

**EFFECT OF CASSAVA STARCH SUBSTITUTION ON THE FUNCTIONAL AND SENSORY PROPERTIES OF TRIFOLIATE YAM (*DIOSCOREA DUMETORUM*) FLOURS**

**Abiodun OA<sup>1\*</sup>, Adegbite JA<sup>1</sup> and Oladipo TS<sup>1</sup>**



**Olufunmilola Abiodun**



**Jacob Adegbite**



**Tajudeen Oladipo**

\* Corresponding author email: [funmiabiodun2003@yahoo.com](mailto:funmiabiodun2003@yahoo.com)

<sup>1</sup>Department of Food Science and Technology, Osun State Polytechnic, Iree. P.M.B 301 Osun State, Nigeria.

**ABSTRACT**

This study was carried out to determine the effect of cassava (*Manihot cranzt*) starch substitution on the functional and sensory properties of trifoliolate yam (*Dioscorea dumetorum*) flour. The trifoliolate yam tubers were peeled, washed and boiled for 30 minutes and dried in hot air oven at 60°C for 48 hrs. The dried samples were milled, sieved (600 µm sieve size) and packaged. The cassava tubers were also peeled, washed and ground. The cassava paste was mixed with water, sieved (muslin cloth), and the cassava starch was allowed to settle and the water decanted. The starch cake was rinsed four times, dried in the oven at 40°C for 24 hrs, milled and sieved. The cassava starch was used to substitute 10, 20, 30, 40 and 50% of trifoliolate yam flour. The control white yam (*Dioscorea rotundata*) tubers were peeled, washed and diced. The diced yam tubers were parboiled at temperature of 70°C and left for 12 hours in the cooking water. They were dried at 60°C for 48 hrs, milled, sieved and packaged. Functional and sensory properties of the flour samples were determined. Statistical analysis was carried out to test for significant difference ( $p < 0.05$ ) using one way analysis of variance (ANOVA). The control sample had the highest peak viscosity (201.22 RVU), holding strength (167.17 RVU), final viscosity (324.25 RVU) and set back viscosity (157.08 RVU). These were significantly different ( $p < 0.05$ ) from all the samples. Sample TF had the least peak viscosity value of 54.13 RVU while sample TC5 (50% cassava starch) had higher value (98.33 RVU) among the substituted samples. Breakdown viscosity follows the same trend with peak viscosity; it increased with increase in cassava starch substitution. Holding strength, final viscosity and setback values ranged from 24.39-39.01 RVU, 36.46-66.42 RVU and 12.08-27.42 RVU respectively. These three parameters decreased with increase in cassava starch substitution with higher values in sample TF (trifoliolate yam flour). Pasting time and pasting temperature also ranged from 4.59-5.24 min and 73.88-79.27°C, respectively. Swelling index and water absorption capacity ranged from 1.97-2.97 and 1.51-2.49 mLH<sub>2</sub>O/g, respectively. There were no significant differences ( $p > 0.05$ ) in samples TC3, TC4 and TC5 (30, 40 and 50% cassava starch) in bulk density but the sensory evaluation showed that sample TC3 (30% cassava starch) was generally acceptable in colour, taste, odour and texture when reconstituted into a stiff dough.

**Key words:** Functional, sensory, trifoliolate yam, cassava

## INTRODUCTION

Yam, a member of genus *Dioscorea* spp is the most important staple food in West Africa after cereals [1]. Out of the 48.7 million tonnes of yam produced worldwide in 2005, Nigeria (the leading producer) produced 34 million tonnes which accounts for about 70% of the total production [2]. There are about ten species of economic significance as food and the most important food species are white yam (*D. rotundata*), yellow yam (*D. cayenensis*), Chinese yam (*D. esculenta*), water yam (*D. alata*), aerial potato yam (*D. bulbifera*), cush-cush yam (*D. trifida*), bitter yam (*D. dumetorum*) and cinnamon yam (*D. opposita*) [3]. The most popular among these species is the white yam because of its ease of processing into commercial products [4].

