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PROXIMATE, FUNCTIONAL AND PASTING PROPERTIES OF WHEAT – YAM FLOUR AS A FUNCTION OF PERCENTAGE LEVEL OF YAM (*D. alata AND D. cayenensis)* FLOUR SUBSTITUTION

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Abstract
This work studied the effect of percentage substitution of yam flour into wheat flour on the proximate, functional and pasting properties of the resulting composite flour using D. alata and D. cayenensis. The yam tubers were harvested at full maturity and processed into flour which were stored in air tight containers at 4^{o}C until needed. The proximate and other functional properties were determined by Standard methods. All data were subjected to ANOVA. The values obtained for Lipid ranged from 0.57 to 0.45%. The values obtained for the different levels of substitution were not significantly different at $p < 0.05$. The starch contents also ranged from 70.11 to 70.22% with all the values having significant differences at $p < 0.05$. The amylose, fibre, ash and moisture content all followed the same pattern. The values obtained were significant at $p < 0.05$. The trend observed for flour compositions using D. alata was also observed for D. cayenensis. The values obtained for functional properties of wheat and wheat-yam flour showed that the three substitution levels of flours were not significantly different at $p < 0.05$ for flours from D. alata and D. cayenensis. The results obtained for the pasting properties of wheat and wheat-yam flour samples were not significantly different at $P < 0.05$ for all levels of substitution. The physicochemical properties of the flour were not affected by storage periods. The results obtained for the Rapid Visco Analysis showed that storage methods and periods have no significant effects on the flour.

Keywords: yam, flour, RVA, functional properties, wheat - yam

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1. INTRODUCTION

Yams belong to the genus *Dioscorea* of the family *Dioscoreaceae.* With approximately 600 yam species, only a few are known for their use in human consumption (*D. alata, D. cayenensis, D. rotundata, D. dumetorum, D. esculenta, D. bulbifera*). The genus is quite dispersed and can be found throughout tropical, sub – tropical and temperate regions (Lebot, 2009). Yam is cultivated predominantly in the humid forest, forest/savanna transition, and the southern Guinea savanna zones of West Africa. It is grown as a sole crop or in various combinations with maize, vegetables, cassava, plantain, sorghum and coffee. The crop matures in 7 to 12 months under ambient conditions (Scott *et al.*, 2000; Bac*oet al.*, 2007). Yam is currently the fourth most important tuber – root crop in the world, after potato (*Solanumtuberosum L.*), Cassava (*ManihotesculentaCrantz*) and Sweet potato (*Ipomoea batatas L.*). In 2008, the estimated world production of yams was 51.7 million tons, with Africa leading the production and Nigeria accounted for over 35 million tons (FAOSTAT, 2010).

In Nigeria, yams are processed into various food forms, which include pounded yam, boiled yam, roasted or grilled, fried yam slices (Sobukola, *et al.*, 2008a, b), yam balls, mashed yam, yam chips and flakes. Fresh tubers are also peeled, chipped, dried and milled into flour (*elubo*). This flour is cooked in boiling water and turned into a thick paste and eaten with soup. Among the 'Yoruba' in Western Nigeria, this is called *amala*, and in the east of River Niger it is called *akwunaji* (Orkwor, 1998). Yams provide, after cassava and cereals, the highest source of dietary energy in Nigeria's food basket (Oguntona, 1994).

The pasting and functional properties of flours a starches are important in determining their application in the industry. Pasting is the phenomenon that follows the gelatinization of starch involving granular swelling, exudation of molecular components from the granules and total disruption of the granules (Atwell et al., 1988). Despite the high levels of yam production in West-Africa (91% of World production) (FAO, 2002) and the high starch content of yam (70-80%) dry basis (Muthukumarasamy and Pannerselvam, 2000), this flour resource have little industrial use and it has received little or no attention from researchers. *D. alata* and *D. cayenensis* which are of lower commercial value in terms of consumption might find an applicable use in this direction. Hence, this work studied the effect of level of substitution of yam flour into wheat flour on the proximate, functional and pasting properties of the resulting composite flour using *D. alata* and *D. cayenensis.*

2. MATERIALS AND METHODS

Materials

Two varieties of yam *(D. alata and D. cayenensis*) were obtained from the research farm of Ladoke Akintola University of Technology, Ogbomoso. The yam tubers were harvested at full maturity and processed into flour immediately and months after storage.

