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Physicochemical and Rheological Properties of Complementary Diet from Blends of Maize, African Yam Bean and Pigeon Pea Flour -

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ABSTRACT

Complementary diets were obtained from maize, African yam beans and pigeon pea varied and the effect of physicochemical and pasting properties were evaluated. The blends considered were 90:5:5, 80:10:10 and 70:15:15 for maize, African yam bean and pigeon pea respectively. The blends were compared with 100% maize gruel and a commercial weaning diet, Nutrend. The results showed that the complementary blend with ration 70:15:15 had 24.29% protein, 4.05% ash, and 58.49% carbohydrate while 100% maize (ogi) had 10.52% protein, 4.2% ash and 73.02% carbohydrate in comparism with commercially produced diet, Nutrend, which had 21.64% protein, 3.58% ash and 61.35% carbohydrate. Also in terms of mineral composition, the result of the diet analyzed showed that 100% maize (ogi) had the 16 best pasting properties followed closely by both the diet with the 70:15:15 ratios and the commercially produced diet, Nutrend. Overall the 70:15:15 ratios had better proximate and mineral composition while the 100% maize gruel (ogi) had the best pasting properties which were closely followed by 70:15:15.

Keywords: Complementary diets; Maize; African yam bean; Pigeon pea; Physicochemical Properties

INTRODUCTION

Scientifically, it has been proven that breast milk is the perfect food for the growing infant during the first six months of life [1]. It contains all the nutrients which an infant requires to maintain optimal health and growth. Beyond this period, the supply of energy and protein and some nutrients from breast milk is no longer adequate to meet an infant's need. Malnutrition during this period of life leads to permanent stunting in growth [2] and this may also lead to deficiencies that affect the brain [3]. In Nigeria, cereals are consumed with little or no protein. This leads to protein-calorie malnutrition and pellagra [4]. Protein malnutrition of infants and children is one of 31 the major challenges of the world today. This constraint is most prominent in the developing nations of the world [5]. In developing countries including Nigeria, many families cannot afford commercial complementary foods to wean their infants due to high level of poverty, and thereby engage in weaning the children on cereal gruels [6]. Scientific findings have shown that cereal gruels are the common complementary foods in developing countries, which is characterized by low energy and protein density [1,7-9] due to large volume of water relative to its solid matter contents during preparation. To increase the energy density of the gruel, more of the solid matter are needed, which will makes the gruel too thick and viscous for infant to eat and too large for their stomach capacity [10]. Infants are therefore unable to fulfill their energy and other essential nutrients requirements [10], which resulted in protein-energy malnutrition among weaning aged children. Improved complementary feeding and breastfeeding practices are essential to achieve the Millennium Development Goals (MDGs) for child survival and prevention of protein-energy malnutrition [1]. To achieve this goal, formulation and development of nutritious complementary diet from local and readily available raw food materials have received a lot of attention in many developing countries [11]; however, locally available African yam bean and Pigeon pea combination have not been tested for complementary diets. Apart from the recent advocacy for the use of recycled agricultural materials Oludumila et al., [12] efforts are also been made at increasing the level of local biodiversity utilization via use of wild and uncultivated forest oilseeds and legumes. The fortification of diets based on inexpensive staples such as maize has resulted in products of high nutritional value [13]. An acceptable, nutritionally-enriched food that can be stored in the home should be produced for consumption in areas where protein intake is low.

African yam bean (*Sphenostylis stenocarpa*) is an edible, underutilized grain legumes widely cultivated in Africa that is used for man and animal nutrition [14]. Like most grain legumes cultivated in Africa, African yam bean is rich in protein (19.5%), carbohydrates (62.6%), fat (2.5%), vitamins and minerals [15]. The protein is made up of over 32 % essential amino acids, with lysine and leucine being predominant [16]. It is also rich in antioxidants and free-radical scavengers [17]. In spite of its composition, it has a low consumption rate. This is mainly due to its long cooking time about 145 min. [18]. Pigeon pea *(Cajanus cajan)* is a rich source of protein for animal and human consumption. It also supplies a significant amount of minerals and vitamins [19]. Pigeon pea's low food value for human is due to low palatability when compared to cowpea and prolonged cooking time, coupled with no industrial use in Nigeria as of now [20]. Hence, a need to develop a diet that is majorly rich in protein, cheap and readily available for the populace.