Trifoliate yam (*Dioscorea dumetorum*) is among the underutilized yam species and is known by various names including three leaved yam, bitter yam and cluster yam. The tuber is large and coarse; one plant usually produced a cluster of tubers which are bitter due to the presence of alkaloids dioscorine [5]. Trifoliate yam is high yielding compared to other species and the starch grains are smaller, more soluble and more digestible than those of other yam species [6]. The proteins are, however, more balanced than those of white yam [7]. It is also rich in vitamins and minerals.

The consumption of trifoliate yam is restricted due to the bitter taste, inability to keep for longer time after harvesting and poor binding capacity of the flour [8, 9, 7, 10]. It has been reported that the bitterness in trifoliate yam could be eliminated during processing (soaking and boiling) [11, 12] and texture of stiff dough (amala) made from the flour could be improved by addition of cassava (*Manihot esculenta*) starch [8]. The objective of this study was to evaluate the effect of cassava starch substitution on the functional and sensory properties of trifoliate yam flour.

## MATERIALS AND METHODS

Trifoliate yam tubers (white), cassava tubers and white yam tubers flour were purchased from Ada market in Osun State, Nigeria. The trifoliate yam tubers were peeled, washed, boiled for 30 min and sliced [7]. They were dried in hot air oven at 60°C for 48 hrs. The dried samples were milled (Kenwood blender) and sieved (600 µm). The proportion of the flour that passed through the sieve was 87.7% while the residue was 11.5%. The trifoliate yam flour was packaged in polythene bags and stored at ambient temperature. The cassava starch was prepared according to method used by Kordylas [13]. Cassava tubers were peeled, washed, ground and sieved using muslin cloth. The starch slurry was allowed to settle for 6hrs and the supernatant was poured away. The remaining starch was washed four times and the cassava starch was dried in the oven at 40°C for 24 hrs. The starch was milled and packed in a sealed polythene bag. Cassava starch was used to substitute 10, 20, 30, 40 and 50% of trifoliate yam flour. The control white yam tubers were peeled, washed and diced. The diced yam tubers were parboiled at temperature of 70°C and left for 12 hours in the cooking water. The diced yam tubers were dried at 60°C for 48 hrs in hot air oven.

The dried sample was milled, sieved (600  $\mu\text{m}$ ) and packaged [14]. The stiff dough was prepared by adding the flour into 250mls of boiled water, stirred thoroughly, to avoid lumps, with a wooden spoon and cooked at  $100 \pm 2^\circ\text{C}$  for 15 min to form soft dough [15]. It was removed from fire and served at a temperature of  $60^\circ\text{C}$ . This was also done for the yam flour which served as the control. The dough could be eaten with stew, vegetable or other types of soup.

### Functional and sensory analysis determination

Pasting properties (peak, holding strength, breakdown, setback, final viscosity, pasting time and pasting temperature) were carried out on the samples using Rapid Visco-Analyzer (RVA model 3D for windows) [16]. Flour suspension was prepared by addition of equivalent weight of 3.0 g dry flour to distilled water to make a total of 28.0 g suspension in the RVA sample canister. This was placed centrally into the paddle coupling and was inserted into the RVA machine. The 12 min profile used was seen as it ran on the monitor of a computer to the instrument. The starting temperature was  $50^\circ\text{C}$  for 1 min and later heated from  $50^\circ\text{C}$  to  $95^\circ\text{C}$  for 3 min. It was held at  $95^\circ\text{C}$  for 3 min before the sample was subsequently cooled to  $50^\circ\text{C}$  over a period of 4 min. This was followed by a period of 1 min where the temperature was kept constant at  $50^\circ\text{C}$ . Pasting properties were carried out in duplicate.

