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PROXIMATE AND FUNCTIONAL PROPERTIES OF ORANGE-FLESHED SWEET POTATO/PIGEON PEA FLOUR BLENDS AND EXTRUDATES

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ABSTRACT

This study evaluated the proximate and functional properties of the flour blends of orange fleshed sweet potato (OFSP) and pigeon pea and their extrudates. Flours from two varieties [TIS 8164 (OFSPF1) and NRS P/05/022 (OFSPF2)] were individually substituted with pigeon pea flour (PPF) at 0%, 10%, 20%, 30%, 40% and 50% levels. The flour blends, adjusted to moisture content of about 55%, were extruded using a single screw laboratory extruder at 110 rpm and 100 °C. The flour blends and extruded products were analysed for proximate composition and functional properties. There were significant (p < 0.05) differences in the proximate composition of the flour blends with 50% PPF-substituted flour having the highest contents of protein, fat, crude fibre and swelling power (at 70 °C)for both OFSPF1 and OFSPF2. OFSPF2 recorded higher values for protein, fat, ash, and crude fibre than OFSPF1. There were significant (p < 0.05) differences in the functional properties of the flour blends and extrudates. Swelling power (at 70 °C)of the flour blends increased as the level of PPF increased for both varieties of OFSP. Swelling index (at 90 °C), water absorption index and bulk density of extrudates decreased as PPF increased for both varieties. Flour blends and extrudates from OFSPF1 had higher values for moisture, carbohydrates and wettability than OFSP2.

Variety of OFSP influenced the proximate composition and functional properties of the OFSPF-PPF flour blends and extrudates.

Keywords: Orange fleshed sweet potato, pigeon pea, functional properties, proximate composition, extrusion cooking, cooking,

INTRODUCTION

Inadequate intakes of fibre, proteins and small quantities of vitamins and minerals required by the body for physical and mental development are widely affecting more than a third of the world's population including developing countries such as Nigeria (Olapade and Oluwole, 2013; Inyang and Ekop, 2015). The consequence of these can sometimes permanently interfere with a child's growth and development, especially by increasing learning disabilities, impairing work capacity, harming reproduction, reducing intelligence, educability and academic achievement, lowering work productivity and occupational choices and may increase likelihood of non-communicable diseases (Mahan and Escott-Stump, 2008). The use of composite flours containing legumes such as soybean, breadfruit, mung bean, pigeon pea, cowpea amongst other have been reported to be a dietary measure that promotes the regular consumption of proteins, vitamins, fibre and mineral- rich foods (Iwe and Ngoddy, 1998; Anuonye et al., 2012; Olapade and Oluwole, 2013). This approach not only promotes development of diversified and nutrient - rich products but also reduces over - exploitation and excessive use of wheat for making several food products.

Extrusion cooking is a food processing technique where a food material is passed though a machine or equipment known as food extruder or extrusion cooker for it to be heated to its melting point under high pressure to give a desired shape (Moscicki and Van Zuilichem, 2012). It is a process by which a set of mixed ingredients are forced though an opening in a perforated plate or die. Several researchers have demonstrated that products such as pasta, ready - to - eat breakfast cereals and snacks can be prepared individually or from a combination of different staples such as rice, soybean, maize, sorghum, wheat, amongst others (Murekatete et al., 2010; Anuonye et al., 2012).

Sweet potato (Ipomoea batatas) is a dicotyledonous plant that belongs to the family convolvulaceae (Austin, 1988). It is a large, starchy, sweet - tasting tuberous root and an important root vegetable (Purseglove, 1991; Woolfe, 1992). It was ranked the seventh most important food crop in the world and the fourth in tropical countries (FAOSTAT, 2004). It comes in different varieties ranging from white, pale yellow, beige, purple and orange skin colour.

Orange fleshed sweet potato is one of the varieties of sweet potato with more beta carotene than those with light colour flesh and its cultivation is being encouraged in Africa, where vitamin A deficiency poses a serious health problem. Currently, most Nigerian commercially available cultivars have a white to light creamy-yellow flesh colour. However, beta-carotene rich orange fleshed sweet potato is being introduced into Nigeria based on its possible contribution of reducing the prevalence of vitamin A deficiency. Beta-carotene participates in protein synthesis and cell differentiation - by keeping the epithelial tissues and skin healthy, contributing to the growth of an individual as well as preventing illness due to infectious diseases (Garrow et al., 2000; Whiney and Rolfes, 2002). Sweet potato roots also contain carbohydrate (especially starch), protein, fat, fibre and high amount of minerals (Grabowski et al., 2008).

