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EFFECT OF CARBOXYMETHYLCELLULOSE INCORPORATION ON THE FUNCTIONAL, PASTING AND SENSORY PROPERTIES OF WATER YAM (*D. ALATA*) FLOUR

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ABSTRACT: *The research aim was to evaluate the effects of carboxymethylcellulose (CMC) incorporation on the functional, pasting and sensory properties of water yam (D. alata) flour. The water yam tuber was processed into flour, blended with CMC at various concentrations (0.05%, 0.25%, 0.50% and 1.00%) and compared with the control with 0.00% CMC. The pasting characteristics were significantly different (p<0.05) among the sample blends. On average, sample blends 0.50C and 0.05A had the lowest and highest value in their pasting properties including; peak viscosity (158.950-287.250RVU), trough viscosity (146.150-248.500RVU), breakdown viscosity (20.70-23.00RVU), final viscosity (270.300-406.100RVU), setback viscosity (12.415-15.760RVU) and pasting temperature (80.025-93.500°C) respectively. The functional properties of the sample blends were significantly different (p<0.05). The pH showed the least level of significance. The sensory attributes of paste from the sample blends were significantly different, although some sampleblends were comparable. These variations would improve on the choice and better utilization of water yam flour in variety of food applications.*

KEYWORDS: Water yam flour, carboxymethylcellulose, substitution, functional properties, paste.

INTRODUCTION

Yam (*Dioscorea spp.*) are climbing plants with smooth leaves and twining stems, which coil readily around a stake (Udensi *et al.*, 2008). They are perennial through root system but are grown annual crop and are grown annual crop and are the third most important tropical root crops after cassava and sweet potatoe (Fu *et al.*, 2005). It is one of the staple foods in Nigeria and a crop of economic, social and cultural importance in many tropical countries (Jova *et al.*, 2005). About 52 million tons of yam were produced globally in 2007, with 96% from West Africa (IITA, 2009). Yam is rich in carbohydrate, dietary fibre and some minerals (Kouassi *et al.*, 2010). Fresh yams

are difficult to store and are subject to deterioration during storage (Afoakwa and Sefa-Dedeh, 2001). Olayemi *et al.* (2012) reported post-harvest losses of yam in Nigeria to be about 37%which underscores the need for processing this staple food crop into products of longer shelf-life such as

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flour. In Nigeria, several attempts have been made to overcome and improve properties of yam flour (Jimoh and Olalidoye, 2009; Obadina *et al.*, 2014; Wahab *et al.*, 2016; Egbuonu *et al.*, 2014; Ogunlakin *et al.*, 2013) especially, those derived from water yam (*Dioscorea alata*). Water yam tubers are valuable source of carbohydrate to supply human need of food especially in arid regions. It is popular and prevalent within Abakiliki agro ecological zone of Ebonyi state, Nigeria where it is called "Mbala or Nvula (Igbo names) (Udensi *et al.*, 2008). They are consumed boiled, roasted, fried or pounded and eaten in association with protein rich sauces. Water yam can also be processed into flour and reconstituted into fufu dough. Although literature abounds on the use of different species of yam; *Dioscorea rotundata*; *Dioscorea alata* and *Dioscorea cayensis* in the production of acceptable flour (Akissoe *et al.*, 2003; Iwuoha, 2004; Ekwu *et al.*, 2005; Babajide *et al.*, 2007; Ukpabi and Omodamiro, 2008; Akinwande *et al.*, 2008), however, there is little information on the properties of yam (*Dioscorea alata*) flour blended with binders. Therefore, this work studies the functional, pasting and sensory properties of carboxymethylcellulose (CMC) blended yam flour.

MATERIALS AND METHODS

Sources of raw materials

Water yam (*Dioscoreaalata*) tubers were purchased at AkwaIdemili market in Orlu Imo state.Carboxymethylcellulose (CMC) used as a binder and Sodium metabisulphitewere purchased from a scientific store in douglas market owerri.

