules in the paste (Miles *et al.*, 1985). Therefore, the lowest final viscosity value of sundried sample may be due to a seeming mild fermentation that might have occurred during the prolonged drying operation, thus reducing the aggregation of its amylose molecules. The lowest and highest setback viscosity as observed in freshly-prepared and oven dried starches respectively can be used to predict the storage life of a food product prepared from such starches (Zaidul *et al*., 2007). Therefore, the implication of this observation is that the doughmeal prepared from freshly prepared starches is most likely to exhibit lower retrogradation tendency than that of others due to lowest setback viscosity.

The results in Table 4 revealed that there were significant differences ($p<0.05$) in the residual cyanide content of dried starches obtained through freeze, oven and sun drying methods. It had earlier been observed that significant reduction in the hydrogen cyanide (HCN) level in a food material could be achieved if sufficient time is created for an effective interaction between cyanogenic glycosides and the endogenous enzymes in the food material particularly after maceration (Akingbala *et al*., 1993). Nevertheless, the doughmeal from cassava starches can be regarded as safe since their HCN concentration are below the maximum allowable HCN concentration (10 mg/Kg) in cassava products, according to World Health Organisation (WHO) (Bourdoux *et al.*, 1982).

Figure 1 presented the results on the softness index of doughmeals prepared from differently dried cassava starches. An earlier observation had revealed that generally the drying operations seemed to weaken the associative forces within the starch structure (Gibbon *et al.*, 2003) thereby facilitating a greater softness index of the doughmeals. A food gel or dumpling could also exhibit variation in its textural characteristics as a result of different degrees of interactions of starch components (i.e. protein, fat, fibre and non-starch polysaccharides) with solubilised amylose and amylopectin components of the starch granules during heating (Hardacre and Clark, 2006). The starch doughmeal, like many other traditional food gels or dumplings, is consumed by swallowing rather than being masticated or chewed and it is the prevailing textural characteristics of the product, at the point of consumption, that usually determine whether such food is swallowable or chewable (Prinz and Lucas, 1995; Szczesniak, 2002). Therefore, lower softness index can predispose the food product towards being masticated or chewed while relative high value encourages swallowability (Ayodele *et al*. 2013).

The results in Table 5 revealed the sensory quality rating of doughmeals from differently dried cassava starches. The highest rating of doughmeal from freshly prepared cassava starch implies that consumers still preferred doughmeal from freshly prepared cassava starch. The doughmeal from freeze dried cassava starch was rated second best in terms of aroma, colour and overall acceptability while it was rated best in terms of taste and mouldability. However, the consumers were of the opinion that dried cassava starches have the advantage of being available at any time due to their good storability.

CONCLUSION

This study has shown variation in the quality of dried starches using freeze drying, oven drying and sun drying methods. Starches from different drying methods showed variation in the pH, total titratable acidity (TTA), water absorption capacity (WAC), bulk density, colour characteristics and pasting properties. There were also variations in the residual content of the samples and the softness index of the doughmeals. The consumers rated the doughmeal from freshly prepared cassava starch higher than others in terms of overall acceptability but good storability and hence availability of dried cassava starches at any time could make them attractive.

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REFERENCES

Acedo, J. Z. and Acedo, A.L. (2013). Controlling postharvest physiological deterioration and surface browning in cassava (M*anihot esculenta* Crantz) roots with hot water treatment. Acta Horticulturae 989:357–362.

Adeniji, A.L; Ega, M.; Adoroda, A.; Adeniyi, B. U and Balagun, A. (1997). Cassava

development in Nigeria: A case study towards a global strategy for cassava development. Department of Agriculture, Federal Ministry of Agriculture and Natural Resources, lagos, Nigeria. Mimeo

Akingbala, J.O., Oguntimein, G.B. and Bolade, M.K. (1993). Effect of unit operations of production on the cyanide content and acceptability of gari. Journal of Food Processing and Preservation 17: 337-350.