Pigeon pea (Cajanus cajan) is a perennial member of the family Fabaceae (Duke, 1981). It is a locally available and affordable legume of the tropics and sub-tropics (Fasoyiro et al., 2010). Pigeon pea is drought resistant, so can be grown in areas with less than 650 mm annual rainfall. It has protein content in the range of 23 – 26%, important amino acids (methionine, lysine and tryptophan) and is rich in minerals and fibre (Oshodi et al., 1985; Nene et al., 1990; El-Tabey, 1992). In Nigeria, the plant has been listed as one of the under-utilized legumes with broad potential which according to Nene et al. (1990) and El-Tabey (1992) is due to the hard-to-cook phenomenon and the presence of anti-nutrients.

This study evaluated the proximate and functional properties of two varieties of orange fleshed sweet potato and pigeon pea flour blends and their extrudates.

MATERIALS AND METHODS

Materials

Two varieties of orange fleshed sweet potato tubers (TIS 8164 and NRS P/05/022) were purchased from FADAMA farm Alabata located in the Federal University of Agriculture, Abeokuta (FUNAAB) Ogun State, Nigeria. Pigeon pea was purchased from Tapa market in Ibarapa, Oyo State, Nigeria. Locally fabricated single screw extruder belonging to the Department of Food Science and Technology in FUNAAB was used.

Methods

Production of orange fleshed sweet potato flour (OFSPF)

The method of Mais (2008) was used. The tubers were sorted and washed with water to remove dirt in form of soil. They were peeled manually using a potato peeler and sliced using a slicer. The resultant slices were drained, dried in the cabinet dryer at 55 ? C for 48 h, after which it was milled using a hammer crusher and sieved using a 2 mm - mesh sieve. The flour obtained was packaged in a zip lock polyethylene bag for further use. Flour made from TIS 8164 variety was tagged OFSPF1 and OFSPF2 represented flour prepared from NRS P/05/022 variety.

Preparation of pigeon pea flour (PPF)

A modified method of Fasoyiro et al. (2010) was adopted. Pigeon pea seeds were sorted manually by hand picking the shaft from the seeds. The seeds were soaked in hot water having an initial temperature of 60 ? C for 48 h with the water being changed at 6 h interval. The seeds were dehulled by using mortar and pestle. The beans were separated from the peel and drained. Drying was done using hot air oven at 50 ? C for 8 h. Milling was done using a hammer crusher and was sieved using a 2 mm - mesh sieve and packaged in a zip lock polyethylene bag for further use.

Experimental design

Table 1 shows the ratio of orange fleshed sweet potato and pigeon pea flours used in the extrusion. The values for feed moisture, screw speed and temperature used in the extrusion ranged from 40-45 mL, 110 rpm and 100^{o}C respectively.

Extrusion of orange fleshed sweet potato and pigeon pea blends

A modified method of Iwe and Ngoddy (1998) was used where each composite flour blend of orange fleshed sweet potato and pigeon pea (100g) were mixed with distilled water of 40 - 45 mL. The mixture was allowed to rest for about 30 min for it to hydrate. During the resting period, 5 g of each mixture were taken and the moisture content was determined to range from 54 - 57%. After the pre - conditioning stage, the blends were extruded using a fabricated single screw extruder at the barrel temperature and screw speed earlier stated. The extrudates were cut manually using a knife at 2cm long. The extrudates were dried in the cabinet dryer for 2 h at 60 ? C after which it was cooled, milled using a Kenwood dry blender and packaged in a zip lock polyethylene bag.

Analyses

Proximate composition of orange-fleshed sweet potato and pigeon pea flour blends and extrudates

Moisture, ash, protein and fat contents were determined according to the method described by AOAC (2010). Percentage carbohydrate was calculated by difference: %CHO = 100 – (%moisture + % ash + % fat + % crude protein + % crude fibre)

Functional properties

Swelling power and solubility index

This was determined using the method of Takashi and Sieb (1988). About 1 g of the sample was weighed into 50 mL centrifuge tube. About 50 mL distilled water was added and gently mixed. The slurry was heated in a water bath at 70 °C, 80 °C and 90 °C respectively for 15 min. The slurry was stirred gently during heating to prevent clumping of the flour. After 15 min the tubes containing the gel was centrifuged at 3000 rpm for 10 min.. The supernatant was decanted immediately after centrifuging. The weight of the sediment was thereafter determined to get the dry matter content of the gel.

$$Swelling\ Power = \frac{Weight\ of\ wet\ mass\ of\ sediment}{Weight\ of\ Dry\ matter\ in\ gel}$$

$$\%Solubility\ index = weight\ of\ dry\ solid\ after\ drying \times 100$$

Bulk density

The bulk density of the samples was determined using the method of Akpapunam and Markakis (1981). A known amount of sample was weighed into 50mL measuring cylinder. The sample was packed up by gently tapping the cylinder on the bench top 10 times from a height of 5cm. The volume of the sample was recorded.
The bulk density was then calculated as:

$$Bulk\ density\ \left(\frac{g}{ml}\ or\ \frac{g}{cm^3}\right) = \frac{Weight\ of\ sample}{Volume\ of\ sample\ after\ tapping}$$

Dispersibility

The dispersibility of the flour blends was determined as described by Kulkarni *et al* (1991). About 10 g of flour was suspended in 100 mL measuring cylinder and distilled water was added to reach a volume of 100mL. The set up was vigorously stirred and allowed to settle for 3 h. The volume of the settled particles was recorded and subtracted from 100. The difference was recorded as percentage dispersibility.