MATERIALS AND METHODS

Collection of Food Material

The raw materials (Maize, African yam beans and Pigeon pea) used for the study were purchased from Bisi Market in Ado Ekiti metroplis, Ekiti State, Nigeria. The samples were thoroughly cleaned by removing all broken kernels and stones, to make it free of extraneous particles.

Steeping of Maize

The clean maize grains were steeped in water for 24 h at room temperature, for germination to take place immediately to prevent fermentation, oven dried at 70°C and milled to flour.

Soaking and Germination of African Yam Bean and Pigeon Pea

The cleaned African yam beans and pigeon pea were steeped in water at room temperature for a period of 24 h to achieve easy germination. The beans were allowed to germinate at room temperature for 48 h after which the beans were dehulled manually. Thereafter the dehulled beans were washed with potable water to remove the outer coat and unwanted particles. The beans were then oven dried at a temperature of 70°C; the dried beans were dry milled into powders and stored for subsequent treatment.

Preparation of the Complementary Diets

To make the complementary diets, the ground maize flour (M), African yam bean flour (A) and the Pigeon pea flour (P) were combined in three different ratios and the control formulations which were determined using NutriSurvey-Linear-Programming Software to obtain the following combinations: The control was 100% maize flour (Ogi) while the M, A and P were at the levels of 90:5:5, 80:10:10 and 70:15:15 ($MAP_{1,}$ MAP_2 andMAP_3). The proportions at different levels were mixed in a Kenwood mixer (Model NX806 H). After that, 5% mineral mix, 2% salt and 5% sucrose (sugar) were added to each of the flour blends and mixed thoroughly in a mixer for 10 min to produce fortified complementary diet formulations. They were carefully packaged and sealed in high density polyethylene bags and kept at ambient temperature until further analyses were carried out.

CHEMICAL ANALYSIS

Proximate analysis

Proximate compositions of the food samples were determined in triplicate using the standard procedures of Association of Official Analytical Chemists [21].

Energy

Energy was determined by the "Atwater factor" according to Iombor et al., [22]. The energy value of the samples were calculated by multiplying the values for fat, CHO and protein with 17:37:17 the "Atwater factors" respectively.

Where protein = 17KJ/ g

Fat = 37KJ/g

CHO = 17KJ/g

FUNCTIONAL PROPERTIES

Water absorption capacity (WAC)

Water Absorption Capacity (WAC) was determined using the method of Adebowale et al. [23]. Ten milliliters of distilled water was added to 1 g of the sample in a beaker. The suspension was stirred using magnetic stirrer for 3 min. The suspension obtained was thereafter centrifuged at 3500 rpm for 30 minutes, and the supernatant was measured into a 10 ml graduated cylinder. The water absorbed by the flour was calculated as the difference between the initial volume of the sample and the volume of the supernatant. The WAC was calculated using Eq 1.

$$WAC(g/g) = \frac{Weight\ of\ water \times density\ of\ water \times 100}{weight\ of\ the\ sample} \quad \ldots Eq\ 1$$

Oil absorption capacity (OAC)

Oil Absorption Capacity (OAC) was determined using the method of Adebowale, et al. [23]. 10 ml of oil was added to 1 g of the sample in a beaker. The suspension was stirred using magnetic stirrer for 3 minutes. The suspension obtained was thereafter centrifuged at 3500 rpm for 30 minutes, and the supernatant was measured into a 10 ml graduated cylinder. The oil absorbed by the flour was calculated as the difference between the initial volume of the sample and the volume of the supernatant. The OAC was calculated using Eq 2.

$$OAC\left(\frac{g}{g}\right) = \frac{\text{weight of water absorbed} \times \text{density of water} \times 100}{\text{Weight of the sample}} \quad \ldots Eq\ 2$$