Production of water yam (*Dioscoreaalata*) flour samples

Raw water yam tubers were washed with clean water to remove soil, fertilizer and other undesirable materials adhering to the yam tubers. The water yam were hand-peeled using kitchen knife and was washed again to remove any contaminate during peeling and was sliced into sizes of 2cm thickness. It was soaked in a 500ml boiled water containing 5g Sodium metabisulphite for 5mins, drained, and sundried for 2days. The dried water yam was milled or grinded to flour. It was sieved using standard sieve of 0.6µm. To every 10g, to produce sample A to D 0.05%, 0.25%, 0.5%, 1% CMC was added respectively. Sample E has 10g of dried water yam with no CMC added. The samples were packaged in an air tight container for analysis

Determination of functional properties

Bulk density

This was determined using the procedure described by Onwuka (2005). 100mL capacity graduated measuring cylinder was weighed and was gently filled with the flour sample. The botton of the cylinder was tapped gently on the laboratory bench several times until there was no further diminution of the sample level after filling to the 10mL mark. The bulk density was calculated thus;

Bulk Density (g/mL)= $\frac{Weight\ of\ Samples\ (g)}{Volume\ of\ samples\ (mL)}$

Wettability

The method of Onwuka (2005) was used. Into a 25 ml graduated cylinder with a diameter of 1 cm, 1g of sample was added. A finger was placed over the open end of the cylinder which was invested and clamped at a height of 10cm from the surface of a 600 ml beaker containing 500 ml of distilled water. The finger was removed and the rest material allowed to be dumped. The wettability is the time required for the sample to become completely wet.

Swelling index

The swelling power of each sample was calculated as a multiple of the original volume as done by Ukpabi and Ndimele (1990). One (1) gram of each flour sample was transferred into clean, dry graduated (50mL) cylinder. The flour samples were gently leveled into it and the volume noted. Distilled water (10mL) was added to each sample. The cylinder was swirled and allowed to stand for 60 minutes while the change in volume (swelling) was recorded every 15 minutes. The swelling index of the sample was given by the formula;

$$\text{Swelling Index} = \frac{\text{Volume occupied by the sample after swelling}}{\text{Volume occupied by the sample before swelling}}$$

Foam capacity

The method described by Onwuka (2005) was adopted. Two grams (2g) of each sample were blended with 100ml of distilled water in Philips blender for 5 minutes at room temperature. The mixture was quickly but carefully transferred to 250 ml measuring cylinder and the foam volume was measured. The volume of foam formed was then recorded as foam capacity in percentage.

$$\text{Foaming capacity} = \frac{\text{volume after whipping} - \text{volume before whipping}}{\text{Volume before whipping}}$$

Water absorption/Oil absorption capacity

The method of Carvea-Benecini (1986) was employed. One gram (1g) of the flour was weighed into six clean dry centrifuge tubes using an analytical weighing balance. The tubes were labelled separately for oil and water. Ten (10) mL of distilled water was added to three tubes and oil to the other and stirred manually. The mixture was allowed to stand at room temperature for some minutes and centrifuge for 30 minutes at 1500 rpm. The supernatant was decanted and the volume in the measuring cylinder was noted and converted to weight (in grams) by multiplying by the density of oil (0.902 g/ml) and water (1 g/ml). The oil and water absorption capacities were expressed as;

$$\text{Water/Oil Absorption Capacity} = \frac{\text{Weightof water/oil absorbed}}{\text{Weight of flour sample}}$$

Viscosity

The method of Onwuka (2005) was adopted. Ten (10) percent of the flour was suspended in distilled water and mechanically stirred for 2h at room temperature. Oswald type Viscometer was used to measure the viscosity.

pH

The pH of the sample was measured with a pH meter as described by Onwuka (2005) .About 10% W/V suspension of the sample was prepared in distilled water and mixed thoroughly in a kenwood blender (BL 330 series), then the pH was taken after standardizing with buffer solutions of pH 4.0 and 7.0.

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Pasting properties

The pasting properties of the flour were determined by Rapid Visco Analyzer (RVA_{-4} Model, Newport Scientific Warrie wood, Australia) according to method described by Sim *et al.*, (2009) and Vongsawasdi *et al.* (2009). Three grams of each of the samples was weighed into the RVA canister; 25mL of distilled water was added and was inserted into the machine. This was followed by a programmed heating and cooling where the sample was held at 50°C to 95°C at a constant rate of 12°C/min and then held at 95°C for 2.5min, cooled to 50°C at the same stirring rate and then held at 50°C for 2min. parameters recorded were pasting temperature (PT), peak time (PKT), peak viscosity (PV), trough viscosity (TV), final viscosity (FV), breakdown viscosity (BV=PV-TV), and setback viscosity (SV=FV-TV).

Sensory Evaluation

The sensory properties of yam flour paste were evaluated using twenty semi-trained panelists consisting of staff and students of the Department of Food Science and Technology, Federal University of Technology Owerri, Nigeria. The paste were evaluated for colour, taste, aroma, mouldability, texture and overall acceptability using nine point Hedonic scale(where 1 = liked extremely and 9 = disliked extremely) (Iwe, 2010). Paste from each blend was presented to panelists. Each panelist was provided with a glass of tap water to rinse the mouth between evaluations.

