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Proximate composition, functional and pasting properties of wheat flour supplemented with combined processed pigeon pea flour

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Abstract
The present study investigated the effect of supplementation of combined sprouted/fermented pigeon pea flour on the proximate composition, functional and pasting properties of wheat flour. The flours were formulated at the ratio of 100:0, 95:5, 90:10, 85:15, 80:20, 75:25 and 70:30 of wheat flour to combined sprouted/fermented pigeon pea flour and analyzed. Proximate result showed significant (p<0.05) increase in protein, fat, crude fibre and ash contents and decrease in carbohydrate and moisture contents as the level of supplementation of combined sprouted and fermented pigeon pea flour with wheat flour increased. The functional properties indicated significant (p<0.05) reduction in bulk density and increment in water absorption capacity, oil absorption capacity, emulsion capacity, swelling capacity and foaming capacity of the flour blends as the level of incorporation of combined processed pigeon pea flour increased. The pasting results showed that peak viscosity, trough viscosity, breakdown viscosity, setback viscosity, final viscosity and peak time significantly (p<0.05) decreased while pasting temperature increased with increase in supplementation of combined processed pigeon pea flour to wheat flour. The blends of wheat and combined sprouted/fermented pigeon pea flours indicated enhanced proximate, functional and pasting properties and can be useful in baked goods production.

Keywords: wheat flour, pigeon pea flour, sprouted, fermented, blended

Introduction

Wheat (*Triticum aestivum*) is a member of the grass family called Graminae. Wheat is produced by countries such as United States of America, Canada, Australia, Argentina, China, Russia, India, Pakistan, and some European Union member countries [16]. Wheat flour is a staple in human nutrition and is the main flour used for the manufacture of baked products. This is due to the fact that wheat flour is easily pliable and has all the qualities required of a flour material for baking. However, wheat flour is expensive to import and the crop cannot be grown in Nigeria because her soil and climate are not favourable to its cultivation. In recent years, researchers in Nigeria have tried earnestly and persistently to focus on the use of inexpensive and available flours from local raw materials to supplement wheat flour in the production of baked products. Pigeon pea can be used to supplement wheat flour for the production of baked and other products. This will reduce the quantity of wheat flour importation and conserve foreign exchange. In addition, this will encourage the large scale cultivation and utilization of pigeon pea.

Pigeon pea (*Cajanus cajan*) is an under-utilized legume belonging to the class Fabaceae. Pigeon pea has been examined and discovered to be an appropriate protein source for supplementing baked products due to its high protein, iron and phosphorus content [18] and the sensory attributes of the products are not altered [39]. But pigeon pea contains antinutrients which is a limitation to its use. To improve its nutritional composition, pigeon pea seeds are subjected to a combination of fermentation and sprouting processing methods. Fermentation is an economic method that could be used to improve the nutritional quality of plant foods [27, 5]. According to Lawal *et al.* [20], fermentation improves digestibility and nutritional quality. Sprouting improves digestibility, bioavailability of vitamins, minerals, amino acids, proteins, and phytochemicals and reduce anti-nutrients and starch of cereals and legumes thereby increasing the absorption of protein and iron [33]. Some researchers had carried out some studies on the effects of combined processing methods on functional and pasting properties of pigeon pea flour [10], but information on the effects of supplementation of combined sprouted/fermented pigeon pea with wheat flour on the proximate composition, functional and pasting properties are scarce hence this study.

This study is aimed at evaluating the effect of inclusion of combined sprouted/fermented pigeon pea flour to wheat flour on the proximate composition, functional and pasting properties.

Materials and Methods

Materials collection

The materials, wheat flour and pigeon pea seeds were purchased from a market in Aba Abia State, Nigeria.