Bulk density determination

The procedure of [24] was used to determine the bulk density. A 100 ml graduated cylinder was weighed and recorded, 15 g of sample were put into the cylinder, tapped hermitically to eliminate air space between the flour, the volume was noted and new mass was recorded. The bulk density was computed in equation 3.

$$\text{Bulk Density}(g/cm) = \frac{\text{mass of the sample}}{\text{Volume of the cylinder}} \quad \ldots Eq\ 3$$

ANTINUTRITIONAL PROPERTIES

Oxalate content determination

Oxalate content in the food samples was determined using methods of [21]. One gram of the sample was weighed into a conical flask and 75 ml of 3M H_2SO_4 was added. The solution was carefully stirred intermittently with a magnetic stirrer for about 1 hour and then filtered using Whatman No 1: 11 µm filter paper. From the filtrate, 25 cm^3 of sample was titrated against a 0.1 N $KMnO_4$ solution to the final point (pink colour) that persisted for at least 30 secs. The oxalate content of each sample was then calculated.

Phytate content determination

The phytate content of each sample was determined using the method described by [25]. Two grams were weighed into 250 ml conical flask. 100 ml of 2% conc. HCl were used to soak the samples then it was filtered using Whatman No 1:11 µm filter paper. 139 Fifty milliliters (50 ml) of each sample filtrate were added to 100 ml of distilled water in a 250 ml beaker to improve acidity. Ten milliliters (10 ml) of 0.3% ammonium thiocyanate solution was added to each sample solution as indicated and titrated with standard iron chloride solution which contained 0.00195 g iron/ml and the end point was signified by brownish – yellow colouration that persisted for 5 min. The percentage of the phytic acid was calculated.

Tannin content determination

Tannin contents were determined by the modified vanillin-HCl methods [25]. Two grams sample was extracted with 50 ml 99.9% methanol for 20 min room temperature with constant agitation. After centrifugation for 10 min. at 653 rpm, 5 ml of vanillin-HCl (2% Vanilli and 1% HCl) reagent were added to 1 ml aliquots, and the colour developed after 20 min at room temperature was read at 500 nm. Correction for interference light natural pigments in the sample was achieved by subjecting the extract to the conditions of the reaction, but without vanillin reagent. A standard curve was prepared using Catechin (Sigma Chemical, St. Louis, MO) after correcting for blank, and tannin concentration was expressed in g/100 g.

Mineral Content

AOAC [21] methods were used to determine mineral compositions of the samples. One gram of sample was digested with nitric/perchloric/sulphuric acids mixture in ratio 9:2:1 respectively, filtered and the filtrate in a 5 ml volumetric flask was loaded to Atomic Absorption Spectrophotometer, (model 703 Perkin Elmer, Norwalk, CT, USA). The standard curve for each mineral (calcium, magnesium, iron, sodium, potassium, phosphorus, copper and zinc), was prepared from known standards and the mineral value of samples estimated against that of standard curve. Sodium and potassium values were determined using Flame photometer (Sherwood Flame Photometer 410, Sherwood Scientific Ltd. Cambridge, UK). The phosphorus was determined using Vanado-molybdate method.

Pasting properties

Pasting characteristics of the flour blends were evaluated using a Rapid Visco Analyzer (RVA). First, 2.5 g of samples were weighed into a dried empty canister; then 25 ml of distilled water was dispensed into the canister containing the sample. The solution was thoroughly mixed and the canister was well fitted into the RVA as recommended. The slurry was heated from 50-95°C with a holding time of 2 min followed by cooling to 50°C with 2 min holding time.

The rate of heating and cooling were at a constant rate of 11.25°C per min. Peak viscosity; trough, breakdown, final viscosity; set back, peak time and pasting temperature were read from the pasting profile with the aid of thermocline for windows software connected to a computer (Newport Scientific, 1998).

Statistical analysis

The data was analyzed using Statistical Package for Social Sciences (SPSS) software version 16.0. The mean and standard deviations of the analyses were calculated. The Analysis of Variance (ANOVA) was performed to determine significant differences between the means while the means were separated using Duncan Multiple Range Test at $P \geq 0.05$.