Wettability

This was determined used the method described by Nwosu (2010). About 1 g of each flour blend sample was placed in a clean, dry measuring cylinder (10mL). Placing a finger over the open end, the cylinder was inverted and clamped at a height of 10 cm from the surface of a 600mL beaker containing 500mL of distilled water. The flour in the cylinder was gradually spread on the water. The time taken for the sample to be completely wet was noted as wettability.

Water absorption index

The water absorption index of the blends was determined using the method described by Ruales *et al.* (1993). Flour sample (1.25g) was weighed into a centrifuge tube and 15mL of distilled water was added. The mixture was centrifuged at 2500 rpm for 30 min. The supernatant was decanted and the weight of the gel formed was recorded. The water absorption index was calculated as gel weight per gram dry sample.

$$WAI = \frac{Gram\ bound\ water}{Weight\ of\ sample} \times 100$$

Data analysis

Data were subjected to statistical analysis using SPSS version 15.0 and means were separated using Duncan multiple range test ($p<0.05$).

RESULTS AND DISCUSSION

Proximate composition of flour blends and extrudates

The proximate composition of orange fleshed sweet potato and pigeon pea flour blends and extrudates is shown in Tables 2 and 3. OFSPF1 contained 5.74% protein, 2.25% fat and 2.1% ash while OFSPF2 had 9.72% protein, 2.95% fat and 2.23% ash (Table 2). Values of 1.3–9.5, 1.1–4.9, and 0.2–3.0/100 g dry weight have been reported for protein, ash, and fat contents of sweet potatoes (Wang *et al.*, 2016). Ginting and Yulifianti (2015) also reported ash and crude fibre contents of 5.3% ash and 4.6% for orange fleshed potato.

The moisture content of OFSPF1-PPF blends ranged from 5.86 - 7.75% while that of OFSPF2-PPF ranged from 6.78 – 7.88%. There was significant ($p < 0.05$) difference among the blends for moisture content with

100% OFSPF1 having the highest value while OFSPF with 50% pigeon pea flour substitution had the least value for both varieties. This result revealed that moisture content decreased as the percentage inclusion of PPF increased in the flour blends.

Moisture content of the OFSPF1-PPF extrudates ranged from 1.27 – 5.27% while the values for OFSPF2-PPF extrudates were between 1.88 and 4.22%. In the case of OFSPF1, the lowest moisture content was observed in 100:0 (OFSPF1:PPF) blend while the highest moisture content was obtained in 50:50 (OFSPF:PPF) blend. No significant ($p < 0.05$) difference was observed in 90:10, and 70:30 (OFSPF1:PPF) blends. On the other hand, 70:30 (OFSPF2:PPF) and 90:10 (OFSPF2:PPF) had the lowest and highest moisture contents respectively. There was no significant ($p < 0.05$) difference in the moisture contents of 80:20 and 50:50 (OFSPF2:PPF) blends. Moisture contents of the extruded samples showed no particular trend. With the low moisture content seen, the deterioration of flour blends and extruded samples would be lowered due to reduced activity of microorganisms. Laelago *et al.* (2015) also reported that microbial proliferation will be minimum at low moisture content and this confers good shelf stability on both the flour blends and extrudates.

The crude protein of the OFSPF1:PPF blends ranged from 5.74 - 12.22% while OFSPF2:PPF blends ranged from 9.72 – 13.17%. Furthermore, the crude protein content of extrudates ranged from 8.65 – 12.15% for OFSPF1:PPF blends and 10.12 - 12.77% for OFSPF2:PPF blends. There were significant ($p < 0.05$) differences among the blends and extrudates with 50% PPF substituted flours having the highest protein content for the two varieties of OFSPF. Control samples had the lowest protein contents for both varieties. This result revealed that crude protein content increased as percentage inclusion of PPF increased.

Fat content of OFSPF1-PPF blends ranged from 2.25 - 5.68% while OFSPF2-PPF blends ranged from 2.95 – 5.00%. For the extrudates, the fat content of OFSPF1-PPF blends was between 1.26 and 3.22% while extruded samples from OFSPF2-PPF blends had a fat content ranging from 1.29 – 2.67%. There was a significant ($p<0.05$) difference in the fat content of the blends and extruded samples for both varieties of OFSPF. OFSPF with 50% PPF had the highest value of fat while 100% orange fleshed sweet potato flour had the least value for both varieties. The low fat content obtained in this study may signify that flour blends and extrudates will not undergo rapid oxidative rancidity during storage if suitably packaged.