Akpapunam, M.A. and Markakis, P. (1981). Physicochemical and nutritional aspects of cowpea flour. Journal of Food Science 46: 972 – 973.

AOAC (1990). Official Methods of Analysis of the Association of Official Analytical Chemists. 15th edition., Association of Official Analytical Chemists, Arlington, USA. 119pp.

Ayodele, B.C., Bolade, M. K. and Usman, M.A. (2013). Quality characteristics and acceptability of 'amala' (yam-based thick paste) as influenced by particle size categorization of yam (*Dioscorea rotundata*) flour. Food Science and Technology International 19(1): 35-43.

Bolade, M. K., Adeyemi, I. A. and Ogunsua, A .O. (2009). Influence of particle size fractions on the physicochemical properties of maize flour and textural characteristics of a maize-based nonfermented food gel. International Journal of Food Science and Technology 44: 646–655.

Booth, R.H. (1976). Storage of fresh cassava (*Manihot esculenta*). I. Post-harvest deterioration and its Control. Experimental Agriculture 12(2): 103-111.

Bourdoux, P., Seghers, P., Mafuta, M., Yanderpas-Rivers, M., Delange, F. And Ermans, A.M. (1982). Cassava product: HCN content and detoxification process. In:

Nutritional Factors Involved in the Goitrogenic Action of Cassava (Delange, F.; Iteke, F.B.; Ermans, A.M. eds.). Pp. 51-58. International Development Research Centre (IDRC), Ottawa, Canada.

Chukwuemeka, O.C. (2007). Effect of process modification on the physio-chemical and sensory quality of fufu-flour and dough. African Journal of Biotechnology 6(16): 1949-1953.

Dengate, H.N. (1984). Swelling, pasting, and gelling of wheat starch. In: Advances in Cereal Science and Technology (Pomeranz, Y., ed). Pp. 49-82. AACC, USA.

Dixon, A.G.O., Okechukwu, R.U., Akoroda, M.O., Ilona, P., Ogbe, F., Egesi, C.N., Kulakow, P., Semakula, G., Maziya-Dixon, B., Iluebbey, P., Yomeni, M.O., Geteloma, C., James, B., Eke-Okoro, O.N., Sanni, L., Ntawuruhunga, P., Tarawali, G., Mahungu, N., Lemchi, J., Ezedinma, C.I., Okoro, E., Kanju, E., Adeniji, A.A. and Nwosu, K. (2010). Improved Cassava Variety Handbook. [Internet document]. www.iita.org/c/document_library/. Retrieved on 20-11-2015.

Fagbemi, T. N. (1999). Effect of blanching and ripening on functional properties of plantain (Musa aab) flour. Plant Foods for Human Nutrition 54: 261–269.

FAOSTAT (2014). Annual production output for cassava. [Internet document]. http://faostat3.fao.org/faostat-gateway/. Retrieved on 23-10-2015.

Farhat, I.A., Oguntona, T. and Neale, J.R. (1999). Characterisation of starches from West African yams. Journal of the Science of Food and Agriculture 79: 2105-2112.

Gibbon, B.C., Wang, X. and Larkins, B.A. (2003). Altered starch structure is associated with endosperm modification in

Quality Protein Maize. Proceedings of National Academy of Science 100(26): 15329-15334.

Hardacre, A.K. and Clark, S.M. (2006). The effect of hybrid and growing environment on the rheological properties of starch and flour from maize (Zea mays L.) grain dried at four temperatures. International Journal of Food Science and Technology, 41(S2): 144-150.

Ihekoronye, A. I. and Ngoddy, P.O. (1985). Integrated Food Science and Technology for the Tropics. Macmillan Publishers, London, U.K. 85pp.

Karathanos, V.T., Kanellopoulos, N.K. and Belessiotis, V.G. (1996). Development of porous structure during air drying of agricultural plant products. Journal of Food Engineering 29(2): 167-183.

