Physicochemical and Pasting Properties of Starch Extracted From Four Improved Cassava Varieties

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Abstract
Three improved provitamin A cassava Manihot esculenta Crantz) varieties namely TMS 01/1368, TMS 01/1412, TMS 01/1371 and a disease resistant variety - NR 8082 were studied to establish their physicochemical and pasting properties. Results show that there were significant differences ($p \leq 0.05$) in the properties studied. The properties had values which ranged from (8.75 – 10.27%) moisture; protein (1.15 - 2.41%); amylose (13.32 – 23.45%); dietary fibre (1.24 - 1.37Kcal/g); bulk density (0.48 – 0.55g/ml); emulsion capacity (19.9 – 21.3%); foam capacity (6.89 – 7.32%); foam stability (2.00 – 4.03%); carotene (3.11 - 5.21µg/g); hydrogen cyanide (1.30 - 1.54mg/kg^{-1}). Other properties studied include peak viscosity (357.52 - 428.46RVU); trough (103.09 - 130.50RVU); breakdown (209.93-250.27RVU); final viscosity (137.22-175.11RVU); setback (33.93- 42.31RVU); peak time (3.63 - 3.72min). No significant effect ($p \geq 0.05$) was recorded for carbohydrate, starch, swelling capacity and pasting temperature. These pasting properties indicate that these samples generally possess low ability to remain undisrupted when subjected to long periods of constant high temperature and consequently, low ability to withstand breakdown during cooking.

Keyword: *Cassava, provitamin A; starch; pasting properties; physicochemical properties*

Introduction

Cassava (*Manihot esculenta C*rantz) is a perennial tuber plant widely grown in many tropical countries including Nigeria as one of the most important commercial crops. Cassava is an important high energy traditional food crop and serves as subsidiary or subsistence food in different parts of the tropical belt (FAO, 2008).

There is a growing interest in ecologically sustainable industrial raw materials from starchy materials. Food and beverage industries mainly use cassava starch in the production of jelly, caramel and chewing gum. Cassava starch is equally used in bakery products as it is a constituent of many flours which increase volume in bread and crispiness in biscuit. It is also used in confectioneries as sweetening agents and enhances spread ability and flavour in jams, jellies and preserves to improve its consistency. In candies, it is used to stop ingredients from sticking together. It is also used in the manufacturing of monosodium glutamate which is a flavouring agent in foods such as meats, vegetables, soups, sauces and gravies. Even though the industrial application of cassava is making rapid advances and is widely used as a replacement for corn starch in the United States (Bahnassey and Breene, 1994), its use in Nigeria is still at a slow pace.

The cassava root contains about 41% of percent of starch unlike cocoyam 43%, sweet potato 33% and yam 32%. The starches they contain are held in small starch granules which when ruptured release powdery starches if the pulp is dry (Okaka, 2005). Unlike other tuber starches, extraction of starch from cassava is simple and the isolated starch is pure white in colour and relatively free from other chemical impurities (Moorthy, 2002).

National Root Crops Research Institute Umudike (NRCRI) and International Institute for Tropical Agriculture Ibadan (IITA) have played a collaborative role through genetic engineering in the development of some recent improved cassava varieties which are disease and pest-resistant, low in cyanide content, drought-resistant, early maturing, high yielding, and high in pro-vitamin. These improved varieties have been introduced in a majority of cassava growing states in Nigeria and it gives sustained yield of about 50% more than the local varieties but is yet to be fully accepted by farmers and processors due to inadequate research findings on the varieties.

Thus, the objectives of this research are, to extract starch from three new pro vitamin A cassava varieties: TMS 01/1368, TMS 01/1412, TMS 01/1371 and a non-pro vitamin A cassava NR 8082 used as a control. To evaluate the nutrient composition of the extracted starch from the four cassava varieties and to evaluate the physicochemical properties.

Methods

Materials

Fresh cassava roots of four improved cassava varieties: TMS 01/1368, TMS 01/1412, TMS 01/1371 and NR 8082 were harvested from the Cassava Programme Farm of National Root Crops Research Institute (NRCRI) Umudike, Nigeria.

Cassava Starch Extraction

Cassava starch was extracted according to the method described by FAO (1990). Roots from each of the cassava variety were harvested, peeled, washed, crushed, sieved, dewatered, starch washed, dewatered and dried within 24 hours and Cassava starch obtained (Fig 1).