Production of Combined Sprouted/Fermented Pigeon Pea Flour

One kilogram (1kg) of pigeon pea seeds were sorted and extraneous materials removed. Sprouting of pigeon pea seeds was done using the method described by Ariahu *et al*. [7]. The seeds were washed and soaked in water for 30 min and the water drained. The grains were then spread in a single layer on a moistened jute bag and allowed to germinate at room temperature for 3 days. During this period of sprouting, the grains were sprayed with water at intervals of 12 hours until the last day of sprouting. The sprouted seeds were dehulled and the rootlets removed. Then the grains were wrapped in plantain leaves and allowed to ferment for 4 days according to Ikemefuna [20] method. After fermentation, the grains were dried in an oven at 60^0C for 7 hours and milled into flour with disc attrition mill (Asiko AII, Addis Nigeria), sieved with standard 1.0mm mesh sieve and packaged in polyethylene bag for analysis.

Supplementation of Wheat Flour with Combined Processed Pigeon Pea Flour

Supplementation of wheat flour with combined sprouted/fermented pigeon pea flour was done by blending the flours in the ratios of 100:0, 95:5, 90:10, 85:15, 80:20, 75:25 and 70:30 (wheat flour: combined sprouted/fermented pigeon pea flour respectively), where 100:0 served as control.

Proximate Analysis

The AOAC [4] methods were used to determine the protein, moisture, crude fibre, fat, ash and carbohydrate content of the samples and their analysis was done in triplicates.

Determination of Functional Properties

Bulk Density

Bulk density was determined according to the method described by Narayana and Narasinga [26]. Ten grams (10g) of the sample was weighed into a 25ml graduated measuring cylinder. The sample was gently tapped continuously on a laboratory table to eliminate spaces between the flour particles until a constant volume is obtained. The experiment was done in triplicate and the mean taken. Bulk density was calculated as:

$$\text{Bulk density (g/ml)} = \frac{Weight}{Volume\ of\ sample\ after\ tapping}$$

Water Absorption Capacity

The modified method of Lin *et al.* [23] as described by Onimawo and Egbekun [33] was employed. Water absorption capacity is expressed as the amount of water absorbed and held by a unit weight of the sample. One gram (1g) of each sample was dispersed into a weighed centrifuge tube. Ten milliliters (10ml) of distilled water was added to sample and mixed very well. The mixture was allowed to stand for one hour before being centrifuged at 3500rpm for 30min. The excess water (unabsorbed was decanted) and the tube was inverted over an absorbent paper to drain dry. The weight of water absorbed was determined by difference. This experiment was done in triplicate and the mean taken.

$$\text{WAC} = \frac{w2-w1}{w3} \times \frac{100}{1}$$

Where:
W_1= weight of sample
W_2=weight of empty tube + sample used
W_3=weight of empty tube + sample + water absorbed

Oil Absorption Capacity

This was carried out according to the method described by Adebowale *et al.* [1]. One gram (1g) of each sample was mixed in 10ml of oil in a weighed centrifuge tube. The mixture was allowed to stand for one hour. Then it was centrifuged at 3500rpm using spectra scientific centrifuge (Model: Merlin, SN976137) for 30min before the excess oil was decanted and the tube was inverted over an absorbance paper to drain dry. The experiment was done in triplicate and the mean taken.

$$\text{OAC} = \frac{w3-w2}{w1} \times \frac{100}{1}$$

Where
W_1= weight of sample
W_2=weight of empty tube + sample used
W_3=weight of empty tube + sample + water absorbed

Emulsion Capacity

This was determined by the method described by Yasumatsu *et al.* [41]. One gram (1g) of each sample was blended with 10ml of distilled water and 10ml of soybean oil in calibrated centrifuge tube. The emulsion was centrifuged at 2000 x g for 5min. The ratio of the height of emulsion layer to the total height of the mixture was calculated as emulsion capacity in percentage.