Kiatkamjornwong, S., Chomsaksakul, W. and Sonsuk, M. (2000). Radiation modification of water absorption of cassava starch by acrylic acid/acrylamide. Radiation Physics and Chemistry 59: 413 – 427.

Lawless, H.T. and Heymann, H. (2010). Sensory Evaluation of Food: Principles and Practices. 2nd edition., Springer, New York, USA. 303pp.

McGuire, R.G. (1992). Reporting of objective color measurement. HortScience 27: 1254 – 1255.

Mestres, C. and Rouau, X. (1997). Influence of natural fermentation and drying conditions on the physicochemical characteristics of cassava starch. Journal of the Science of Food and Agriculture 74(2): 147–155.

Miles, M.J., Morris, V.J., Orford, P.D. and Ring, S.G. (1985). The roles of amylose and amylopectin in the gelation and retrogradation of starch. Carbohydrate Research 135: 271-281.

Newport-Scientific (1996). Operational Manual for the Series 4 Rapid Visco Analyser. Newport Scientific Pty, Ltd, Sydney, Australia. 28pp.

Njoku, D. N., Amadi, C.O., Mbe, J. and Amanze. N.J. (2014). Strategies to overcome post-harvest physiological deterioration in cassava (*Manihot esculenta*) root: a review. Nigeria Agricultural Journal 45:51–62.

Owiti, J., Grossmann, J., Gehrig, P., Dessimoz, C., Laloi, C. Hansen, M.B., Gruissem, W. and Vanderschuren, H. (2011). iTRAQ-based analysis of changes in the cassava root proteome reveals pathways associated with post-harvest physiological deterioration. *Plant Journal*, 67:145–156.

Prinz, J.F. and Lucas, P.W. (1995). Swallow thresholds in human mastication. Archives of Oral Biology 40: 401- 403.

Ragaee, S. and Abdel-Aal, E.M. (2006). Pasting properties of starch and protein in selected cereals and quality of their food products. Food Chemistry 95: 9-18.

Sadler, G.D. and Murphy, P.A. (2010). pH and titratable acidity. In: Food Analysis, 4th edition (Nielsen, S.S., ed). Pp. 219-238. Springer, New York, USA.

Sathe, S. K., Salunkhe, D. K. and Desphande, S.S. (1982). Functional properties of lupin seed protein concentrates. Journal of Food Science 47: 491-492.

Szczesniak, A.S. (2002). Texture is a sensory property. Food Quality and Preference 13: 215- 225.

Timothy, A.T. and Adeoti, A.I. *(2006). Gender inequalities and economic efficiency: New evidence from cassava-based farm holdings in rural south-western Nigeria. African Development Review 18: 428–443.*

Tulyathan, V., Tananuwong, K., Songjinda, P. and Jaiboon, N. (2002). Some physicochemical properties of Jackfruit

(*Artocarpus heterophyllus* Lam) seed flour and starch. ScienceAsia 28: 37-41.

Wang, L. and Flores, R.A. (2000). Effects of flour particle size on the textural properties of flour Tortillas. Journal of Cereal Science 31: 263-272.

Wojdylo, A., Figiel, A. and Oszmianski, J. (2009). Effect of drying methods with the application of vacuum microwaves on the bioactive compounds, color, and antioxidant activity of strawberry fruits. Journal of Agricultural and Food Chemistry 57: 1337-1343.

Wrolstad, R.E. and Smith, D.E. (2010). Colour analysis. In: Food Analysis. 4th edition (Nielsen, S.S., ed). Pp. 573-586. Springer, New York, USA.

Zaidul, I.S.M., Yamauchi, H., Kim, S., Hashimoto, N. and Noda, T. (2007). RVA study of mixtures of wheat flour and potato starches with different phosphorus contents. Food Chemistry 102: 1105-1111.