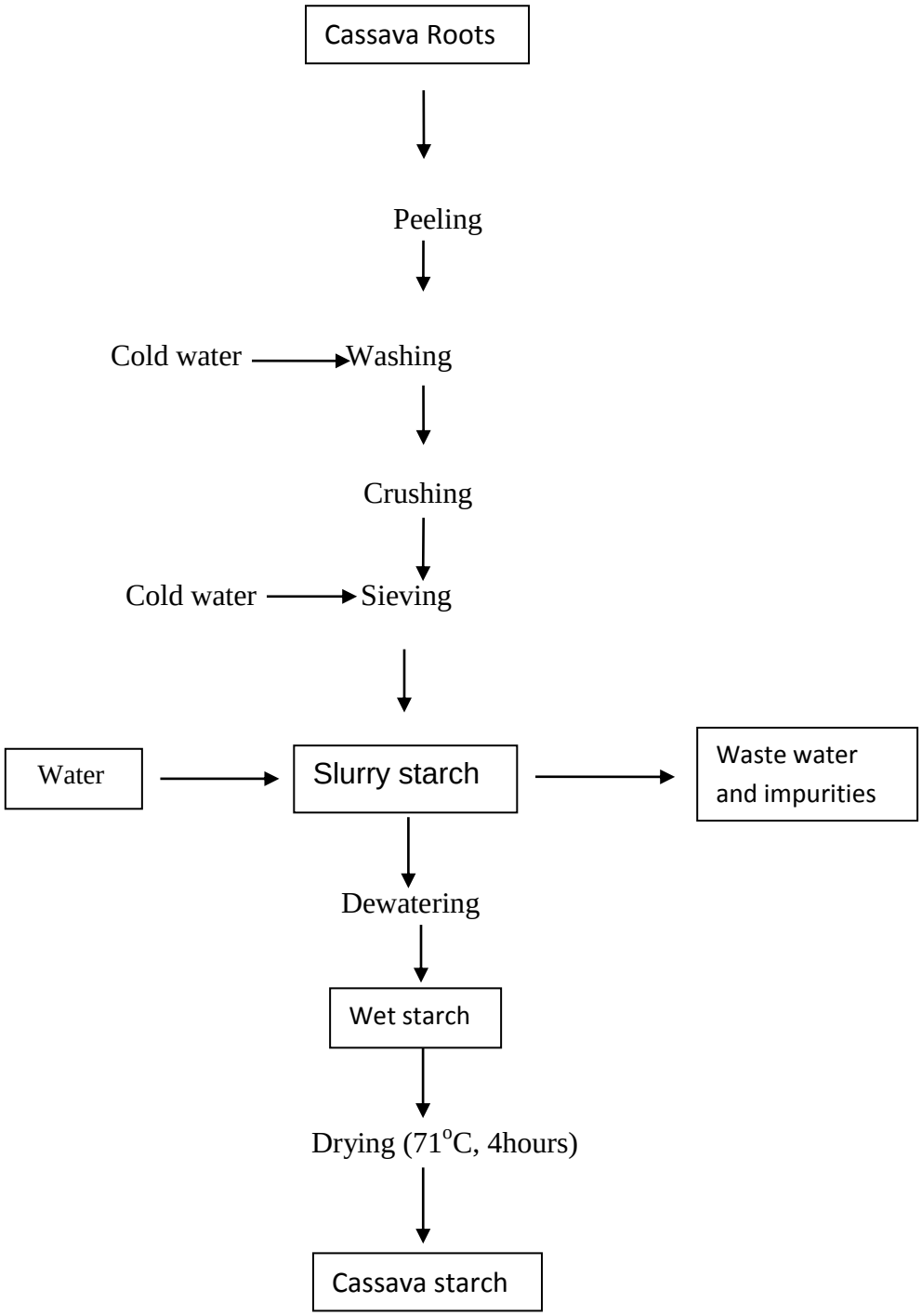

Fig 1: Flow Chart of Cassava Starch production
Source: www.fao.org (October, 2014)

Proximate Analysis
Moisture content was determined by method described by Benesi (2005) with modifications.

Physicochemical Analysis
Hydrogen cyanide and amylose content were determined by methods described by Onwuka (2005). A method described by AOAC (1987) was used to determine the total dietary fibre. Bulk density was determined by the method described by Okezie and Bello (1988). Swelling capacity was determined by the method described by Leach *et al.* (1989). A method described by Radley (1976) was used to determine starch content. Foaming capacity and stability were determined by the method described by Abbey and Ibeh (1988). Emulsification capacity and stability were determined by the method described by Padmashree *et al.* (1987). For carotenoid content**,** sample extraction procedure essentially followed the method described by Othman *et al.* (2015). Total carotenoid concentrations were determined by spectrophotometric method as described by Othman *et al.* (2015). All analyses were conducted in triplicates.