Statistical analysis

The data were subjected to analysis of variance (ANOVA) as described by (SAS, 2000). The means were then separated with the use of Duncan's multiple range test, compared by Least Significant Difference (LSD) with mean square error at 5% probability using the statistical package for the social sciences, SPSS 19.0 software.

RESULTS AND DISCUSSIONS

Functional properties

The functional properties of the various samples were shown in Table 1. The mean value obtained for bulk density of the samples were significantly different ($p<0.05$). The bulk density of the flour blends were higher (0.50C-0.90g/mL) and lower (0.05A-0.14g/mL; 1.00D-0.12g/mL; 0.00E-0.320g/mL) than 0.64-0.76g/mL reported for varieties of water yam flour (Udensi *et al.*, 2008), except 0.25B (0.70g/mL) which was within the range. The differences in the value might be as a result of the CMC additions. Sample blend 0.25B bulk density is comparable to that obtained for sweet potato flour (0.7453g/mL) used as thickner or as a base in foods like yoghurt (USDA, 2009). Bulk density is an indication of the porosity of a product and a function of flour wettability which influences packaging design and could be used in determining the required type of packaging material (Iwe and Onalope, 2001; Akubor, 2007). High bulk densities have been found desirable for greater ease of dispersibility and reduction of paste thickness (Udensi and Eke, 2000). Low bulk density of flour are good physical attributes when determining transportation and storability since the products could be easily transported and distributed to required locations (Agunbiade and Sanni, 2001). The bulk densities of 0.05A, 1.00D and 0.00E were relatively low and suggests its potentiality in the formulation of complementary foods where high nutrient to low bulk density is needed (Mepba *et al.*, 2007).

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pH of the samples were significantly different ($p<0.05$) except sample blends 0.00E and 0.05A; 0.25B and 1.00D which showed no significant difference. However, these differences were not apparent. The pH values falls within the range 5.10-6.40 reported by Obadina *et al.* (2014) for yam flours. These values are between low acid and medium acid food classes (Potter and Hotchkiss, 2007).

Swelling index of the sample blends were significantly different ($p<0.05$). Sample blends 0.00E and 0.25B have swelling index (5.685 and 7.430) within the range reported by Kafilat (2010) for *D. rotundata* flour (5.45-8.00). Sample 0.00E swelling index falls within the range reported by Adebayo-Oyetoro *et al.* (2016) for cassava flour. Sample blends 0.25B and 0.50C have the lowest and highest swelling index respectively. The variation in swelling index indicates the degree of exposure of the internal structure of the starch present in the flour to the action of water Kafilat (2010). Swelling and gelatinization properties are controlled in part, by the molecular structure of amylopectin starch, compositions and granule architecture (Crystalline to amorphous ratio) (Srichuwong *et al.*, 2005).

Water absorption capacity obtained ranges from 1.840-3.34(g/g) and showed significant differences ($p<0.05$). Sample blends 0.05A and 0.50C have the lowest and highest water absorption capacity respectively. The values obtained including the control sample (0.00E) are higher than water absorption capacity (1.77g/g) reported by Iwuoha (2004) for water yam in Nigeria. These variations may be attributed to specie of water yam, regional differences, and addition of CMC. Water absorption capacity is an important functional property required in food formulation especially those involving dough handling such as yam fufu. It has been reported that high water absorption capacity may assure product cohesiveness as required in the development of ready to eat foods (Ogunlakin *et al.*, 2012). Also high water absorption capacity have been found to be useful as functional ingredients in bakery products as this could prevent staling by reducing moisture loss (Obatolu *et al.*, 2007). Low water absorption capacity is a desirable trait in foods such as sausage, custards and dough because these are supposed to imbibe water without dissolution of protein thereby attaining body thickening and viscosity (Seena and Sridher, 2005).
Oil absorption capacities as shown in Table 1 were significantly different ($p<0.05$). Sample blends 0.50C and 0.00E exhibited the highest and lowest value. High oil absorption capacity of flour makes it suitable as it enhances flavour and mouthfeel (Appiah *et al.*, 2011).

Foam capacity of the sample blends showed significant differences ($p<0.05$) except sample blends 0.05A and 0.25B which were not significantly different ($p>0.05$). The foam capacities range from 5.80-25.00, with samples 0.25B and 1.00D having the highest and lowest values. Low foam capacity flours are desirable in food processes where excessive foaming is not required as it reduces loss due to foam spillage or the need for including extra steep or antifoaming agent to check foaming. Also, flours with high foaming ability could form large air bubbles surrounded by thinner and less flexible protein films (Adeleke and Odedeji, 2010). These air bubbles might be easier to collapse and consequently lower the foaming stability.