Foam Capacity

The method of Narayana and Narasinga Rao [25] was used. One gram (1g) of each sample was blended with 50ml of distilled water in a warring blender for 5 min at room temperature to foam. The mixture was quickly but carefully transferred to the measuring cylinder and the foam volume was measured and recorded after 30 seconds in the first instance, then the foam volume was recorded at 15min interval for one hour. The experiment was done in triplicate and the foam capacity was calculated from the volume of foam after the first 30 seconds as given by the formula:

$$\text{FC} = \frac{va-vb}{vb} \times \frac{100}{1}$$

Where
Va= volume after blending
Vb= volume before blending

Swelling Capacity

This was determined with the method described by Okaka and Potter [31]. Hundred milliliters (100ml) graduated cylinder was filled with each sample to 10ml mark. The distilled water was added to give a total volume of 50ml. The top of the graduated cylinder was tightly covered and mixed by inverting the cylinder. The suspension was inverted again after 2 min and left to stand for a further 8 min. The volume occupied by the sample was taken after the 8^{th} min.

Pasting Properties

Pasting properties was determined with a Rapid Visco Analyzer (RVA) (Model RVA 3DH, Newport Scientific Australia). Twenty-five grams (25g) of each sample was weighed into a dried empty canister, and then 25ml of distilled water was dispensed into the canister containing the sample. The slurry was thoroughly mixed and the canister was well fitted into the RVA as recommended. The slurry was heated from 50 ^{0}C to 95 ^{0}C with a holding time of 2 min followed by cooling to 50 ^{0}C with 2 min holding time. The rate of heating and cooling was at 22.5 ^{0}C per min. Peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, pasting temperature and peak time were read from the pasting profile with the aid of a thermocline for windows software connected to a computer [27].

Statistical Analysis
All data obtained were statistically analyzed with one-way analysis of variance (ANOVA) to determine significant difference at 5% level of acceptance using SPSS version 17. All data were expressed as mean ± standard deviation of triplicate values.

Results and Discussion
Proximate Composition
Table 1 depicts the proximate composition of wheat flour supplemented with combined sprouted/fermented pigeon pea flour. The moisture content ranged between 8.0-8.5%. The sample 100:0 (100% wheat flour) had the highest (8.50%) moisture content while the samples 85:15 (85% wheat flour and 15% combined sprouted/fermented pigeon pea flour) and 70:30 (70% wheat flour and 30% combined sprouted/fermented pigeon pea flour) had the least moisture content (8.00%). The low moisture content recorded for the samples is beneficial due to the fact that it will decrease the growth of pathogenic microorganisms, hence leading to prolonged shelf life of the product.

Table 1: Proximate composition of wheat flour supplemented with combined processed pigeon pea flour

Samples	Moisture	Protein	Fat	Crude fibre	Ash	Carbohydrate
100:0	8.50+0.0^a	13.30+0.0^g	1.72+0.1^g	0.86+0.0^g	0.73+0.02^g	74.89+0.0^a
95:5	8.20+0.02^c	17.20+0.01^f	2.80+0.0^f	1.15+0.1^f	1.50+0.0^f	69.15+0.0^b
90:10	8.30+0.0^b	20.18+0.01^e	3.00+0.0^e	2.80+0.02^e	2.00+0.1^e	65.72+0.1^c
85:15	8.00+0.0^e	23.50+0.0^d	3.20+0.0^d	3.50+0.0^d	2.50+0.0^d	59.30+0.02^d
80:20	8.30+0.0^b	26.15+0.0^c	3.60+0.0^c	4.20+0.1^c	3.30+0.0^c	54.25+0.1^e
75:25	8.10+0.0^d	28.40+0.0^b	3.80+0.1^b	4.85+0.0^b	3.90+0.1^b	51.05+0.02^f
70:30	8.00+0.1^e	32.00+0.01^a	4.15+0.0^a	6.00+0.0^a	4.20+0.02^a	45.65+0.1^g
LSD	0.00179	0.00219	0.00191	0.00198	0.00179	0.26646

Means with different letter within a column are significantly different ($p<0.05$). LSD= least significant difference