Analysis of Pasting Properties of Extracted Starch
Pasting temperature, peak time, peak viscosity, hot paste viscosity, breakdown viscosity, final viscosity and setback viscosity were determined using the method described by Nuwamanya *et al*. (2011). The Rapid Viscosity Analyser (RVA model 3D, New Port Scientific, Sydney, Australia) was used to run the analyses.

Statistical Data Analysis
Statistical analysis of data obtained from the proximate, physicochemical and pasting properties analyses of extracted starch was conducted using SPSS package (1995). Mean scores were subjected to One-way Analysis of Variance (ANOVA) and significant differences between the cassava varieties were determined using Fischer's Least Significant Difference (LSD) Method ($p \geq 0.05$

Results and Discussions

Table 1: Proximate Composition of Starch Samples

Parameter	LSD	TMS 01/1368	TMS 01/1412	TMS 01/1371	NR8082
Moisture content (%)	0.0462	$8.75^{d} \pm 0.02$	$8.98^{c} \pm 0.02$	$9.51^{b} \pm 0.01$	$10.27^{a} \pm 0.06$
Ash (%)	0.0172	$2.11^{b} \pm 0.02$	$1.42^{c} \pm 0.02$	$2.21^{a} \pm 0.01$	$0.46^{d} \pm 0.01$
Crude fibre (%)	0.0140	$2.31^{a} \pm 0.02$	$1.84^{c} \pm 0.01$	$2.02^{b} \pm 0.01$	$1.17^{d} \pm 0.01$
Fat (%)	0.0435	$0.93^{c} \pm 0.02$	$0.37^{d} \pm 0.02$	$1.30^{b} \pm 0.05$	$1.4^{a} \pm 0.03$
Crude Protein (%)	0.0394	$1.98^{c} \pm 0.01$	$2.41^{a} \pm 0.18$	$2.16^{b} \pm 0.01$	$1.15^{d} \pm 0.01$
Carbohydrate (%)	-	83.92±3.07	84.98±3.96	82.80±3.00	85.55±0.67

^{a,b,c,d} mean values in each row with the same superscript are not significantly different ($p \geq 0.05$) from each other. Where LSD = Least Significant difference.

From the table 1, the extracted cassava starch samples had low moisture content and this is a good storage property. However the lowest moisture content was recorded in TMS 01/1371 compared with other improved varieties analyzed, which indicates that it may possess longer storage life if well packed and stored. (Table. 1).

Ash content ranged from 0.46% (for NR8082) to 2.21% (for TMS 01/1371). Values obtained were lower than those of peeled bitter cassava (2.41% dry weight basis), and sweet cassava (4.44% dry weight basis) obtained by Okigbo (1980), but higher than those of root tubers (0.84%) reported by Bradbury and Holloway (1988). Ash is a reflection of the inorganic mineral elements present in the samples. TMS 01/1371 had the best quantity of ash and values obtained were significantly different ($p \geq 0.05$) from each other.

Crude fibre values obtained ranged from 1.17% (NR 8082) to 2.31% (TMS 01/1368). These values were higher than the range, 1.10% (Buitrago, 1990) to 1.4% (Bradbury and Holloway, 1988) for root tubers, but lower than sweet cassava (10.31%) and comparable with bitter cassava (3.09%) reported by Okigbo (1980). Crude fibre represents that portion of a food not used up by the body but mainly made up of cellulose together with little lignin and is known to increase bulk stool (Eleazu *et al*., 2011). It consists largely of cellulose and lignin (97%) plus some mineral matter. It represents only 60% to 80% of the cellulose and 4% to 6% of the lignin.

The fat content of the extracted cassava starch in this work ranged from 0.37% to 1.4%. This encompasses the fat content values of 0.47% to 0.53% in root tubers reported by Buitrago (1990) and Okigbo (1980). Means were significantly different ($p \geq 0.05$) from one another. Increased fat content is reported to improve starch textural properties and lead to viscosity stability hence improving the quality properties of starch (Moorthy and Ramanujam , 1986).

The extracted starch had low levels of protein on dry basis with averages ranging from 1.15 – 2.41%.

Carbohydrate values ranged from 82.80% (TMS 01/1371) to 85.55% (for NR 8082). There was no significant difference in the carbohydrate content of the starch samples. These carbohydrate values were lower than 87.8% obtained for TMS 30572 cassava starch (Oladunmoye *et al.*, 2014). The physicochemical composition of the starch samples analysed is as shown in Table 2.