Viscosity of the samples was significantly different ($p<0.05$) except samples 1.00D and 0.50C; 0.50C and 0.25B; 0.25B, 0.05A and 0.00E that showed no significant difference ($p>0.05$). The

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viscoity of the sample blends shows that addition of CMC decreases their viscosities. This shows that samples with high CMC blends could be suitable in foods that require low viscosity.
The wettability of the samples were significantly differently ($p<0.05$) except samples 0.05A and 0.25B that showed no significant difference ($p>0.05$). Wettability time of the samples increased as the amount of CMC blend increases. Wettability provides a useful indication of the degree to which dried flour such as *D. alata* flour is likely to possess instant characteristics.

Table 1:Functional properties of carboxymethylcellulose blended water yam flour

Sample	Bulk density	pH	swelling index	WAC	OAC	foam capacity	Viscosity	Wettability
0.05A	0.140^{e}	5.939^{a}	10.480^{d}	1.840^{a}	3.440^{d}	28.000^{d}	1.350^{c}	63.500^{b}
0.25B	0.700^{c}	6.060^{d}	7.430^{b}	3.035^{c}	3.185^{c}	30.000^{d}	1.200^{bc}	67.500^{b}
0.50C	0.900^{d}	6.005^{bc}	11.390^{e}	3.340^{e}	3.510^{e}	11.000^{b}	0.850^{ab}	189.00^{c}
1.00D	0.120^{a}	6.060^{d}	9.330^{c}	2.245^{b}	2.965^{b}	5.800^{a}	0.500^{a}	249.000^{d}
0.00E	0.320^{b}	5.939^{a}	5.685^{a}	3.270^{d}	2.515^{a}	25.000^{c}	1.350^{c}	56.500^{a}
LSD	0.169	0.015	0.047	0.034	0.043	2.439	0.481	4.810

Mean in the sample column with the sample superscripts are not significantly different at $P> 0.05$ and those with different superscripts are significantly different at $P < 0.05$.

Key:
0.05A - Yam flour blended with 0.05% CMC.
0.25B - Yam flour blended with 0.25% CMC.
0.50C - Yam flour blended with 0.50% CMC.
1.00D - Yam flour blended with 1.00% CMC.
0.00E - Yam flour blended with 0.00% CMC (Control).

Pasting properties

The pasting properties of the sample blends are shown in Table 2. The results obtained peak viscosity (158.950-287.250RVU), trough viscosity (146.150-248.500RVU), breakdown viscosity (20.700-38.600RVU), final viscosity (270.300-406.100RVU), setback viscosity (12.415-15.760RVU), pasting temperature (80.025-93.500^{o}C) showed significant differences ($p<0.05$) among the sample blends of each parameters.

Peak viscosity points to the water binding capacity and viscosity of the flour sample (Abiodun and Akinoso, 2014), which reflects the ability of starch granules to swell freely before been broken down physically (Wireko-Manu *et al.,* 2011). Peak viscosity of the sample blends was 158.950-287.250RVU which is in consonance with those 70-280RVU reported by Kafilat (2010) and Baah(2009). Zaidul *et al.* (2007) reported that lower amylose content was associated with higher

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peak viscosity; on the contrary, Baah (2009) showed that amylose content did not affect peak viscosity. Estiasih *et al.* (2013) also found that amylose content of blanched yellow water yam flour had higher peak viscosity. Jimoh *et al.* (2009) reported that water absorption capacity, biology and morphological properties of starch affected peak viscosity.

Trough viscosity of the sample blends (146.150-248.500RVU) obtained was in accordance with Kafilat (2010) and Baah (2009). Trough viscosity shows starch ability to cook and granule weakness. Sample blends 0.50C and 0.05A have the lowest and highest trough viscosity.
0.50C and 0.05A showed the lowest and highest breakdown viscosity. The values obtained for breakdown viscosity (20.700-38.600RVU) was within the range of values (2.4-61.6RVU) reported for *D. alata* flour from Nigeria (Baah, 2009). Lower breakdown viscosity indicates flours more stable at high temperature, that is, the capacity of the starch granules to rupture is reduced. Higher breakdown viscosity indicates lower ability of sample to withstand heating and shear stress during cooking (Adebowale *et al.*, 2005).