Swelling index was carried out by weighing three grammes (3 g) portions of each flour sample into clean, dry, and graduated (50 ml) cylinders. The flour sample was gently leveled and the volume was noted before addition of 30 ml distilled water ( $27^\circ\text{C}$ ). The cylinder was swirled manually and allowed to stand for 60 min while the change in volume (swelling) was recorded [17]. The swelling index of each flour sample was calculated as the final volume of the sample in the cylinder divided by the initial volume of sample in the cylinder. Water absorption capacity was done by weighing 1 g of flour sample from each treatment was weighed into dry centrifuge tube. Distilled water was mixed with the flour to make up to 10 ml dispersion. It was then centrifuged at 3500 rpm for 15 min. The supernatant was discarded while the tube with its content was reweighed. The gain in mass was the water absorption capacity of the flour sample [17].

Bulk density was determined by filling 5 ml cylinder with the flour samples. The bottom of the cylinder was gently tapped and the bulk density was estimated as mass per unit volume of the sample [18]. Sensory analysis of the stiff dough was carried out by selecting randomly 10 untrained panelists drawn from Yoruba ethnic group among the lecturers of Department of Food Science and Technology, Osun State Polytechnic, Iree, Osun State, who were used to eating stiff dough made from yam flour. The panelists were requested to examine the dough and score according to their degree of likeness with a 9-point hedonic scale ranging from 1 (extremely liked) to 9 (extremely disliked). The parameters evaluated were the colour, taste, odour, texture and overall acceptability.



### Statistical analysis

The pasting and sensory properties were carried out in duplicate while the swelling index, water absorption capacity and bulk density were carried out in triplicate. The results obtained were statistically analyzed using one way analysis of variance (ANOVA) (SPSS 10.0 for windows) to test for significant differences ( $p < 0.05$ ) between the samples. The parameters analyzed were the mean, standard deviation, standard error. The differences in the mean values for the samples were shown using the Turkey's test.

### RESULTS

The results of pasting properties of the flour samples are shown in Table 1. The control sample had the highest peak viscosity (201.22 RVU), holding strength (167.17 RVU), final viscosity (324.25 RVU) and setback viscosity (157.08 RVU). These were significantly different ( $p < 0.05$ ) from all the samples. Peak viscosity and breakdown values of TF and substituted flour samples ranged from 54.13-98.33 RVU and 15.12-73.94 RVU. Peak viscosity and breakdown values increased with increase in cassava starch substitution with sample TC5 (50% cassava starch) having the highest values of 98.33 and 73.94 RVU respectively. Increase in viscosity was reported to depend more on the starch content of a product [19]. Breakdown is a measure of susceptibility of cooked starch granules to disintegration and has been reported to affect the stability of the flour products [20].

A low breakdown value indicated that the flour products were more stable under hot condition (73.88°C). Sample TF was more stable than the other samples substituted with cassava starch. The holding strength and final viscosity values of sample TF were not significantly different ( $p > 0.05$ ) from sample TC1 (10% cassava starch) while the setback value of sample TF was not significantly different ( $p > 0.05$ ) from sample TC1 and TC2 (20% cassava starch). The values obtained for holding strength and final viscosity indicated that sample TF had low cooking loss, superior eating quality and are resistant to shear stress than other treated flour samples [21].

Sample TF showed higher tendency to retrograde than the other samples and the values decreased with addition of cassava starch. Setback value is an index of the tendency of the cooked flour to harden on cooling due to amylose retrogradation [22]. Pasting time values of samples TC1 and TC2, and TC3 and TC4 were not significantly different ( $p > 0.05$ ) from each other. Sample TF had the least value (4.59 min) which was significantly different ( $p < 0.05$ ) from other samples. Sample TC4 had higher value (79.27 °C) in pasting temperature while the least value was in sample TF. Sample TC4 was significantly different ( $p < 0.05$ ) from other samples. There was no significant difference ( $p > 0.05$ ) between samples TC1, TC2, TC3 and TC5 in their values.

Table 2 showed the results of the swelling index, density and water absorption capacity of the flour samples. Sample TF had higher swelling index value (2.97) than the control sample which had the least value of 1.23. There were no significant

differences ( $p < 0.05$ ) in samples TC2, TC3, TC4 and TC5. Swelling index values of 5.90-7.50ml/g were reported for three species of yam flour [23] these values were higher than the values obtained due to the method used, the starch content and species of yam used. The characteristics of food products had been shown to be reflections of the functional properties of specific starch or flour fractions [24].