Yam Flour Production

The yam samples were peeled/sliced into water containing sodium meta – bisulphate (0.25%w/v) to prevent browning reactions. All yam slices were drained and dried in a Cabinet dryer at 60 ^oC for three days. The dried chips were subsequently milled into flour with a laboratory hammer mill to pass through a mesh of 150 μm screen size. The flour samples were stored in air tight containers at 4^oC until needed.

Determination of proximate, functional and pasting properties

The fat content was determined by the soxhlet extraction method. The protein content of the samples was determined according Hach (1990) method. The sugar and starch contents were determined according to the method of AOAC (1990) while the moisture content was determined by the AOAC (1990) method. Lipid was solvent-extracted with petroleum ether (40 - 60^oC) according to the method of Vasanthan and Hoover (1992). Amylose content, swelling power and solubility, water absorption capacity (WAC), Oil absorption properties were determined using the methods described by Juliano (1971), Leach *et al.*, (1959) and Solsulski (1962) respectively. The Foaming capacity, Oil emulsifying capacity (EC), Gelation properties and Bulk densitywere also determined according to the methods described of Makri*et al.*, (2005), Naczk*et al.*, 1985, Dipak and Kumar, 1986, Adebowale *et al.*, (2005) and Asoegwu *et al.*, (2006) respectively.

Determination of pasting properties

A rapid viscoamylograph (RVA) model 3D (New port scientific pry.Ltd, Nairabean Australia) was used to determine the pasting properties of the flour sample. (Collado and Corke, 1997). A suspension of 3g (14% m.c) sample in 25m|s of distilled water was allowed to go through a program, heating and cooling cycle under constant shear where it was held at 50^0C to 95^0C at 60^0C/min held at 95^0C for 5 minutes and allowed to cool at 50^0C at 6^0C/min and held at 50^0C for 1 minutes. Pasting parameters in terms of pasting temperature peak viscosity, trough, breakdown, and final viscosity, setback from trough and peak time was recorded.

Statistical analysis

Data obtained were subjected to Analysis of Variance (ANOVA) using SAS (Version 12.0, 2004) and means were separated using Duncan Multiple Range Test with statistical significance of $p < 0.05$.

3. RESULTS AND DISCUSSION

Proximate properties of wheat and wheat – yam flours. Tables 1 and 2 presents the proximate composition of wheat and wheat-yam flour samples. The values obtained for Lipid ranged from 0.57 to 0.45% with 100% wheat flour having the highest and 100% yam flour having the lowest. The values obtained for the different levels of substitution were not significantly different at $p > 0.05$. Protein values obtained for flours from *D. alata* ranged from 1.25 to 14.96% with all the values significantly different from one another at $p < 0.05$. Sugar values ranged from 3.31 and 3.96% with flour from 100% yam having the highest. The differences in sugar content of 50% wheat & 50% yam and 75% wheat and 25% yam flours were not significant at $p > 0.05$. The starch contents also ranged from 70.11 to 70.22% with all the values having significant differences at $p < 0.05$. The amylose (17.08 – 19.02%), fibre (0.82 – 1.67%), ash (0.46 – 1.94%) and moisture content (11.35 – 12.14%) all followed the same pattern with 100% wheat flour having the lowest while 100% yam flour had the highest. The values obtained were significant at $p < 0.05$. The same trend obtained for flour compositions using *D. alata* was also observed for flour compositions from *D. cayenensis.*

Generally, flour protein content has a positive correlation with noodle brightness (Guoquan and Mark, 1998). Thus, there is an optimum flour protein content required for each noodle type. Japanese Udon noodle type requires soft wheat flour of 8.0 – 9.5% protein while other noodles require hard wheat flours of high protein content (10.5 – 13.0%), giving a firmer bite and springy texture (Guoquan and Mark, 1998). High lipid contents of flour may result in low clarity of starch pastes and regress starch granule swelling (Kasemsuwan *et al*., 1989). The ash and fibre contents were found to be very low. Guoquan and Mark (1998) reported that low ash content in flour is always an advantage for noodle production since flour ash is traditionally viewed as causing discolouration. The low fibre content of the flour is an important characteristic making it suitable for noodle production (Guoquan and Mark, 1998).