The ash content of the OFSPF1-PPF ranged from 1.70 - 2.61% while OFSPF2-PPF blends ranged from 1.52 - 2.42%. There was a significant ($p < 0.05$) difference in the ash content, with 80:20 and 50:50 blends having the highest and lowest values respectively for both varieties. The ash content of the extruded samples ranged from 2.05 – 2.58% and 1.79 - 2.97% for OFSPF1-PPF and OFSPF2-PPF respectively. The ash contents of the extrudates followed similar trend as the flour blends. Thus, the ash content decreased as percentage inclusion of PPF increased. Ash content usually signifies the presence of minerals in a food material.

The percentage carbohydrate of the OFSPF1-PPF blends ranged from 60.40 - 77.71% while OFSPF2-PPF had 59.64 - 68.93%. The extrudates on the other hand had 63.85 – 80.84 % and 65.92 - 75.33% for OFSPF1-PPF and OFSPF2-PPF respectively. There were significant ($p < 0.05$) differences among the blends and extrudates with 100% OFSPF having the highest value while OFSPF with 50% PPF substitution had the least value, for both varieties. Carbohydrate content decreased as percentage inclusion of pigeon pea flour increased. High carbohydrate content of extruded samples makes it a good source of metabolisable energy and can assist in fat metabolism.

Crude fibre content of the OFSPF1-PPF blends ranged from 4.46 - 14.16% while OFSPF2-PPF blends ranged from 8.71 - 13.63%. It was observed that the crude fibre contents of the extrudates ranged from 4.85 – 13.46% and 7.50 – 13.84% for OFSPF1-PPF and OFSPF2-PPF blends respectively. There were significant ($p < 0.05$) differences in the crude fibre contents among the flour blends and extruded samples with 50% PPF-substituted blends having the highest value while 100% OFSPF had the least value, for both varieties. Crude fibre content increased as percentage of pigeon pea flour increased. Foods with more fibre are desirable because they allow easy passage of waste by expanding the inside walls of the colon, provide an effective anti-constipation mechanism, lower cholesterol level in the blood and reduce the risk of various cancers (Mahan and Escott-Stump, 2008). The observation that there were increases in the protein, fat and crude fibre contents of the blends as the PPF increased conforms with the report of Buzo *et al.* (2016).

Functional properties of OFSPF and PPF flour blends and extrudates

The functional properties of flour blends and extrudates are shown in Table 4, 5, 6 and 7.

Swelling power which measures the ability of starch to imbibe water and swell is temperature dependent and is accompanied by solubilisation of starch granules constituents (Buckman *et al.*, 2017). The swelling power of the OFSPF1-PPF blends at 70, 80 and 90 °C ranged from 13.73 - 45.20%, 21.44 - 113.08%, and 35.60% - 53.18% respectively. On the other hand, the swelling power of OFSPF2-PPF blends at 70, 80 and 90 °C varied from 11.08 - 40.09%, 60.19 - 86.90% and 40.38 – 75.95% respectively. Swelling power ranged from 43.83 - 67.60% at 70 °C, 32.44 – 66.81% at 80 °C and 34.47 – 56.98% at 90 °C for extrudates prepared from OFSPF1-PPF blends. The swelling power of extrudates prepared from OFSPF2-PPF blends ranged from 23.83 – 48.98% at 70 °C, 28.77 – 49.96% at 80 °C and 34.47 – 56.98% at 90 °C. There were significant ($p < 0.05$) differences in the swelling power of the flour blends and extrudates. Inyang and Ekop (2015) reported that swelling capacity affects the temperature at which product forms gel. High swelling capacity obtained in this study has been reported as part of the criteria for good quality products (Achinewhu *et al.*, 1998).

Solubility index (SI) according to Spinello *et al*. (2014) serves as an indicator to measure the degradation of molecular components (starch). It determines the amount of free polysaccharide or polysaccharide released from the granules after the addition of excess water. The SI ranged from 11.50 – 31.50% at 70 °C, 14.00 – 44.00% at 80 °C and 28.00 – 35.00% at 90 °C for flour blends of OFSPF1-PPF while it ranged from 14.00 – 35.50% at 70 °C, 11.50 – 18.00% at 80 °C and 22.50 - 41.00% at 90 °C for flour blends of OFSPF2-PPF. The SI of the extrudates obtained from OFSPF1-PPF ranged from 13.50 - 28.00% at 70 °C, 12.00 – 27.50% at 80 °C and 14.00 – 27.00% at 90 °C while those of OFSPF2-PPFextrudates ranged from 15.50 – 23.00% at 70 °C, 12.00 - 20.00% at 80 °C and 14.00 – 27.00% at 90 °C. It was observed that there was a significant decrease in SI as the percentage inclusion PPF increased in the composite flour blends and this may be due to the large quantity of polysaccharides from sweet potato flour. Zhu *et al*. (2010) and Spinello *et al*. (2014) also reported that SI depends on the intensity, type of reaction that occurs and the temperature of the extruder during extrusion which may have influenced the amount of soluble molecules.