Density of the flour increased with increase in cassava starch substitution. Bulk density values of 0.50-0.62 g/ml were reported for the flour samples of *D. cayenensis*, *D. bulbifera* and *D. rotundata* [23]. Increase in bulk density increased the sinkability of powdered particles which aids wetting by aiding their ability to disperse [25]. Sample TC3 and TC4 had higher bulk density but these were not significantly different ( $p < 0.05$ ) from sample TC5 and the control.

Sample TF had higher water absorption capacity of 2.49 ml H<sub>2</sub>O/g while the least value was in the control (1.12 ml H<sub>2</sub>O/g). The values decreased with increase in cassava starch substitution. Water absorption capacity values of 3.50, 5.00 and 6.00 g/g were also reported for *D. bulbifera*, *D. cayenensis* and *D. rotundata* respectively [23]. Percentage of water absorption capacity recorded for different varieties of *D. rotundata* ranges from 21.30-193.30% [1].

The results of the sensory evaluation are shown in Table 3. Sample TC3 was more acceptable in colour among the substituted yam flour samples while there were no significant difference ( $p < 0.05$ ) in samples TC3, TC4 and TC5 in taste and odour. The colour of the reconstituted flour became lighter while the odour and bitter taste were reduced with increase in cassava starch substitution. Texture of the reconstituted trifoliolate yam flour was also improved with the addition of cassava starch. There were no significant difference ( $p < 0.05$ ) in texture and overall acceptability of TC3 and TC4. These compared well with the control sample (YF). The sample substituted with 30% cassava starch was the most acceptable among the samples. Yam flour was also fortified with cassava flour and the major complaints were on the taste and the aroma of the food [26] but Cassava starch has bland flavour, excellent freeze thaw stability and non-retrogradation tendency [27].

## DISCUSSION

The increase in peak viscosities observed in the substituted trifoliolate yam flour samples is associated with the cassava starch concentration. High peak viscosity and stability was reported to be associated with cassava starch [28] and there exists a linear logarithmic correlation between maximum viscosity and starch concentration as observed by Moorthy *et al* and Mepha *et al* [29, 30]. Also, increase in pasting temperature of the substituted flour samples indicates that the substituted flour samples gels at a temperature higher than the trifoliolate yam flour. Sample TC5 showed low stability during cooking due to its high susceptibility to shear stress. Similar observation was reported by Mepha *et al* [30] for different starch blend. The high retrogradation tendency observed for the control sample could be due to the crystallization involving amylose molecules and the long-branch chain of amylopectin

[30]. Amylose content reported for cassava starch ranged from 18.6-25.6% and 27.6-38.2% in yam [31, 32, 33].

Sample TF and the substituted flour samples had higher swelling index values than the control sample. It was explained that the starch of white yam exhibits low and restricted swelling capacity at ambient conditions. Differences in swelling index were explained by varying granular association coupled with the amylose – amylopectin ratio of starches from various species of yam [17]. Amylose was reported to restrict swelling and that starch granules show complete swelling after amylose has been leached out of the granules [21]. Sample TC3 and TC4 had higher bulk density and therefore had ability to disperse in water during processing. The samples would likely weigh more during reconstitution than other samples.

Sample TF had higher water absorption capacity than the control sample. This agrees with the finding of Akinwande *et al* [34]. Sample TF would require more water during reconstitution than the substituted samples and the control. The high water absorption capacity was attributed to loose association of starch polymers in the native granule [1]. Addition of cassava starch lowered the water absorption capacity of the substituted flour samples. Water absorption capacity in Life flour was also observed to be lowered with the addition of cassava starch from 60.8-59% while there was an increase in Golden penny flour upon addition of cassava starch from 56.3%-59% at 600 B.U [35]. The differences observed in water absorption capacity of the samples could be explained in terms of the differences in the degree of association of starch granules in them [36].