The protein content indicated significant increases ($p<0.05$) as increased quantity of combined sprouted/fermented pigeon pea flour was supplemented with wheat flour. The sample 70:30 had the highest (32.0%) protein content. The fat, crude fibre and ash contents showed the same trend of increase with values ranging from 1.72 – 4.15%, 0.86 – 6.0% and 0.73 – 4.2% respectively. The reverse was the case for carbohydrate content which decreased with increased supplementation of combined sprouted/fermented pigeon pea flour with wheat flour. The increased protein is expected since combined sprouted/fermented pigeon pea flour has high protein content. This is in agreement with the reports of Adepeju *et al.* [2] and Arukwe [8] for inclusion of pigeon pea flour in snack production and biscuit production respectively.

Functional Properties
Table 2 shows the functional properties of wheat flour supplemented with combined sprouted/fermented pigeon pea flour.

Bulk Density
These ranged between 0.586 - 0.693g/ml. The sample 100:0 had the highest (0.693g/ml) value of bulk density which significantly decreased ($p<0.05$) with increased supplementation of combined sprouted/fermented pigeon pea flour with wheat flour. The reduced bulk density for samples supplemented with combined sprouted/fermented pigeon pea flour may be due to their low carbohydrate content since high carbohydrate foods exhibit high bulk density [18]. Arukwe *et al.* [10] recorded low bulk density for pigeon pea flour and high bulk density was reported for cocoyam flours by Arukwe and Onugha [9]. Bulk density of flours is important for packaging, transportation and mixing. High bulk density flours are employed as thickeners in food products [3] while low bulk density flours can find use in baby food formulations where high nutrient density to bulk is required [24].
Therefore, the combined sprouted/fermented pigeon pea and wheat flour blends in this study with low bulk density will be useful for infant food products.

Table 2: Functional properties of wheat flour supplemented with combined processed pigeon pea flour

Samples	Bulk density (g/ml)	Water absorption capacity (%)	Oil absorption capacity (%)	Emulsion capacity (%)	Swelling capacity (%)	Foam capacity (%)
100:0	0.693+0.0^a	136.10+0.01^g	138.00+0.02^g	26.85+0.0^g	13.00+0.0^g	5.50+0.01^g
95:5	0.682+0.0^b	136.82+0.02^f	138.38+0.0^f	27.50+0.01^f	13.30+0.01^f	5.70+0.0^f
90:10	0.673+0.01^c	137.15+0.0^e	138.80+0.0^e	28.00+0.01^e	14.00+0.0^e	5.85+0.01^e
85:15	0.669+0.01^c	137.50+0.0^d	139.05+0.02^d	28.15+0.0^d	14.50+0.02^d	6.20+0.0^d
80:20	0.660+0.02^d	137.86+0.01^c	139.62+0.01^c	28.50+0.02^c	15.01+0.0^c	6.80+0.0^c
75:25	0.592+0.02^e	138.00+0.0^b	140.11+0.01^f	28.82+0.01^b	16.25+0.02^b	7.45+0.0^b
70:30	0.586+0.0^e	138.50+0.02^a	140.73+0.0^a	30.02+0.0^a	16.50+0.01^a	8.00+0.01^a
LSD	0.00231	0.00202	0.00195	0.00219	0.00222	0.00207

Means with different letter within a column are significantly different ($p<0.05$). LSD= least significant difference

Water Absorption Capacity

The water absorption capacity showed significant (p<0.05) increase with increased supplementation of wheat flour with combined sprouted/fermented pigeon pea flour and the values ranged between 136.10 – 138.50%. Water absorption capacity depicts flour water imbibition ability under limited water supply. Increase in water absorption capacity indicates increase in digestibility and such flours can serve for formulation of infant foods [30]. Arukwe *et al.* [10] also reported increased water absorption capacity for combined sprouted/fermented pigeon pea flour.