Table 2: The Physicochemical Composition of Starch Samples

Parameter	**LSD**	**TMS 01/1368**	**TMS 01/1412**	**TMS 01/1371**	**NR8082**
Starch content (%)	--	17.27±0.02	13.82±0.02	19.01±0.03	18.32±0.0
Emulsion capacity (%)	0.0924	21.3^{a}±0.06	20.60^{b}±0.06	20.40^{c}±0.06	19.90^{d}± 0.1
Foam capacity (%)	0.0159	6.91^{c}±0.01	6.93^{b}±0.02	6.89^{d}±0.01	7.32^{a}±0.01
Foam stability (%)	0.0535	4.03^{a}±0.06	2.03^{b}±0.06	4.00^{a}± 0.00	2.00^{b}±0.00
Bulk density (g/ml)	0.0263	0.55^{a}±0.01	0.52^{b}±0.01	0.52^{b}±0.01	0.48^{c}± 0.00
Amylose content (%)	0.0829	13.20^{d} ±0.10	20.30^{b}±0.06	23.45^{a}±0.04	18.72^{c}±0.03

Swelling capacity (g/ml)	--	2.70±0.01	2.67±0.02	2.60±0.012	2.40±0.02
Dietary fibre (Kcal/g)	0.0471	1.26 ^{bc} ±0.05	1.28^{b}±0.03	1.24^{bc}±0.02	1.37^{a}±0.02
Carotene content (µg/g)	0.0278	3.98 ^{b}±0.01	3.11 ^{c} ±0.01	5.21 ^{a} ±0.01	--
Hydrogen cyanide (mg/kg^{-1})	0.0036	1.41 ^{b} ±0.01	1.32^{c}±0.00	1.30^{c}±0.00	1.54^{a}±0.01

^{a,b,c,d} mean values in each row with the same superscript are not significantly different (p≥0.05) from each other.
Where LSD = Least Significant difference.

As shown in Table 2, low starch content was recorded in the investigated starch samples which averaged from 13.82- 19.01%. Since the retrogradation of starch is usually influenced by its amylose content (Klucinec and Thompson, 2002), a relationship was observed between starch and amylose levels and thus inferring that high starch containing cassava varieties are equally high in amylose content. Significant difference was not observed in terms of starch content (p ≥0.05).

Results of the emulsion capacity ranged from 19.90% (NR 8082) to 21.3% (TMS 01/1368). The emulsion capacity, which reflects the ability of the proteins to aid formation and stabilization of newly created emulsion, was observed to be low in the starch samples investigated.
Results of the foaming capacity ranged from 6.89% (TMS 01/1371) to 7.32% (NR 8082). Foaming capacity may be referred to as the ability of a food component to be formed into light textured dispersions of a gas, such as air, in a liquid or solid, typically achieved by whipping or frothing. The ability of a food product to foam and stabilize foams to an extent may depend on the type of protein, degree of denaturation, pH, temperature and whipping methods. Foaming capacity is a property which is mainly desirable in the production of alcoholic beverages and it appears to be due to solubilized protein. The lower values recorded may reduce the functionality of its use in the production of cakes and ice-cream where foaming is an important property.
Results of the foaming stability ranged from 2.00% (NR 8082) to 4.03% (TMS 01/1368,) with significant differences across. Foam stability is important in food processing/preparations since success of a whipping agent depend on its ability to maintain the whip as long as possible.
From Table 2, results of the bulk density of the extracted cassava starch ranged from 0.48% (NR 8082) to 0.55% (TMS 01/1368). The low bulk density recorded here could be an advantage in the processing or formulation of baby weaning foods.
Results for the amylose content in the extracted cassava starch shows that the amylose content ranged from 13.2% – 23.45% (Table 2). On a comparative basis, most of the samples analysed were lower than the range of values (17 to 35%) reported by Mbofung *et al*. (2006), for six varieties of taro. There were no significant differences observed in amylose contents of the extracted cassava starch. Amylose content is important in almost all starch properties with low amylose contents leading to increased relative crystallinity of starch due to the reduced amorphous regions within the starch granule (Tukomane *et al.*, 2007). Amylose content also affects the retrogradation properties of starch where high amylose starches have increased retrogradation tendencies caused by the aggregation of amylose which acts as nuclei during the process of amylopectin retrogradation (Rodríguez-Sandoval *et al.*, 2008).