Sample TC3 compared well with the control sample in colour. There was no significant difference ( $p > 0.05$ ) in their values. Colour of sample TC5 became lighter due to high concentration of cassava starch in the sample. Sample TC3, TC4 and TC5 compared well with the control in taste. The bitterness and odour were reduced with increase in cassava starch substitution. Texture of the substituted flour sample TC3, TC4 and TC5 were firm while those of TF, TC1 and TC2 were sticky. Although sample TC3 was more acceptable, there were no significant differences ( $p > 0.05$ ) between TC3 and TC4 in overall acceptability.

## CONCLUSION

The substitution of trifoliolate yam flour with cassava starch improves the functional and textural properties of the yam flour. Trifoliolate yam flour could be made into stiff dough which would be acceptable when 30% cassava starch is added to the flour. This stiff dough could be eaten with okro soup, vegetable soup or meat stew. This will improve the utilization of the trifoliolate yam in another form thus curbing food insecurity. Also, different processing methods such as fermentation and soaking could be used to reduce the odour and bitter taste of reconstituted trifoliolate yam flour.

**Table 1: Effect of cassava starch substitution on the pasting properties of trifoliate yam flour**

Sample	Peak viscosity (RVU)	Holdin g strengt h (RVU)	Breakdow n value (RVU)	Final viscosity (RVU)	Setbac k value (RVU)	Pastin g time (min)	Pasting temperatur e (°C)
TF	54.13 <sup>d</sup>	39.01 <sup>b</sup>	15.12 <sup>de</sup>	66.42 <sup>b</sup>	27.42 <sup>b</sup>	4.59 <sup>d</sup>	73.88 <sup>c</sup>
TC1	58.83 <sup>d</sup>	35.89 <sup>b</sup>	19.95 <sup>d</sup>	62.55 <sup>bc</sup>	26.67 <sup>b</sup>	4.79 <sup>c</sup>	79.16 <sup>b</sup>
TC2	57.06 <sup>d</sup>	31.73 <sup>b</sup>	25.33 <sup>d</sup>	53.20 <sup>c</sup>	21.47 <sup>b</sup>	4.85 <sup>c</sup>	75.42 <sup>bc</sup>
TC3	73.61 <sup>c</sup>	27.13 <sup>c</sup>	46.48 <sup>b</sup>	41.34 <sup>d</sup>	14.21 <sup>c</sup>	5.18 <sup>a</sup>	76.54 <sup>b</sup>
TC4	77.92 <sup>c</sup>	25.76 <sup>c</sup>	52.16 <sup>b</sup>	39.23 <sup>d</sup>	13.46 <sup>c</sup>	5.24 <sup>a</sup>	79.27 <sup>a</sup>
TC5	98.33 <sup>b</sup>	24.39 <sup>c</sup>	73.94 <sup>a</sup>	36.46 <sup>d</sup>	12.08 <sup>c</sup>	5.00 <sup>b</sup>	75.90 <sup>b</sup>
YF	201.22 <sup>a</sup>	167.17 <sup>a</sup>	34.05 <sup>c</sup>	324.25 <sup>a</sup>	157.08 <sup>a</sup>	4.80 <sup>c</sup>	79.10 <sup>b</sup>

Mean values followed by the same letter down the column were not significantly different ( $p > 0.05$ ). TF= trifoliate flour; TC1= Trifoliate flour with 10% cassava starch, TC2s= Trifoliate flour with 20% cassava starch, TC3= Trifoliate flour with 30% cassava starch, TC4= Trifoliate flour with 40% cassava starch and TC5= Trifoliate flour with 50% cassava starch, YF = white yam flour