Starch contributes to the textural attributes of pastry products with good firmness and dehydration capacities (Guoquan and Mark, 1998). Starch properties largely influence noodle qualities while starch with high amylose is generally preferred for noodle production. The results obtained for sugar was not unexpected since *D. cayenesis*is naturally sweeter than *D. alata.*

Table 1: Results for proximate analysis on Wheat and Wheat – Yam flours from *D. alata*

Wheat-Yam Flour Samples	**Lipid**	**Protein**	**Sugar**	**Starch**	**Amylose**	**Fibre**	**Ash**	**Moisture content**
100% W	0.57^{a}	14.96^{a}	3.31^{a}	72.24^{a}	17.08^{a}	0.82^{a}	0.46^{a}	11.35^{a}
25% W & 75 % Y	0.47^{a}	2.80^{b}	3.88^{b}	70.22^{b}	18.98^{b}	1.47^{b}	1.52^{b}	12.08^{b}
50% W & 50 % Y	0.50^{a}	5.45^{c}	3.84^{b}	71.05^{c}	18.40^{c}	1.40^{abc}	1.48^{abc}	12.02^{c}
75% W & 25 % Y	0.52^{a}	10.95^{d}	3.78^{ac}	71.78^{a}	18.24^{d}	1.34^{ac}	1.47^{ac}	11.96^{d}
100% Y	0.45^{ab}	1.25^{e}	3.96^{c}	70.11^{d}	19.02^{b}	1.67^{d}	1.94^{h}	12.14^{a}

Values are mean of triplicate measurements. Values with the same superscript in each column are not significantly different at P < 0.05.

Table 2: Results for proximate analysis on Wheat and Wheat – Yam flours from *D. cayenensis*

Wheat-Yam Flour Samples	**Lipid**	**Protein**	**Sugar**	**Starch**	**Amylose**	**Fibre**	**Ash**	**Moisture content**
100% Wheat	0.57^{a}	14.96^{a}	3.31^{a}	72.24^{a}	17.08^{a}	0.82^{a}	0.46^{a}	11.35^{a}
25% W & 75 % Y	0.52^{a}	3.30^{b}	4.00^{b}	71.18^{a}	19.10^{b}	0.85^{a}	0.51^{a}	10.06^{b}
50% W & 50 % Y	0.53^{a}	4.90^{c}	3.92^{c}	71.26a	18.92^{c}	0.84^{a}	0.50^{a}	10.01^{bc}
75% W & 25 % Y	0.54^{a}	10.20^{d}	3.84^{d}	71.65^{a}	18.84^{d}	0.81^{a}	0.48^{a}	9.96^{bc}
100% Yam	0.52^{a}	1.26^{e}	4.07^{e}	71.08^{b}	19.62^{f}	1.73^{b}	1.96^{b}	10.15^{bcd}

Values are mean of triplicate measurements. Values with the same superscript in each column are not significantly different at P < 0.05

X-Wheat; Y-Yam

Table 3: Results for functional properties of wheat-yam blended flours from *D.cayenensis.*

Wheat-yam flour samples	***Water Absorption capacity*** **WAC** g^{s-1}	***Emulsion capacity*** **E.C % w.f**	***Gelation capacity*** **G.C %**	***Bulk density*** **B.D** g/cm^3	**Oil Absorption Capacity OAC** g^{s-1}	**Foaming Capacity FC %**	**Swelling Power SP %**	**Solubility SS %**
100% Wheat	2.45^{a}	14.68^{a}	10.15^{a}	7.47^{a}	2.15^{a}	4.12^{a}	16.44^{a}	4.63^{a}
100% Yam	2.28^{b}	12.88^{b}	9.90^{b}	6.85^{b}	1.82^{b}	3.46^{b}	8.75^{b}	7.09^{b}
75%W&25%Y	2.38^{b}	15.16^{b}	9.40^{b}	7.12^{b}	2.10^{a}	3.98^{a}	12.72^{b}	6.58^{a}
50%W&50%Y	2.24^{c}	15.18^{b}	9.36^{b}	6.98^{c}	2.08^{ab}	3.86^{ab}	12.98^{c}	6.91^{c}
25%W& 75%Yam	2.18^{d}	15.20^{b}	9.35^{b}	6.94^{c}	2.06^{b}	3.82^{ab}	13.10^{c}	7.54^{c}