The water absorption index (WAI) of OFSPF1-PPF blends ranged from 2.06 – 2.80% while that of OFSPF2-PPF blends ranged from 2.05-3.35%. There were significant $p < 0.05$) differences in the WAI of the blends. Oladipo and Nwokocha (2011) attributed high water absorption capacity to loose structure of starch polymers while low value indicates compactness of the structure. Iwe and Onadipe (2001) reported that the ability of flour to absorb water improved dough making potentials Water absorption index increased as OFSPF increased.

The bulk density of processed products dictates the characteristics of its container or package and also indicates the relative amount of load the sample can carry, if allowed to rest directly on one another (Obadina *et al.,* 2013). The bulk density of OFSPF1-PPF blends ranged from 0.67 - 0.73 g/cm^3 while it was between 0.66 and 0.77 g/cm^3 for OFSPF2-PPF blends. Significant ($p < 0.05$) differences occurred in the bulk density of the flour blends. Bulk density increased as percentage inclusion of pigeon pea flour increased. The high bulk density of flour blends suggests their suitability for use in food preparations in terms of machinability and packaging.

The dispersibility of OFSPF1-PPF blends ranged from 56.06 – 65.00% and 53.50% and 60.50% for OFSPF2-PPF blends. There was a significant ($p < 0.05$) difference among the blends. Dispersibility increased as percentage addition of pigeon pea flour increased. Dispersibility is an index that measures how well flour or flour blends can be rehydrated with water. The higher the dispersibility values the better and the easier the reconstitution of flour or flour blend (Kulkani *et al*., 1991). Since the dispersibility value for all the flour blends is relatively high, it implies that they will reconstitute easily to fine consistent dough during mixing (Kulkani *et al*., 1991; Adebowale *et al*., 2008).
The wettability of the blends which were significantly ranged from 17.07 – 19.75 s and 11.78 - 16.92 s for OFSPF1-PPF and OFSPF2-PPF respectively. There were significant ($p < 0.05$) differences among the blends. Wettability increased as percentage inclusion of pigeon pea flour increased. From the results obtained, less than 20 s is required by the flour blends to be fully wet Nwosu (2010).

CONCLUSION

The study investigated the proximate composition and functional properties of flour blends and extrudates from two varieties orange fleshed sweet potato (OFSP) and pigeon pea.

The protein, fat and crude fibre contents of both the flour blends and extrudates increased as pigeon pea flour (PPF) increased for the two varieties of OFSP. The swelling power (at 70 °C) of the blends increased with increase in the quantity of PPF for the two varieties of

OFSP. The bulk density of the flour blends obtained from the two varieties of OFSP was similar. The swelling power of extrudates obtained from TIS 864 variety increased as PPF increased at 80 and 90 °C while this trend in SP was only observed at 90 °C for NRS P/05/022 variety. There was a reduction in the swelling index and water absorption index of extrudates as PPF increased for the two varieties of OFSP. Extrudates obtained from the OFSPF-PPF blends were similar in terms of the swelling power at 90 °C, water absorption index and bulk density.

Variety of OFSP influenced the proximate composition and functional properties of the OFSPF-PPF flour blends and extrudates.

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Table 1: Experimental design showing blend ratio

Experimental Run ID	*OFSPF*	PPF
A	100	0
B	90	10
C	80	20
D	70	30
E	60	40
F	50	50

Table 2:Proximate composition of orange fleshed sweet potato and pigeon pea flour blends

Ratio	Moisture (%)		Protein (%)		Fat (%)		Ash (%)		CHO (%)		Crude fibre (%)	
OFSP:	TIS	NRS	TIS	NRS	TIS	NRS	TIS	NRS	TIS	NRS	TIS	NRS
PPF	8164	P/05/022	8164	P/05/022	8164	P/05/022	8164	P/05/022	8164	P/05/022	8164	P/05/022
100:00	7.75^{a}	7.47^{bc}	5.74^{c}	9.72^{e}	2.25^{e}	2.95^{f}	2.10^{bc}	2.23^{ab}	77.71^{a}	68.93^{a}	4.46^{f}	8.71^{f}
90:10	7.04^{d}	7.88^{a}	10.42^{b}	9.92^{d}	3.10^{d}	3.83^{ef}	2.22^{b}	2.18^{ab}	67.48^{b}	66.60^{bc}	9.75^{e}	9.71^{e}
80:20	7.32^{b}	6.95^{cd}	10.52^{b}	10.37^{cd}	3.61^{cd}	4.21^{cd}	2.61^{a}	2.42^{a}	65.44^{c}	64.00^{c}	10.96^{d}	12.06^{d}
70:30	7.18^{d}	7.43^{bc}	11.46^{a}	10.89^{c}	3.95^{c}	4.33^{c}	2.14^{bc}	2.06^{c}	64.18^{d}	62.90^{d}	11.10^{c}	12.39^{c}
60:40	7.22^{bc}	7.15^{c}	11.75^{a}	11.53^{b}	4.33^{b}	4.68^{b}	1.86^{d}	2.06^{c}	62.69^{e}	61.19^{e}	12.17^{b}	13.41^{b}
50:50	5.86^{e}	6.78^{d}	12.22^{a}	13.17^{a}	5.68^{a}	5.00^{a}	1.70^{d}	1.52^{d}	60.40^{f}	59.94^{f}	14.16^{a}	13.63^{a}