Oil Absorption Capacity

The oil absorption capacity followed the same trend of increase with increased supplementation of wheat flour with combined sprouted/fermented pigeon pea flour. Oil absorption capacity is necessary for flavor retention and improves texture and mouth feel of food [6]. The increment in oil absorption capacity of the flours Incorporated with combined processed pigeon pea flour portray that they can be used in bakery products [15] or in sausage and soups where oil absorption is required [22].

Emulsion Capacity

The emulsion capacity ranged from 26.85 – 30.00%. There were significant (p<0.05) increase in emulsion capacities of the samples with increased addition of combined sprouted/fermented pigeon pea flour to wheat flour. Emulsion capacity is a significant consideration in the production of baked goods, coffee whiteners and frozen desserts.

Swelling Capacity

Swelling capacity of the samples ranged between 13.0 – 16.50% and these were markedly increased (p<0.05) with increased inclusion of combined sprouted/fermented pigeon pea flour to wheat flour. This increment could be attributed to the decreased wheat flour ratio in the blends. This result is in agreement with the findings of Bello *et al.* [11] who reported increase in the swelling index of blends of wheat flour supplemented with pigeon pea and unripe plantain flours. Swelling capacity is a rise in volume of dry starch when kept in a moist environment and it is an important index in baking.

Foaming Capacity

There were significant differences (p<0.05) in the foaming capacities of the samples and these ranged from 5.50 – 8.00%. The foaming capacities increased with increase in the addition of combined sprouted/fermented pigeon pea flour to wheat flour. The values obtained in this study for foam capacity are close to the values (4.00 – 11.33%) reported for germinated tiger nut varieties by Chinma *et al.* [13].

Pasting Properties

Table 3 depicts the pasting properties of wheat flour supplemented with combined sprouted/fermented pigeon pea flour.

The peak viscosity ranged from 935 – 1510 RVU with the sample 100:0 recording the highest value. Peak viscosities of the samples significantly decreased (p<0.05) with increasing inclusion of combined processed pigeon pea flour into wheat flour. Peak viscosity is the maximum viscosity attained during or immediately after heating. It is associated with degree of starch damage and high starch damage results to high peak viscosity [34, 31]. Peak viscosity indicates the water holding capacity of starch and is often correlated with the final product quality. The low peak viscosity obtained for the flour blends supplemented with combined sprouted/fermented pigeon pea flour are nutritionally beneficial in infant food formulation [17].

Table 3: Pasting properties of wheat flour supplemented with combined processed pigeon pea flour

Samples	Peak Viscosity (RVU)	Trough Viscosity (RVU)	Breakdown Viscosity (RVU)	Setback Viscosity (RVU)	Final Viscosity (RVU)	Pasting Temperature (^{0}C)	Peak Time (Min)
100:0	1510+0.01^a	915+0.0^a	750+0.01^a	910+0.0^a	1825+0.0^a	85.20+0.01^g	6.50+0.0^a
95:5	1425+0.0^b	860+0.0^b	703+0.0^b	870+0.01^b	1732+0.0^b	85.51+0.01^f	6.35+0.0^b
90:10	1282+0.0^c	783+0.01^c	640+0.0^c	797+0.01^c	1580+0.01^c	86.30+0.0^e	6.20+0.01^c
85:15	1130+0.01^d	716+0.01^d	600+0.0^d	739+0.0^d	1455+0.01^d	86.80+0.0^d	6.13+0.01^d
80:20	1098+0.0^e	625+0.0^e	556+0.0^e	695+0.01^e	1370+0.0^e	87.50+0.0^c	6.00+0.01^e
75:25	1023+0.0^f	601+0.0^f	513+0.01^f	661+0.01^f	1262+0.01^f	88.00+0.02^b	5.82+0.0^f
70:30	935+0.0^g	588+0.0^g	484+0.01^g	612+0.0^g	1200+0.0^g	88.10+0.02^a	5.65+0.0^g
LSD	0.01652	0.01932	0.01373	0.01270	0.01895	0.00812	0.00191

Means with different letter within a column are significantly different (p<0.05). LSD= least significant difference

Trough, breakdown, setback and final viscosities followed the same trend of decrease with increasing addition of combined processed pigeon pea flour into wheat flour.