Values are mean of triplicate measurements. Values with the same superscript in each column are not significantly different at P < 0.05.
X-Wheat; Y-Yam

Table 4: Results for functional properties of wheat and wheat-yam blended flours for *D.alata*

Wheat-Yam Flour Samples	***Water Absorption capacity*** **WAC** g^{s-1}	***Emulsion capacity*** **E.C % w.f**	***Gelation capacity*** **G.C %**	***Bulk density*** **B.D** g/cm^3	**Oil Absorption Capacity OAC** g^{s-1}	**Foaming Capacity FC %**	**Swelling Power SP %**	**Solubility SS %**
100% Wheat	2.45^{a}	14.46^{a}	10.75^{a}	7.74^{a}	2.15^{a}	4.12^{a}	16.44^{a}	4.63^{a}
100% Yam	2.15^{c}	12.96^{c}	8.62^{c}	6.60^{c}	1.61^{c}	3.01^{c}	8.75^{b}	7.11^{b}
75%W 25%Y	2.20^{b}	15.20^{b}	8.54^{b}	6.80^{b}	1.96^{b}	3.84^{b}	11.25^{b}	5.98^{b}
50% W &50%Y	2.18^{b}	15.21^{b}	8.52^{b}	6.78^{b}	1.94^{b}	3.82^{b}	11.98^{c}	6.80^{c}
25%w75%Y	2.16^{b}	15.24^{b}	8.52^{b}	6.77^{b}	1.91^{b}	3.81^{b}	12.20^{c}	7.58^{d}

Values are mean of triplicate measurements. Values with the same superscript in each column are not significantly different at P < 0.05
X-Wheat; Y-Yam

Table 5: Pasting properties of commercial wheat flour and wheat – yam *(D. alata)* composite flour.

Wheat-Yam Flour Samples	**Peak (RVU)**	**Trough (RVU)**	**Break down (RVU)**	**Final Viscocity (RVU)**	**Setback value (RVU)**	**Peak time (min)**	**Pasting Temp (^{O}C)**
100% Wheat	264.25^{a}	148.33^{a}	155.92^{a}	227.92^{a}	109.58^{a}	6.51^{a}	69.03^{a}
25%W & 75% Y	264.90^{bc}	148.42^{a}	155.98^{a}	228.00^{a}	109.60^{a}	6.49^{a}	69.01^{a}
50%W & 50% Y	275.30^{cd}	148.98^{ab}	156.10^{a}	228.30^{a}	109.65^{a}	6.47^{a}	68.99^{a}
75%W & 25% Y	270.50^{c}	149.30^{b}	156.20^{a}	228.40^{a}	109.72^{a}	6.46^{a}	68.98^{a}
100% Yam	275.67^{d}	188.38^{c}	179.28^{b}	270.50^{b}	128.12^{b}	5.67^{b}	84.80^{b}

Values are mean of triplicate measurements. Values with the same superscript in each column are not significantly different at P < 0.05
X-Wheat; Y-Yam

Table 6: Pasting properties of commercial wheat flour and wheat – yam flour *(D. cayenensis)* composite flour

Wheat-Yam flour Sample	**Peak (RVU)**	**Trough (RVU)**	**Break down (RVU)**	**Final Viscosity (RVU)**	**Setback value (RVU)**	**Peak time (min)**	**Pasting Temp (^{O}C)**
100% Wheat	274.25^{a}	148.33^{a}	165.92^{a}	227.92^{a}	119.58^{a}	6.51^{a}	68.05^{a}
25%W & 75% Y	274.28^{a}	148.35^{a}	165.93^{a}	227.94^{a}	119.59^{a}	6.49^{a}	68.02^{a}
50%W & 50% Y	274.35^{a}	148.36^{a}	165.95^{a}	227.95a	119.61^{a}	6.48^{a}	68.00^{a}
75%W & 25% Y	274.36^{a}	148.39^{a}	165.95^{a}	227.97^{a}	119.63^{a}	6.46^{a}	67.98^{a}
100% Yam	298.43^{b}	188.42^{b}	189.02^{b}	270.33^{b}	134.92^{b}	5.66^{b}	81.81^{b}