Means within the same column with different superscripts are significantly different at $p<0.05$
Where OFSP = Orange Fleshed Sweet potato Flour, PPF = Pigeon pea Flour, CHO=Carbohydrate.

Table 3: Proximate composition of extruded orange fleshed sweet potato and pigeon pea flour blends

Ratio	Moisture (%)		Protein (%)		Fat (%)		Ash (%)		CHO (%)		Crude fibre (%)	
OFSP: PPF	TIS 8164	NRS P/05/022	TIS 8164	NRS P/05/022	TIS 8164	NRS P/05/022	TIS 8164	NRS P/05/022	TIS 8164	NRS P/05/022	TIS 8164	NRS P/05/022
100:0	1.74^{d}	2.80^{b}	8.65^{a}	10.12^{a}	1.36^{a}	1.29^{a}	2.58^{de}	2.97^{f}	80.84^{e}	75.33^{d}	4.85^{a}	7.50^{a}
90:10	5.26^{a}	3.77^{cd}	10.02^{b}	10.35^{ab}	1.61^{ab}	1.55^{b}	2.34^{c}	2.51^{e}	73.05^{d}	71.99^{c}	7.74^{b}	9.85^{b}
80:20	4.53^{b}	2.91^{b}	10.67^{bc}	10.48^{ab}	1.88^{b}	1.59^{bc}	2.32^{c}	2.43^{d}	68.93c	72.12^{c}	11.72^{c}	10.49^{c}
70:30	3.68^{c}	1.88^{a}	10.97^{c}	11.78^{b}	2.68^{c}	1.76^{c}	2.28^{bc}	2.00^{c}	68.18^{c}	70.94^{b}	12.23^{d}	11.65^{d}
60:40	5.22^{a}	4.22^{e}	11.27^{d}	12.70^{c}	2.82^{d}	1.84^{d}	2.12^{b}	2.15^{b}	66.29^{b}	66.40^{a}	12.29^{d}	12.71^{e}
50:50	5.27^{a}	3.03^{c}	12.15^{e}	12.77^{d}	3.22^{e}	2.67^{e}	2.05^{a}	1.79^{a}	63.85^{a}	65.92^{a}	13.46^{e}	13.84^{f}

Means within the same column with different superscripts are significantly different at $p<0.05$
Where OFSP = Orange Fleshed Sweet potato Flour, PPF = Pigeon pea Flour, CHO=Carbohydrate.

Table 4: Functional properties of orange fleshed sweet potato (TIS 8164) and pigeon pea flour blends

OFSP:PPF Ratio	[illegible]	SP at 80 ? C (%)	SP at 90 ? C (%)	SI at 70 ? C (%)	SI at 80 ? C (%)	SI at 90 ? C (%)	WAI (%)	BD [illegible]	D (%)	W (s)
100:0	$13.73^{de}\pm5.54$	$21.44^{c}\pm8.15$	$35.60^{b}\pm15.60$	$31.50^{a}\pm5.50$	$44.00^{a}\pm11.00$	$35.00^{a}\pm15.00$	$2.80^{bc}\pm0.02$	$0.67^{b}c\pm0.00$	$56.00^{d}\pm1.00$	$19.75^{a}\pm0.15$
90:10	$21.80^{cde}\pm8.26$	$113.08^{a}\pm6.32$	$39.01^{c}\pm14.29$	$22.00^{c}\pm4.00$	$34.00^{ab}\pm29.00$	$32.00^{a}\pm12.00$	$2.57^{c}\pm0.31$	$0.68^{b}c\pm0.01$	$61.00^{b}\pm1.00$	$17.07^{c}\pm0.21$
80:20	$19.74^{cde}\pm6.36$	$52.06^{b}\pm3.56$	$53.18^{e}\pm36.41$	$24.00^{c}\pm2.00$	$19.00^{bc}\pm1.00$	$34.00^{a}\pm22.00$	$2.07^{d}\pm0.45$	$0.69^{b}\pm0.02$	$60.50^{bc}\pm0.50$	$17.60^{b}c\pm0.07$
70:30	$19.60^{cde}\pm6.22$	$60.28^{abc}\pm7.95$	$43.17^{d}\pm16.36$	$23.50^{c}\pm2.50$	$15.50^{c}\pm2.50$	$30.00^{a}\pm13.00$	$2.06^{d}\pm0.30$	$0.69^{b}\pm0.02$	$61.00^{b}\pm0.00$	$18.58^{ab}\pm0.14$
60:40	$39.60^{ab}\pm8.40$	$51.85^{bc}\pm4.47$	$30.95^{a}\pm11.18$	$13.00^{d}\pm2.00$	$14.50^{c}\pm1.50$	$34.00^{a}\pm11.00$	$2.40^{cd}\pm0.01$	$0.73^{a}\pm0.02$	$60.50^{bc}\pm0.50$	$17.35^{bc}\pm1.41$
50:50	$45.20^{a}\pm10.91$	$53.91^{b}\pm6.85$	$36.52^{bc}12.83$	$11.50^{d}\pm2.50$	$14.00^{c}\pm2.00$	$28.00^{a}\pm8.00$	$2.43^{cd}\pm0.03$	$0.73^{a}\pm0.02$	$65.00^{e}\pm0.50$	$18.62^{ab}\pm0.04$