**Table 2: Effect of cassava starch substitution on the functional properties of trifoliate yam flour**

Sample	Swelling index	Density g/cm <sup>3</sup>	Water holding capacity ml H <sub>2</sub> O/g
TF	2.97 ± 0.02 <sup>a</sup>	0.71 ± 0.01 <sup>c</sup>	2.49 ± 0.01 <sup>a</sup>
TC1	2.26 ± 0.04 <sup>b</sup>	0.72 ± 0.01 <sup>c</sup>	2.13 ± 0.02 <sup>b</sup>
TC2	2.04 ± 0.06 <sup>c</sup>	0.74 ± 0.01 <sup>b</sup>	1.88 ± 0.02 <sup>c</sup>
TC3	2.03 ± 0.04 <sup>c</sup>	0.77 ± 0.01 <sup>a</sup>	1.83 ± 0.03 <sup>d</sup>
TC4	1.98 ± 0.01 <sup>c</sup>	0.77 ± 0.01 <sup>a</sup>	1.70 ± 0.02 <sup>e</sup>
TC5	1.97 ± 0.02 <sup>c</sup>	0.76 ± 0.02 <sup>a</sup>	1.51 ± 0.02 <sup>f</sup>
YF	1.23 ± 0.03 <sup>d</sup>	0.76 ± 0.02 <sup>a</sup>	1.12 ± 0.01 <sup>g</sup>

Mean values followed by the same letter down the column were not significantly different (p > 0.05). TF= trifoliate flour; TC1= Trifoliate flour with 10% cassava starch, TC2= Trifoliate flour with 20% cassava starch, TC3= Trifoliate flour with 30% cassava starch, TC4= Trifoliate flour with 40% cassava starch and TC5= Trifoliate flour and 50% cassava starch, YF=white yam flour

**Table 3: Effect of cassava starch substitution on the sensory quality attributes of trifoliate yam flour**

Sample	Colour	Taste	Odour	Texture	Acceptability
TF	5.55 ± 0.21 <sup>ab</sup>	8.45 ± 0.35 <sup>a</sup>	8.70 ± 0.14 <sup>a</sup>	9.00 ± 0.00 <sup>a</sup>	9.00 ± 0.00 <sup>a</sup>
TC1	4.30 ± 0.28 <sup>bc</sup>	7.35 ± 0.49 <sup>a</sup>	6.80 ± 0.57 <sup>b</sup>	8.65 ± 0.00 <sup>a</sup>	9.00 ± 0.00 <sup>a</sup>
TC2	4.15 ± 0.21 <sup>c</sup>	4.30 ± 0.28 <sup>b</sup>	5.35 ± 0.35 <sup>c</sup>	6.65 ± 0.49 <sup>b</sup>	4.85 ± 0.49 <sup>b</sup>
TC3	2.40 ± 0.14 <sup>d</sup>	2.20 ± 0.14 <sup>c</sup>	2.70 ± 0.42 <sup>d</sup>	2.35 ± 0.21 <sup>d</sup>	2.45 ± 0.49 <sup>c</sup>
TC4	3.80 ± 0.70 <sup>c</sup>	2.10 ± 0.14 <sup>c</sup>	2.10 ± 0.00 <sup>d</sup>	2.85 ± 0.91 <sup>d</sup>	3.25 ± 0.07 <sup>c</sup>
TC5	6.45 ± 0.07 <sup>a</sup>	2.10 ± 0.14 <sup>c</sup>	2.00 ± 0.00 <sup>d</sup>	4.80 ± 0.28 <sup>c</sup>	4.96 ± 0.37 <sup>b</sup>
YF	1.3 ± 0.02 <sup>d</sup>	1.10 ± 0.10 <sup>c</sup>	1.00 ± 0.21 <sup>e</sup>	1.80 ± 0.08 <sup>d</sup>	1.2 ± 0.16 <sup>d</sup>

Mean values followed by the same letter down the column were not significantly different ( $p > 0.05$ ). TF= trifoliate flour; TC1= Trifoliate flour with 10% cassava starch, TC2= Trifoliate flour with 20% cassava starch, TC3= Trifoliate flour with 30% cassava starch, TC4= Trifoliate flour with 40% cassava starch and TC5= Trifoliate flour with 50% cassava starch, YF = White yam flour