RESULTS AND DISCUSSION

Proximate composition of maize, African yam bean-Pigeon pea enriched complementary diet

The result of the proximate composition of the complementary diet formulations prepared from Maize/ African yam beans/ Pigeon pea flour blends and the control sample are presented in table 1. The moisture content of the Ogi sample was 7.57 ± 0.23 and the complementary diets from Maize, African yam beans and pigeon pea (MAP_1, MAP_2 and MAP_3) had 7.05 7.05 ± 039, 7.43 ± 0.21 and 7.65 ± 0.11 respectively while Nutrend had 8.45 ± 0.22. This observation indicated that the Ogi and diets made from Maize, African yam beans and Pigeon pea samples had lower moisture content, than Nutrend. Studies have shown that moisture content in food products facilitate the growth of microorganisms, which in turn causes spoilage and low nutritional qualities of the food products [13,26].The protein content of the ratio at MAP_3 (24.29 ± 1.39%) was higher than the formulations at MAP_2 (21.25 ± 1.01%), MAP_1 (19.38 ± 1.23%), Nutrend (21.64 ± 1.14 %) and Ogi (10.52 ± 1.27 %). However, the protein contents of complementary diet combinations in this present study were higher than [27] recommended value for infant complementary food (≥ 15 g/100 g), and also higher than the value reported for complementary foods formulated from sorghum, sesame, carrot and crayfish [28]. This addition effect was also observed for ash and fiber contents of the diet. The fiber content of the diets increased steadily with increasing supplementation, which was in accordance with that of [29]. The carbohydrate content of the diets reduced as the formulations increased readily with increasing content of African yam beans and Pigeon pea flour and was similar with the report of [19]. Energy value of MAP_1 (346.58 ± 0.09 KJ/kg) was also higher than those of MAP_2 (345.95 ± 0.22 KJ/kg) and MAP_3 (342.84 ± 0.03 KJ/kg) samples, however, energy values of formulated diets were lower when compared with those of control samples, that is, '*Ogi*' (347.30 ± 0.20 kJ/kg) and Nutrend (347.53 ± 0.11 kJ/kg). This observation could be attributed to low carbohydrate contents that were observed in Maize, African yam beans and pigeon pea flour blends. Nutritionally, the high protein and energy values observed in this study, particularly with MAP_3 blend, showed that the formulation is suitable for infants as complementary diet; and also could be substituted for traditional complementary diet, that is, cereal gruel, which had been implicated as one of the major causes of protein–energy malnutrition among weaning aged children in Nigeria and other developing countries [30].

Functional properties of maize, African yam bean-Pigeon pea complementary diet

Functional properties of the complementary diets formulated from African yam bean and Pigeon pea are presented in table 2. Bulk density of diet at MAP_3 *is* 0.66 g/ cm³ which was lesser that the other ratios and was not significantly different from that of Nutrend 0.65 g/cm³. As the substitution level increased in water absorption capacity and oil absorption capacity, the values reduced. Comparatively, it was observed that the diets were higher in bulk density, water and oil absorption capacity than in Nutrend. The higher values of water and oil absorption capacity and bulk density that were observed in this study compared with the control samples do not limit the nutritional advantages of these products. However, these values were similar to other plant-based food products [31,32]. Higher water absorption capacity indicates higher protein content in the formulations, which absorbs and binds with more water [33]. According to [34], appropriate complementary food is the one which produce a gruel or porridge that is neither too thick for the infant to consume nor so thin that energy and nutrient density are reduced. Therefore, low water absorption capacity is desirable in complementary food for making thinner gruels with high caloric density per unit volume.

Anti-nutritional factors in maize, African yam bean and Pigeon pea formulations

The concentrations of anti–nutrients in the formulated complementary diet samples are presented in table 3. The values of oxalate and tannin in MAP_2 and MAP_3 blends were significantly higher compared to values in the blends of MAP_1. The values of MAP_1 of phytate were higher when compared to the values of MAP_2 and MAP_3. It was generally observed in this study that the antinutrient compositions of the formulations were generally low and they are within the tolerable levels. For instance, the oxalate and tannin contents of the formulated complementary diets were lower compared with the complementary food based on Soybean and Tigernut [6].