Means within the same column with different superscripts are significantly different at $p<0.05$
Where:
OFSP-Orange Fleshed Sweet potato Flour, PPF-Pigeon pea Flour, SP-Swelling power, SI-Solubility index, WAI-Water absorption index, BD-Bulk density, D-Dispersibility, W-Wettability

Table 5: Functional properties of orange fleshed sweet potato (NRS P/05/022) and pigeon pea flour blends

OFSP:PPF Ratio	SP at 70 ? C (%)	SP at 80 ? C (%)	SP at 90 ? C (%)	SI at 70 ? C (%)	SI at 80 ? C (%)	SI at 90 ? C (%)	WAI (%)	BD (g/cm^3)	D (%)	W (s)
100:0	$11.08^{c}\pm0.39$	$72.98^{abc}\pm3.73$	$40.38^{d}\pm28.98$	$35.50^{a}\pm0.50$	$15.00^{c}\pm1.00$	$41.00^{c}\pm24.00$	$3.04^{d}\pm0.10$	$0.66^{c}\pm0.01$	$53.50^{c}\pm0.50$	$11.78^{e}\pm0.71$
90:10	$20.69^{cde}\pm3.77$	$61.81^{abc}\pm15.13$	$75.95^{a}\pm43.06$	$25.00^{bc}\pm1.00$	$18.00^{a}\pm4.00$	$22.50^{a}\pm14.50$	$3.35^{c}\pm0.01$	$0.67^{c}\pm0.00$	$57.50^{b}\pm0.50$	$13.90^{cd}\pm0.22$
80:20	$28.70^{bcd}\pm15.37$	$60.19^{abc}\pm3.08$	$47.94^{c}\pm19.83$	$22.50^{c}\pm7.50$	$16.50^{ab}\pm1.50$	$29.00^{b}\pm13.00$	$2.05^{a}\pm0.35$	$0.67^{c}\pm0.00$	$60.00^{ab}\pm0.00$	$12.36^{d}\pm0.08$
70:30	$20.62^{cde}\pm10.79$	$63.31^{abc}\pm14.15$	$44.98^{cd}\pm19.78$	$28.00^{bc}\pm8.00$	$16.00^{ab}\pm3.00$	$30.00^{b}\pm14.00$	$3.00^{d}\pm0.33$	$0.69^{b}\pm0.00$	$60.50^{a}\pm0.50$	$14.76^{c}\pm0.39$
60:40	$34.50^{abc}\pm2.97$	$72.41^{abc}\pm1.33$	$52.56^{b}\pm21.65$	$14.00^{d}\pm0.01$	$11.50^{d}\pm0.50$	$23.50^{a}\pm8.50$	$2.62^{b}\pm0.02$	$0.73^{a}\pm0.02$	$59.50^{ab}\pm0.50$	$16.73^{ab}\pm0.98$
50:50	$40.09ab\pm5.22$	$86.90^{ab}\pm25.40$	$43.75^{cd}\pm20.75$	$14.00^{d}\pm0.01$	$9.50^{e}\pm0.50$	$28.00^{b}\pm12.00$	$2.70^{b}\pm0.01$	$0.73^{a}\pm0.25$	$60.00^{ab}\pm0.00$	$16.92^{a}\pm1.70$

Means within the same column with different superscripts are significantly different at $p<0.05$
Where:
OFSP-Orange Fleshed Sweet potato Flour, PPF-Pigeon pea Flour, SP-Swelling power, SI-Solubility index, WAI-Water absorption index, BD-Bulk density, D-Dispersibility, W-Wettability

Table 6: Functional properties of extruded orange fleshed sweet potato (TIS 8164) and pigeon pea flour blends