Values are mean of triplicate measurements. Values with the same superscript in each column are not significantly different at P < 0.05
X-Wheat; Y-Yam

Functional properties of wheat and wheat – yam flours

Functional properties of wheat and wheat-yam flour samples are presented in Table 2. The values obtained are as followed: Water Absorption Capacity (2.15 – 2.45 g^{s-1}), Emulsion Capacity (12.96 – 15.24 % w.f), Gelation Capacity (8.62 - 10.75%), Bulk Density (6.60 – 7.74 g/cm^3), Oil Absorption Capacity (1.61 – 2.15 g^{s-1}), Foaming Capacity (3.01 - 4.12 %), Swelling Power (8.75 – 16.44 %) and Solubility (4.63 – 7.58 %). The values obtained for the three substitution levels of flours were not significantly different at $p < 0.05$. 100% Wheat flour had the highest value in all parameters determined except for the solubility value which was the lowest. These results were true for flours from D. *alata* and *D. cayenensis.*

The functional properties determine the application and use of food material for various food products. The results obtained for water absorption capacity showed that there was a steady decrease as the percentage of yam flour increases; there were significant differences in the values obtained. The high value obtained for 100% wheat flour may be attributed to the high protein content when compared to the very low percentage in yam flour since protein content is mainly responsible for the bulk of water uptake and to a less extent the starch and cellulose at room temperature (Houssou and Ayernor, 2002). Water absorption capacity is important in the development of ready to – eat food since a high absorption may assure product cohesiveness (Houssou and Ayernor, 2002).

The values obtained for Emulsion capacity showed that there was a steady increase as the percentage of yam flour increases and there were significant differences between the values obtained for wheat flour and the composite flour irrespective of the level of substitution. Emulsion properties play a significant role in many food systems where the protein has the ability to bind fat such as in batter, dough and salad dressing (Sathe and Salkhe, 1981). These results were in agreement with the findings of Adeleke and Odedeji (2010). The gelation capacity of the blended samples was on the decrease as the percentage of yam flour increase. Abbey and Ibeh (1998) reported that variations in gelling properties of different flours may be due to variations in the ratio of different constituents such as carbohydrates, lipids and proteins that make up the flours while Adebowale and Adebowale (2008) also reported that gelation is one of the most important functional properties which determine the suitability of incorporation of a particular substance into food products. Bulk density values obtained showed that as more yam flour was incorporated into wheat flour, the bulk density was on the decrease. Bulk density is generally affected by the particle size and the density of the flour and it is very important in determining the packaging requirement, material handling and application in wet processing in the food industry (Karuna*et al.,* 1996). The oil absorption capacity equally decreased as more and more yam flour is incorporated even though they were not significantly different at $P > 0.05$ indicating a diluting effect of yam flour on wheat flour oil absorption capacity. The mechanism of oil absorption is attributed mainly to the physical entrapment of oil and the binding of fat to the apolar chain of protein (Wang and Kinsella, 1976). Foam is a colloid of many gas bubbles trapped in a liquid or solid. Flours are capable of producing foams because protein in flours is surface active (Karuna *et al.,* 1996). The trend observed in *D. cayenensis* was also observed in *D. alata* giving an indication that there is no varietal difference in the values obtained for all the functional properties that were determined. The swelling power of flour samples is often related to their protein and starch contents (Woolfe, 1992). Higher protein content in flour may cause the starch granules to be embedded within a stiff protein matrix, which subsequently limits the access of the starch to water and restricts the swelling power. Furthermore, the amylopectin is primarily responsible for granule swelling, thus higher amylose content would reduce the swelling factor (Tester and Morisson, 1990). The values obtained for solubility was different from one another with *D. alata* having the highest even though the difference was not significant at $p < 0.05$. Swelling power is affected by the extent of chemical cross – bonding within the granules (Schoch, 1964) and non – carbohydrate substances such as lipid or phosphate (Leach *et al*., 1959). The results obtained for *D. cayenensis* swelling properties was not in any way different from the value obtained for *D. alata*. The values obtained for solubility followed the same trend as we have in swelling properties with significant differences in values obtained. It was reported by Galliard and Bowler (1987) that the presence of lipids in starch/flour may have a reducing effect on the swelling of the individual granules. Therefore, the little differences in the values obtained for fat may explain the differences in the swelling power of these flours. The swelling power and solubility provide evidence of the magnitude of interaction between starch chains within amorphous and crystalline domains. The extent of this interaction is also influenced by the amylose to amylopectin ratio, and by the characteristics of amylose/amylopectin in terms of molecular weight/distribution, degree and length of branching and conformation (Hoover, 2001). The differences obtained in the solubility values may be attributed to differences in morphological structure of starch granule. Amylose plays a role in restricting swelling. The increase in solubility with concomitant in suspension clarity is seen mainly as the result of granule swelling, permitting the exudation of the amylase, the lipid content of the starch and the ability of the starch to form amylase – lipid complexes. E. Shinelis *et al*., (2006) reported that swelling power and solubility pattern, pasting behavior, physicochemical and functional properties are important quality of food products.