Final viscosity obtained was below those reported by Obadina *et al.* (2014) for yam flour soaked at various time, but within 157.11-649.58RVU reported by Wahab *et al.* (2016) for yam flour. The final viscosity (indicates the ability of the material to form a viscous paste) has been reported as the most commonly used parameter to determine the ability of starch-based materials to form a viscous paste or gel after cooking and cooling as well as the resistance of the paste to shear force during stirring (Adebowale *et al.*, 2005; Maziya-Dixon *et al.*, 2007).

Setback viscosity (12.415-15.760RVU) was below those reported by Wahab *et al.* (2016) and Ogunlakin *et al.* (2013). Sample blends 0.50C and 0.05A experienced the lowest and highest setback viscosity. Setback viscosity is the recovery of the viscosity during cooling of the heated starch suspension (Kaur *et al.*, 2006). High setback is also associated with syneresis or weeping during freeze/thaw cycles (Adebowale *et al.*, 2005), while low setback during the cooling of the paste from starch or starch-based food indicates greater resistance to retrogradation (Sanni *et al.*, 2004). The smaller tendencies to retrograde are advantage in food products such as soup and sauce which undergo loss of viscosity and precipitates as a result of retrogradation (Adebowale and Lawal, 2003). For this reason sample blend 0.50C may be suitable for products like soup mixes.
Pasting temperature is a measure of the minimum temperature required to cook a given food sample (Sandhu *et al.*, 2005) and accounts for the temperature obtained was within the range reported (80-92^{o}C) by Baah (2009) and Estiasih *et al.* (2013) for water yam flour. High pasting temperature implies longer cooking time, since the onset of rise in viscosity and gelatinization temperature is as a result of the pasting temperature (Otegbayo *et al.*, 2013).

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Table 2: Pasting properties of carboxymethylcelluloseblended water yam flour

Sample	Peak Viscosity	Trough Viscosity	Breakdown Viscosity	Final Viscosity	Setback Viscosity	Pasting Temperature
0.05A	287.250^{e}	248.500^{e}	38.600^{e}	406.100^{e}	15.760^{e}	91.250^{d}
0.25B	189.800^{b}	167.250^{b}	23.000^{b}	296.500^{b}	12.925^{b}	87.175^{b}
0.50C	158.950^{a}	146.150^{a}	20.700^{a}	270.300^{a}	12.415^{a}	80.025^{a}
1.00D	277.700^{d}	241.600^{d}	24.200^{c}	379.200^{d}	13.740^{d}	93.500^{e}
0.00E	256.500^{c}	232.150^{c}	36.050^{d}	362.150^{c}	13.000^{c}	89.535^{c}
LSD	**3.401**	**2.806**	**5.317**	**4.691**	**3.604**	**0.458**

Mean in the sample column with the sample superscripts are not significantly different at P> 0.05 and those with different superscripts are significantly different at P < 0.05.

Sensory properties

The sensory analysis results (Table 3) showed significant (p<0.05) and no significant (p>0.05) difference among samples paste of the same parameter. The values in each sensory parameter increased as the amount of CMC added increases, except in taste and mouldability. The CMC might have been the major factor that influenced the colour, taste, aroma, mouldability, texture and overall acceptability of the sample paste. The sensory result suggests that paste produced from sample blend 1.00D would have the most desirable sensory qualities.

Table 3: Sensory properties of paste prepared from carboxymethylcellulose blended water yam flour samples.

Sample	Colour	Taste	Aroma	Mouldability	Texture	Overall Acceptability
0.05A	4.000^{a}	7.400^{e}	3.400^{a}	5.600^{b}	5.600^{a}	5.400^{a}
0.25B	5.800^{b}	5.600^{b}	3.800^{ab}	5.400^{b}	6.400^{b}	5.200^{a}
0.50C	5.400^{ab}	5.800^{b}	5.000^{b}	5.000^{b}	6.800^{b}	6.800^{b}
1.00D	7.600^{c}	7.000^{c}	8.400^{c}	6.800^{c}	7.400^{b}	8.000^{c}
0.00E	4.000^{a}	4.800^{ab}	3.000^{a}	3.600^{a}	4.400^{a}	4. 400^{a}
LSD	**1.421**	**1.022**	**1.293**	**1.252**	**1.072**	**1.104**

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Mean in the sample column with the sample superscripts are not significantly different at P> 0.05 and those with different superscripts are significantly different at P < 0.05.

CONCLUSION

The results of this study showed that incorporation of yam flour with carboxymethylcellulose affected the functional, pasting and sensory properties of yam flour. The variation in these properties would serve as criteria for proper decision, selection and application of yam flour in food processing.

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