At higher temperatures, the differences generally disappeared. Uptake of water by starch granules results in progressive swelling as temperature increases (Charles *et al*., 2007). Swelling capacity is an important parameter especially in characterization of starches from different botanical origins, which display different swelling capacities at a given temperature (Moorthy, 2002; Charles *et al.*, 2007). Low swelling capacity results in low digestibility and inability to use starch in solution suggesting unimproved dietary properties. Swelling capacity also affects both the eating quality of cassava roots and the use of starch in a number of industrial applications (Moorthy, 2002). Swelling capacity is regarded as quality criterion in some food formulations such as bakery products. It has been reported that the amylose acts both as a diluent and inhibitor of swelling, especially in the presence of lipids which can form insoluble complexes with some of the amylose during swelling and gelatinization.

The dietary fibre ranged from 1.24 – 1.37Kcal/g with significant ($p \geq 0.05$) effects on a number of pasting properties such as hot paste viscosity, pasting temperature, breakdown viscosity, peak viscosity and peak time. Increase in dietary fibre results in reduction in peak viscosity and increase in the pasting temperature.

The cassava starches from the yellow varieties investigated have low quantities of carotene in the range of 3.11 - 5.21 µg/g, whereas the cassava starch from the NR8082, which is a white variety, had none (Table 2). The consumption of the yellow variety of cassava may not contribute much to the amount of dietary supplement needed to meet the RDA of vitamin A in humans which is 900µg and 700µg Retinol Activity Equivalent (RAE) for adult and aged males and females respectively (IMFNB,2001).

Carotenoid compounds are found in plants and enhance the human health immune response, reduce risk of degenerative diseases such as cancer, cardiovascular diseases etc and these have been attributed to their scavenging and free radical activities (Eleazu and Eleazu, 2012).

Several authors have reported the lethal dose of cyanide in humans as ranging between 50 to 300 mg kg^{-1} body weights (Bolhius, 1954; Akiyama *et al*., 2006). The residual cyanide level of the extracted cassava starch samples investigated ranged from 1.3 mg kg^{-1} to 1.54 mg kg^{-1} (Table 2) with NR8082 having the highest cyanide level among the cassava starch samples investigated (1.54 mg kg^{-1}), while TMS 01/1412 and TMS 01/1371 had the least values which were not significantly different from each other. The low cyanide levels of the samples evaluated may be attributed to the method of processing. The pasting properties of Starch samples are shown in Table 3.

Table 3: Pasting Properties of Starch Samples

Parameter	LSD	TMS 01/1368	TMS 01/1412	TMS 01/1371	NR8082
Peak viscosity (RVU)	0.0462	363.49^{b}±0.04	428.46^{a}±0.03	357.52^{c}±0.05	350.93^{d}±0.03
Trough/HPV (RVU)	0.0652	103.09^{d}±0.04	130.50^{a}±0.02	104.29^{c}±0.04	106.08^{b}±0.05
Breakdown (RVU)	0.0652	209.93^{d}±0.03	250.27^{a}±0.03	223.49^{b}±0.06	210.42^{c}±0.05
Final viscosity (RVU)	2.18	149.72^{c}±0.06	175.11^{a}±0.21	137.22^{d}±0.09	152.10^{b}±0.19
Set back (RVU)	0.0652	39.65^{c}±0.02	40.59^{b}±0.06	33.93^{d}±0.07	42.31^{a}±0.03

Pasting temperature (^{o}C)	--	66.43±0.06	66.45±0.04	66.43±0.09	64.50±0.02
Peak time (Min)	0.0272	3.66^{c}±0.02	3.63^{d}±0.03	3.69^{b}±0.01	3.72^{a}±0.00

^{a,b,c,d} mean values in each row with the same superscript are not significantly different ($p \geq 0.05$) from each other. Where LSD = Least Significant difference; HPV=Hot Paste Viscosity; RVU= Rapid Viscosity Units.