Deatherage *et al*., (1955) reported that the amylose content of wheat starch varies from 18–30%. The variations observed in the amylose content may be attributed to the activities of the enzymes involved in starch biosynthesis (Krossman and Lloyd, 2000). The variation in amylose content among the starches from different and similar plant sources may also be attributed to the different starch isolation procedures and analytical methods used to determine amylose content (Kin *et al*., 1995).

Pasting properties of wheat and wheat – yam flours

Table 3 presents the pasting properties of wheat and wheat-yam flour samples. The results obtained for Peak 1 were between 274.25 and 298.43 (RVU), Trough 1 (148.33 – 188.42 RVU), Breakdown (165.92 – 189.02 RVU), Final Viscosity (227. 92 - 270. 33 RVU), Setback (119. 58 – 134.92 RVU), Peak Time (5.66 – 6.51 min) and Pasting Temperature (67. 98 – 81.81^{o}C). In all parameters determined there were no significant differences $P < 0.05$ at all levels of substitution and 100% wheat flour. However, the values obtained for 100% yam flour for all parameters were higher and significantly different at $P < 0.05$ from the values obtained for 100% wheat flour and all other composites. This particular trend was also observed when *D. alata* flour was used in compositing the flour.

Starch pasting characteristics plays an important role in the flour utilization. The ratio of amylose to amylopectin content determines starch - pasting characteristics. Measurement of pasting viscosity of flour relates to noodle quality and eliminates a starch isolation step.

Values obtained for Peak l fall within the range reported for the two varieties concerned by Akinwande (2005). The peak viscosity is a measure of the ability of the starch to form a paste during cooking. It occurs at equilibrium between swelling (which increases velocity) and granule rupture and alignment (which cause its decrease). The high peaks of curves could be explained to be due to granules swelling to about seventy (70) times their original size before rupturing (Rasper and Coursey, 1967). Lee *et al*. (1995) also suggested that a low breakdown value translates to stability under hot condition and that it is a measure of susceptibility of cooked starch granules to disintegration. There was an observed irregularity in the breakdown values which may be attributed to the weak associative force between the granules due to increased granule size (Beta *et al*., 2001).

Newport Scientific (1995) reported that starches with low paste stability and high breakdown have very weak cross – linking within granules. This indicates that there is less stability to paste breakdown. Setback is regarded as a measure of retrogradation tendency. Setback values obtained were significantly different with *D. alata* having the highest. The pasting temperature is the temperature at which irreversible swelling of the starch granule occurs, leading to the formulation of a viscous paste in aqueous solution.

4. CONCLUSION

This study was able to show that yam flour can be used as a substitute to wheat flour in the production of noodle at 75% wheat flour and 25% yam in relation to the findings of this study.

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