OFSP:PPF (%)	SP at 70 ? C (%)	SP at 80 ? C (%)	SP at 90 ? C (%)	SI at 70 ? C (%)	SI at 80 ? C (%)	SI at 90 ? C (%)	WAI (%)	BD (g/cm³)
100	$54.91^{ab}\pm18.03$	$32.44^{fg}\pm0.60$	$34.47^{e}\pm3.37$	$21.00^{ab}\pm3.00$	$27.50^{a}\pm0.50$	$27.00^{a}\pm2.00$	$5.08^{a}\pm0.14$	$0.91^{ab}\pm0.40$
90:10	$52.29^{ab}\pm30.72$	$40.95^{de}\pm0.70$	$43.51^{bcd}\pm3.91$	$28.00^{a}\pm14.00$	$23.00^{b}\pm3.00$	$19.50^{cd}\pm0.50$	$3.97^{de}\pm0.05$	$0.84^{d}\pm0.04$
80:20	$52.14^{ab}\pm21.51$	$66.81^{a}\pm4.81$	$39.22^{cde}\pm0.77$	$20.50^{ab}\pm6.50$	$12.00^{f}\pm1.00$	$18.50^{cde}\pm0.50$	$3.78^{def}\pm0.32$	$0.85^{cd}\pm0.02$
70:30	$43.83^{abc}\pm5.18$	$59.72^{b}\pm8.93$	$38.43^{cde}\pm0.89$	$20.00^{ab}\pm3.00$	$14.00^{ef}\pm0.00$	$17.00^{def}\pm1.00$	$3.51^{ef}\pm0.44$	$0.91^{ab}\pm0.00$
60:40	$67.60^{a}\pm17.40$	$43.54^{cde}\pm5.80$	$45.41^{bc}\pm4.06$	$13.50^{b}\pm6.50$	$16.00^{de}\pm2.00$	$17.00^{def}\pm0.00$	$3.94^{de}\pm0.44$	$0.89^{bc}\pm0.02$
50:50	$54.62^{ab}\pm6.05$	$44.88^{cd}\pm3.83$	$56.98^{a}\pm1.83$	$14.50^{b}\pm0.50$	$15.50^{de}\pm1.50$	$14.00^{g}\pm1.00$	$4.10^{cd}\pm0.48$	$0.93^{a}\pm0.02$

Means within the same column with different superscripts are significantly different at $p<0.05$
Where:
OFSP-Orange Fleshed Sweet potato Flour, PPF-Pigeon pea Flour, SP-Swelling power, SI-Solubility index, WAI-Water absorption index, BD-Bulk density, D-Dispersibility, W-Wettability

Table 7: Functional properties of extruded orange fleshed sweet potato (NRS P/05/022) and pigeon pea

OFSP:PPF (%)	SP at 70 ? C (%)	SP at 80 ? C (%)	SP at 90 ? C (%)	SI at 70 ? C (%)	SI at 80 ? C (%)	SI at 90 ? C (%)	WAI (%)	BD (g/cm^3)
100	$38.45^{cd}±1.74$	$45.25^{b}±2.44$	$34.47^{e}±3.37$	$23.00^{a}±1.00$	$20.00^{a}±1.00$	$27.00^{a}±2.00$	$5.08^{a}±0.14$	$0.91^{ab}±0.40$
90:10	$43.67^{b}±2.89$	$40.00^{c}±0.17$	$43.51^{bcd}±3.91$	$19.00^{ab}±1.00$	$18.00^{ab}±0.00$	$19.50^{bc}±0.50$	$3.97^{bc}±0.05$	$0.84^{d}±0.04$
80:20	$41.72^{c}±5.95$	$45.23^{b}±0.45$	$39.22^{cde}±0.77$	$18.50^{ab}±3.50$	$12.00^{abcd}±1.00$	$18.50^{bc}±0.50$	$3.78^{d}±0.32$	$0.85^{cd}±0.02$
70:30	$23.83^{d}±8.53$	$28.77^{d}±1.83$	$38.43^{cde}±0.89$	$20.50^{ab}±6.50$	$14.00^{abc}±0.00$	$17.00^{bcd}±1.00$	$3.51^{e}±0.44$	$0.91^{ab}±0.00$
60:40	$48.98^{a}±3.40$	$49.96^{a}±1.38$	$45.41^{bc}±4.06$	$15.50^{abc}±3.50$	$16.00^{abc}±2.00$	$17.00^{bcd}±0.00$	$3.94^{bc}±0.44$	$0.89^{bc}±0.02$
50:50	$39.44^{cd}±2.02$	$37.82^{cd}±1.69$	$56.98^{a}±1.83$	$18.50^{ab}±5.50$	$15.50^{abc}±1.50$	$14.00^{e}±1.00$	$4.10^{bc}±0.48$	$0.93^{a}±0.02$

Means within the same column with different superscripts are significantly different at $p<0.05$
Where:
OFSP-Orange Fleshed Sweet potato Flour, PPF-Pigeon pea Flour, SP-Swelling power, SI-Solubility index, WAI-Water absorption index, BD-Bulk density, D-Dispersibility, W-Wettability