The peak viscosity of the extracted cassava starch ranged from 350.93RVU to 428.46 RVU (Table 3) with significant differences (p=0.05) observed. Peak viscosity reflects the ability of starch to swell freely before their physical breakdown (Sanni *et al.*, 2004). Peak viscosity is often correlated with final product quality. It has been suggested that high peak viscosity contributes to good texture of paste, which depends on high viscosity and moderately high gel strength (Rosenthal *et al.*, 1974). The relatively high peak viscosity exhibited by most of the samples indicates that the starch may be suitable for products requiring high gel strength and elasticity.
As shown in Table 3, values of the breakdown viscosity ranged from 209.93RVU to 250.27RVU.
The hot paste viscosity ranged from 103.09RVU to 130.50RVU. It is the minimum viscosity value in the constant temperature phase of the RVA profile and measures the ability of paste to withstand breakdown during cooling. Large values indicate little breakdown of sample starches. The rate of breakdown depends on the nature of the material, the temperature, and degree of mixing and shear applied to the mixture. The ability of a mixture to withstand this heating and shear stress is an important factor for many processes. Cross-linked starches are more resistant to breakdown.
Values of final viscosity ranged from 149.72RVU to 175.11RVU. Final viscosity is the change in the viscosity after holding cooked starch at 50°C and it represents cooked starch stability. Final viscosity is the most commonly used parameter to define the quality of a particular sample, as it indicates the ability of the material to form a viscous paste or gel after cooking and cooling as well as the resistance of the paste to shear force during stirring. The low final viscosity observed compared to the peak viscosity indicate the high tendency of tapioca starch to retrograde (Moorthy, 2002). The viscosity after cooling to 50°C represents setback or viscosity of cooked paste. It is a stage where retrogradation or re-ordering of starch molecules occurs.
Values of setback viscosity ranged from 33.93RVU to 42.31RVU (Table 3). Setback has been correlated with texture of various products. High setback is also associated with syneresis, or whipping, during freeze/thaw cycles. Low setback values are recorded to indicate higher retrogradation tendency and vice versa (Tolmasquim *et al.*, 1971). These values recorded may have correlated with the inability of the starches investigated to gel into semi solid pastes easily on cooking. A higher value is useful if the starch is to be used in domestic products, which require high viscosity and paste stability at low temperature (Oduro *et al.*, 2000).
The pasting temperature of cassava starch samples ranged from 64.50° – 66.45^{o}C .When starch based foods are heated in an aqueous environment, they undergo a series of changes known to constitute gelatinization and pasting. These are two of the most important properties that influence quality and aesthetic considerations in the food industry, since they affect texture and digestibility as well as the end use of starchy foods. Pasting temperature gives an indication of the gelatinization time during processing. It is the temperature at which the first detectable increase in viscosity is measured and is an index characterized by the initial change due to the

swelling of starch. Pasting temperature has been reported to relate to water binding capacity. A higher pasting temperature implies higher water binding capacity, higher gelatinization, and lower swelling property of starch due to a high degree of association between starch granules (Emiola and Delarosa, 1981; Numfor *et al.*, 1996). Cassava starch investigated recorded good pasting temperature (average 63^{o}C), hence it forms pastes much easier compared to starches with higher pasting temperatures such as potato (average 72°C) (Moorthy, 2002) and rice (average 69.5°C) (Cameron *et al.*, 2007). It is reported that the low stability of cassava starch granules on heating makes them loose their molecular structure easily (Novelo-Cen and Betancur-Ancona, 2005). The influence of amylose on the pasting properties depends on its leaching out of the amylopectin network during heating into the solution affecting the starch viscoelastic properties (Charles *et al.*, 2005). Increase in amylose content leads to increase in the pasting temperature (Novel-Cen and Betancur-Ancona, 2005) due to the prolonged escape of amylose out of the amylopectin network during the gelatinization of starch leading to prolonged swelling of starch granules (Moorthy, 2002), hence increasing the temperature required to form a starch paste. These properties indicate that these samples generally possess low ability to remain undisrupted when subjected to long periods of constant high temperature and ability to withstand breakdown during cooking.

Values of the peak time ranged from 3.63 min to 3.72 min. The peak time, which is a measure of the cooking time, was within a very close range. The peak times was low hence their inability to form pastes much easier. Significant differences were observed in the different peak time of the extracted cassava starch samples.

Conclusions

The physicochemical analysis results indicated that, the emulsion capacity was generally low 19.90 to 21.3% indicating its minute ability to form and stabilize newly created emulsions, thus its low acceptance in the preparation of processed foods based upon emulsions. Foam capacity was observed to be low (6.89-7.32%) which may indicate its hampered ability to form light textured gas dispersions upon whipping or frothing, thus its low acceptance as brewery adjunct whereas the foam stability recorded may have indicated the inability of starch from these cassava varieties to maintain prolonged whip hence its low acceptance in food formulations. Low bulk densities (0.48-0.55g/ml) observed is an indication of the effectiveness of starch from these varieties for the manufacture of baby weaning foods. Low amylose (13.2-23.45%) and starch contents (17.27-19.01%) of the samples may be implicated in its high retro gradation tendency. Low swelling capacity (2.40-2.70g/ml) observed in the starch samples from these varieties could affect its eating quality on cooking and its usage in industrial applications such as baking. Low dietary fibre of 1.24-1.37Kcal/g recorded in the starch samples could have affected a good number of its pasting properties. The low hydrogen cyanide 1.30-1.54mg/kg^{-1} recorded may have indicated that the starch samples may not confer a toxic effect on the end user if consumed or used for further food formulation. The carotene content (3.11-5.1µg/g) of TMS 01/1368, TMS 01/1412, TMS 01/1371 and NR 8082 were low. Thus, carotene level of cassava should be boosted in order to meet the amount of dietary supplements needed to meet the recommended dietary allowance of vitamin A in humans which is 900µg and 700µg Rectinol Activity Equivalent for adult and aged males and females respectively.