## REFERENCES

- 1 **Ekwu FC, Ozo NO and OJ Ikegwu** Quality of fufu flour from white yam varieties (*Dioscorea* spp). Nig. Food J. 2005; **23**: 107-113.
- 2 **IITA**. Yam. Research review. International Institute of Tropical Agriculture, Ibadan, Nigeria. 2006: 1-4.
- 3 **Craufurd PQ, Summerfield RJ, Asiedu R and PVV Prasad** Dormancy in yam. Exp. Agric., 2001: **37**: 147-181.
- 4 **Akanbi CT, Gureje PO and IA Adeyemi** Effect of heat-moisture pre-treatment on physical characteristics of dehydrated yam. J. Food Engr., 1996: **28**: 45-54.
- 5 **Onwueme IC** The tropical tuber crops- yam, cassava, sweet potatoes and cocoyam. Longman, 1978 66-68.
- 6 **Treche S and P Guion** Nutritional repercussions of the differences in physicochemical characteristics of starches of two yam species grown in Cameroon. Paper prepared for the fifth Symp. of the Intl Soc for Trop. Root Crops, Manila, Philippines, 1980 September 17-21.
- 7 **Mbome LI and S Treche** Nutritional quality of yam (*Dioscorea dumetorum* and *D. rotundata*) flours for growing rats. J. Sci. Food Agric., 1994; **66**: 441-455.
- 8 **Martin GS, Treche L, Noubi T, Agbor E and A Gwangwa** Introduction of flour from *Dioscorea dumetorum* in a rural area. In: Terry ER, Doku EV, Arene OB and Mahungu NM (eds), Tropical Root Crops: Production and uses in Africa. Proceeding of the second triennial Symposium of the International Society for Tropical Root Crops Africa, Doaula, Cameroon. 1983; 161-163.
- 9 **Doku EV** Production potentials of major tropical roots and tuber crops. In: Terry ER, Doku EV, Arene OB and Mahungu NM (eds), Tropical Root Crops: Production and uses in Africa. Proceeding of the second triennial Symposium of the International Society for Tropical Root Crops Africa, Doaula, Cameroon 1983; 19-24.
- 10 **Sefa-dedeh SK and EO Afoakwa** Biochemical and textural changes in trifoliate yam (*Dioscorea dumetorum*) tubers after harvest. IFT Annual meeting-New Orleans, Louisiana. 2001.
- 11 **Eka OU** Root and Tubers. In: Osagie AU and Eka OU (eds). Nutritional Quality of Plant Foods Macmillian Press, London 1998; 1 - 31.

- 12 **FAO.** Effect of processing on the nutritional value: Roots, tubers, plaintains and banana in human nutrition FAO, United Nations, 1990; 76 - 78.
- 13 **Kordylas JM** Traditional and industrial processing of tubers. In: Processing and preservation of tropical and subtropical foods. Macmillian Education Ltd. London, 1990; 34-48.
- 14 **Nwaegbute AC, Osho SM and VA Obatokun** Proceeding conference on post harvest technology and commodity marketing in West Africa. Accra, Ghana, 1995; 162-178.
- 15 **Abioye VF, Ogunlakin Go, Babarinde GO and B Adeoti** Effect of drying temperatures and yam slice thickness on the quality attributes of yam flour. proceedings of the 32<sup>nd</sup> annual conference/general meeting. Otunola ET (eds) 13-17 Oct 2008; 270-271.
- 16 **Newport Scientific.** Applications Manual for the Rapid Visco<sup>TM</sup> Analyser. Newport Scientific Pty. Ltd. Australia, 1998; 36 – 58.
- 17 **Iwuoha C I** Comparative evaluation of physicochemical qualities of flours from steam-processed yam tubers. J. Food Chem, 2004; **85**: 541-551.
- 18 **Nwanekezi EC, Ohagi NC and OC Afam-Anene** Nutritional and organoleptic quality of infant food formulations made from natural and solid state fermented tubers (cassava, sprouted and unsprouted yam) - soybean flours blend. Nig. Food j., 2001; **19**: 55-62.
- 19 **Adeyemi IA and O Beckley** Effect of period of maize fermentation and souring on chemical properties and Amylograph pasting viscosity of ogi. J. Cereal Sci., 1986; **4**: 353-360.
- 20 **Beta T, Harold C, Lloyd WR and RNT John** Starch properties as affected by sorghum grain chemistry. J. Sci. Food and Agric., 2000; **81**:245-251.
- 21 **Bhattacharya M, Zee SY and H Corke** Physico-chemical properties related to quality of rice noodles. Cereal Chem., 1999; **76 (6)**: 861-867.
- 22 **Adeyemi IA** Cereals as food and industrial raw materials. In: Aribisala OA and Olorunfemi BN (eds). Proceedings of the first meeting of the Action Committee on Raw Materials, Raw Materials Research and Development Council. Lagos, Nigeria. 1989; 131-138.
- 23 **Igyor MA, Ikyo SM and DI Gernah** The food potential of potato yam (*Dioscorea bulbifera*). Nig. Food J., 2004; **22**: 209-215.
- 24 **Richard J** Quality aspects of Tropical root crop starches. In: Proceedings of 9<sup>th</sup> Symposium Intl Soc. Tropical Root Crops, Accra, Ghana. 1991: 89-93.