Trough viscosity is the minimum viscosity value that measures the ability of paste to withstand breakdown during cooling. It is a measure of the cooked starch vulnerability to disintegration. The low trough viscosity recorded for the combined sprouted/fermented pigeon pea and wheat blended flour samples indicated their usefulness in filler meat canning industry.

A low breakdown viscosity value indicates the stability of starches under hot condition. The higher the breakdown viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking [1]. This implies that the wheat flour blends supplemented with combined processed pigeon pea flour with low breakdown viscosities may be able to withstand heating and shear stress.

Final viscosity is the parameter used to determine the quality of a starch-based sample. It gives an idea of the ability of starch to gel after cooking and cooling [38] and indicates the stability of cooked paste in actual use. This suggests that the blends of wheat flour supplemented with combined processed pigeon pea flour with low final viscosities will be more stable after cooling.

Setback viscosity: Higher setback viscosity value during cooling of the paste is indicative of reduced dough digestibility [39] whereas low setback viscosity value suggests lower retrogradation [37, 36] and improved dough digestibility [10]. This implies that the blended wheat and combined processed pigeon pea flour samples with low setback viscosity values will be more digestible.

The peak time significantly (p<0.05) reduced with increasing supplementation of wheat flour with combined processed pigeon pea flour. Peak time is a measure of the cooking time [1]. This implies that the blended flours of combined processed pigeon pea and wheat with decreased peak time will cook faster.

Pasting temperature

It is a measure of the lowest temperature needed to cook a given food sample [36]. The pasting temperature results indicated increment as the level of inclusion of combined sprouted/fermented pigeon pea flour to wheat flour increased. Pasting temperature has been associated with water absorption capacity, implying that high pasting temperatures of the blended flours of combined processed pigeon pea and wheat may be due to their high water absorption capacities.

It was observed in this study that the pasting properties decreased (except pasting temperature) as the ratio of inclusion of combined processed pigeon pea flour to wheat flour increased. This may be as a result of the effect of the high protein in pigeon pea on the starch. It was reported that sorghum with higher protein content produced thinner gruel and had a lower degree of starch gelatinization than sorghum with lower protein content [12]. Therefore, it can be deduced that proteins restrict starch gelatinization. Also, Derycke *et al*. [14] opined that protein significantly affected the pasting attributes of rice, may be by decreasing heat-induced swelling of the starch. The decrease in the peak, trough, breakdown, setback and final viscosities and increment in pasting temperature of the flour blends with increased level of inclusion of combined sprouted/fermented pigeon pea flour (more protein content) is in agreement with the report of Ohizua *et al*. [29] on the pasting profile of blends of unripe cooking banana, pigeon pea and sweet potato flours.

Conclusion

This study showed the effect of supplementation of combined sprouted/fermented pigeon pea flour on the proximate composition, functional and pasting properties of wheat flour. The proximate contents (protein, fat, ash, crude fibre) increased while carbohydrate and moisture decreased with increased level of supplementation with combined processed pigeon pea flour.

The water absorption capacity, oil absorption capacity, emulsion capacity, swelling capacity and foaming capacity significantly (p<0.05) increased while bulk density decreased for the flour blends as the level of supplementation of wheat flour with combined processed pigeon pea flour increased. The peak viscosity, trough viscosity, breakdown viscosity, setback viscosity, final viscosity and peak time decreased with increase in the substitution of combined processed pigeon pea flour with wheat flour while the pasting temperature increased.

Furthermore, the proximate, functional and pasting properties of the wheat/combined processed pigeon pea blends showed improved qualities and can find use in the production of nutritious bakery products.

Conflict of Interest

The author hereby states that there is no conflict of interest.

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