Regarding the pasting properties of starch extracted from the study, peak viscosity was observed to be high (350.93-48.46RVU) which may have indicated the ability of the samples to swell easily before its final breakdown. Low hot paste viscosity of 103.09-130.50RVU was recorded

and may be implicated in the total breakdown of the paste formed which is not a desired property in the use of the starch for further processing. The pasting temperatures (64.50-66.43^{o}C) recorded tends to indicate that the starch samples could gelatinize at temperature above 60^{o}C, which may cause lower swelling and high water binding capacity. Low peak time of 3.63-3.7min also recorded was an indication of inability of the starch samples to form paste much easier. Low final viscosity (137.22-175.11RVU) and low setback viscosity (33.93-4.31RVU) reflected high tendency of the investigated samples to retrograde easily.

REFERENCES

Abbey, B. W. and Ibeh, G.O. (1988). Functional properties of raw and heat processed cowpea (*Vigna unguiculata*, Walp) Flour. *Journal of Food Science 53 (6)* 1775-1778.

Akiyama, H. T., Toida, S., Sakai, Y., Amakura, K., Kondo, Y., Sugita-Kunishi and Maitani (2006). Determination of cyanide and thiocyanate in sugihiriratake mushroom using HPLC method with fluorometric detection. *J. Health Sci., 52:* 73 – 77.

Allem, A. C. (2002). The origins and taxonomy of cassava. In: Hillocks, R. J., Thresh, J. M. and Bellotti, A. C. (Eds), Cassava biology, Production and Utilization. CABI Publishing, Wallingford, UK, 1- 16.

Bahnassey, Y. A. and Breene, W. M. (1994). Rapid Visco-Analyzer (RVA) pasting properties of wheat, corn, waxy corn, tapioca and amaranth starches (*A. hypochondriacus* and *A. cruentus*) in the presence of konjac flour, gellan, guar, xanthan and locust bean gums. *Starch/Starke. 4*: 134-141.

Benesi, I. R. (2005). Characterization of Malawian Cassava Germsperm for Diversity, Starch Extraction and its Native and Modified Properties. PhD Thesis, Department of Plant Sciences, University of the Free State, South Africa. 74-123.

Bolhuis, G.G. (1954). The toxicity of cassava roots. Neth. J. Agric., 2:176-185.

Bradbury, J. H. and Holloway, W. D. (1988). Chemistry of tropical root crops: significance for nutrition and agriculture in pacific. ACIAR Monograph No 6.

Buitrago, J. A. (1990). La yucca em alimentacion animal. Publicacion 85, CIAT, Cali, Colombia.

Cameron, D.K.., Wang, Y., and Moldenhauer, A. K (2007). Comparison of Starch Physicochemical Properties from Medium-Grain Rice Cultivars Grown in California and Arkansas Starch/Stärke 59: 600-608.

Charles, A. L., Chang, Y. H., Ko, W. C., Sriroth, K. and Huang, T. C. (2005). Influence of Amylopectin Structure and Amylose Content on the Gelling Properties of Five Cultivars of Cassava Starches. *Journal of Agricultural and Food Chemistry*. 40: 5-10.

Charles, A. L., Huang, T., Lai, P., Chen, C., Lee, P. and Chang, Y. (2007). Study of wheat flour–cassava starch composite mix and the function of cassava mucilage in Chinese noodles. Food Hydrocolloids 21: 368-378.

Eleazu, C.O and Eleazu, K.C. (2012). Determination of the Proximate Composition, Total Caroteniod, Reducing Sugars and Residual Cyanide Levels of Flours of 6 New Yellow and White Cassava *(Manihot esculenta Crantz*) Varieties. *American J. Of Food Technology 7(10)* 642-649.