- 25 **Brennah JG, Bitters JR, Cowell ND and AEV Lielly** Effect of agglomeration on the properties of spray-drier rouibos tea. *Inter. J. Food Sc. Tech.*, 1976; **23**: 43-48.
- 26 **Abulude F and VA Ojediran** Development and quality evaluation of fortified 'amala'. *Acta Sci. Pol., Technol. Aliment.* 2006; **5(2)**:127-134.
- 27 **Odigbo EU** Cassava: Production, processing and utilization. In: Chan HT ed. *Handbook of Tropical Foods*, New York, Marcel Dekkar, 1983 145-200.
- 28 **Adeyemi IA and O Omolayo** Utilization of cocoyam flour and starch for biscuits and cake making, *Nigerian Journal of Science* 1984; **18**:34-37.
- 29 **Moorthy SN, Rickard J and JMR Blanshard** Influence of gelatinization of cassava starch and flour on the textural properties of some food products. In: *Cassava flour and starch: progress in research and development*. D Dufor, GM O'Brien and Rupert Best (eds). Montpellier, France 1996' 150-155.
- 30 **Mepah HD, Eboh L, Aron AAN and JU Ukpabi** Rheological, baking and sensory characteristics of fermented cassava starch-wheat-cowpea blends. *Nigerian Food Journal* 2009; **27 (1)**: 172-186.
- 31 **Peroni FHG, Rocha TS and CML Franco** Some structural and physico-chemical characteristics of tuber and root starches. *Food Science and Technology International* 2006; **12**: 505-513.
- 32 **Hoover R** Composition, molecular structure and physico-chemical properties of tuber and root starches review. *Carbohydrate Polymers* 2001; **45**: 253-267.
- 33 **McPherson AE and J Jane** Comparison of waxy potato with other root and tuber starches. *Carbohydrate Polymers* 1999; **40**: 57-70.
- 34 **Akinwande BA, Abiodun OA, Adeyemi IA and CT Akanbi** Effect of steaming methods and time on the physico-chemical properties of flour from four species of yam tubers. In Otunola ET (eds). *Challenges of research and development for food/nutrient security and Agro-industrialization*. Proceedings of the 32<sup>nd</sup> annual conference/ General meeting, 13<sup>th</sup> -17<sup>th</sup> Oct 2008; 294-295.
- 35 **Ogunsua AO** The use of deffated oilseeds in composite flours for breadmaking. *Nig. Food J.* 1986; **4 (1)**: 45-52.
- 36 **Soni PL, Sharnia HW, Dobhal NP, Bisen SS, Scrivastava HC and MM Gharia** The starches of *Dioscorea ballophylla* and *Amorphophallus. Companulatus* Starch/Starke, 1985; **137(1)**:6-19.