Eleazu, C.O., Amajor, J.U., Ikpeama, A.I. and Awa, E. (2011). Studies on the nutrient composition, antioxidant activities, functional properties and microbial load of the flours of 10 elite cassava (*Manihot esculenta*) varieties. *Asian J. Clin. Nutr., 3:* 33-39.

Emiola, L. and Delarosa, L.C. (1981). Physicochemical characteristics of yam starches. *J. Food Biochem. 5,* 115-130.

FAO (2008). First International Meeting on Cassava Breeding, Biotechnology and Ecology, "Cassava improvement to enhance livelihoods in sub-Saharan Africa and north eastern Brazil" Brasilia 11–15, 102.

IMFNB (2001). Institute of Medicine Food and Nutrition Board. Dietary intakes for vitamin A, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon and zinc. Washington, D.C: National Academy Press.

Leach, H.W., McCovwen, D.L. and Schoch, T.J. (1959). Swelling and solubility patterns of various Starches, structure of gramiles. Cereal Chem. 36:534-544.

Mbofung, C.M.F., Aboubakar, Y.N., Njintang, A., Abdou, B., and Balaam, F. (2006). Physicochemical and Functional properties of six varieties of Taro (*Colocasia escutenta* L. Schott) flour. *J. Food Technol. 4(2):* 1350-142.

Moorthy, S. N. (2002). *Tuber crop starches*, Tech. Bull. No 18, CTCRI, Trivandrum, 52.

Moorthy, S. N. and Ramanujam, T. (1986). Variation in properties of starch in cassava varieties in relation to age of the crop. *Starch*/*Stärke. 38*, 58-61.

Novelo-Cen, L. and Betancur-Ancona, D. (2005). Chemical and Functional Properties of *Phaseolus lunatus* and *Manihot esculenta* Starch Blends, Starch/ Starke 57: 431 – 441.

Numfor, F.A., Walter, W.M. and Schwartz, S.J. (1996). Effect of Emulsifiers on the physical properties of native and fermented cassava starches. *J. Agric. Fd. Chem*. 44**,** 2595 – 2599.

Oduro, I., Ellis, W. O., Dziedzoave, N. T. and Nimakoyeboah, K. (2000). Quality of gari from selected processing zones in Ghana. Food Control **11,** 297-303.

Okaka, J.C. (2005). Handling, Storage and Processing of Plant Foods. OCJ Academic Publishers, Enugu. 256-269.

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

Okigbo, B.N. (1980). Nutritional implications of projects giving high priority to the production of staples of low nutritive quality. In the case for cassava (*Manihot esculenta*, Crantz) in the humid tropics of West Africa, *Food and Nutrition Bulletin* **2** pp. 1–10.

Onwuka (2005). Food analysis and instrumentatation. Theory and practice. Naphthali prints, Lagos. Pp. 58-128.

Oladunmoye, O .O., Aworh, O.C., Maziya-Dixon, B., Erukainure, O.L. and Elemo, G.N (2014). Chemical and Functional properties of Cassava starch, Durum wheat semolinaflour and their blends. *J. Food Science and Nutrition 2(2):* 132-138.

Othman, R., Jaswir, I. and Jamal, P. (2015). Characterisation of carotenoid content in diverse local sweet potato (*Ipomoea batatas*) flesh tubers. *International J. of Pharmacy and Pharmaceutical Sciences. Vol 7*, Issue 2, 2015. 975-1491.

Padmashree, T.S. and Kshmi, L.V. and Puttaragi S. (1987). Effect of traditional processing on the functional properties of cowpea (*Vigna catang*) flour. *J. of Food sci. and tech. vol. 24:* 221-225.

Radley, J.A. (1976). Starch production technology. Applied science publisher limited, London, England. Pp. 45-65.

Rodríguez-Sandoval, E., Fernández-Quintero, A., Cuvelier, G., Relkin, P. and Bello-Pérez, L., (2008). Starch Retrogradation in Cassava Flour from Cooked Parenchyma.

Rosenthal, F.R.T., Nakamura, T., Espindola, A.M.C. and Jochimek, M.R. (1974). Structure of starch granules. Die Starke 26, 50-55.

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. *Intl. J. Food Prop*. **7(2),** 229–237.

Tolmasquim, E., Correˆ a, A.M.N. and Tolmasquim, S.T. (1971). New starches. Properties of five varieties of cowpea starch. Cereal Chem. **48,** 132–139.

Tukomane, T., Leerapongnun, P., Shobsngob, S. and Varavinit, S. (2007). Preparation and Characterization of Annealed- Enzymatically Hydrolyzed Tapioca Starch and the Utilization in Tableting. Starch/ Stärke 59: 33-45.