Table 1: Proximate composition (g/100 g) of complementary diets formulated from Maize, African yam beans and Pigeon pea flour.

Sample (%)	Protein (%)	Fat (%)	Ash (%)	Fiber (%)	Moisture (%)	CHO (%)	Energy (KJ/ kg)
Ogi	10.52^e ± 1.27	1.46^e ± 0.03	4.26^a ± 0.21	3.17^d ± 0.07	7.57^c ± 0.23	73.02^a ± 0.26	347.30^b ± 0.20
MAP_1	19.38^d ± 1.23	1.54^d ± 0.04	3.97^c ± 0.13	3.26^c ± 0.00	7.05^e ± 0.39	64.80^b ± 0.22	346.58^c ± 0.09
MAP_2	21.25^c ± 1.01	1.70^c ± 0.02	3.74^d ± 0.03	3.47^b ± 0.14	7.43^d ± 0.21	62.41^c ± 0.02	345.95^d ± 0.22
MAP_3	24.29^a ± 1.39	1.85^a ± 0.01	4.05^b ± 0.19	3.66^a ± 0.20	7.65^b ± 0.11	58.49^e ± 0.40	343.84^e ± 0.03
NUTREND	21.64^b ± 1.14	1.73^b ± 0.23	3.58^e ± 0.17	3.25^c ± 0.18	8.45^a ± 0.22	61.35^d ± 0.45	347.53^a ± 0.11

Mean values with different superscript in a column are significantly different ($P \geq 0.05$).Values are mean ± standard deviation from triplicate determinations.
Ogi = 100% Maize, 0% African yam beans and 0% Pigeon pea.
MAP_1 = 90% Maize, 5% African yam beans and 5% Pigeon pea.
MAP_2 =80% Maize, 10% African yam beans and 10% Pigeon pea.
MAP_3 = 70% Maize, 15% African yam beans and 15% Pigeon pea.
Nutrend = Control.

Study had shown that oxalates in large amounts bind with calcium forming calcium oxalate, which is insoluble and not absorbed by the body [35]. Oxalates are considered poisonous at high concentration, but harmless when present in small amounts [36]. Tannin had been implicated to form insoluble complexes with proteins thereby reducing digestibility and utilization of food proteins, interference with the absorption of Iron and inhibition of trypsin, chymotrypsin, amylase and lipase [37,38].

Mineral composition of maize, African yam beans and Pigeon pea complementary diets

Mineral content of the blends were higher in all the minerals tested for as presented in table 4. The mineral contents in the formulated diets were comparatively higher than that of the Ogi and Nutrend samples. The higher mineral content observed in the formulated diets when compared with the Nutrend therefore makes it a good and cheap source of a commercial complementary diet than the Nutrend. In this study, micronutrients were used to fortify the diets during its production. To compensate for lost of macronutrients and micronutrients in processed foods, a number of researchers have advocated for food fortification, particularly infants foods, during the production process [39,40]. The Ca/P and Na/K molar ratios of the blends showed that all the samples met the recommended values, which indicates that the formulated diets would support bone and teeth formation in children and also would not pose any danger to heart of the infant whenever taken as complementary food.

Table 2: Functional properties of complementary diets formulated from Maize, African yam bean and Pigeon pea.

Samples (g/ ml)	Water absorption capacity (g/ ml)	Oil absorption capacity (g/ ml)	Bulk Density
Ogi	1.18^{b} ± 0.16	0.91^{b} ± 0.01	0.63^{d} ± 0.05
MAP$_1$	1.63^{a} ± 0.74	0.97^{a} ± 0.01	0.77^{a} ± 0.02
MAP$_2$	1.12^{c} ± 0.08	0.82^{c} ± 0.03	0.72^{b} ± 0.00
MAP$_3$	1.00^{d} ± 0.09	0.81^{c} ± 0.01	0.66^{c} ± 0.03
Nutrend	0.90^{e}±0.07	0.76^{d} ± 0.02	0.65^{c} ± 0.00

Mean values with different superscript in a column are significantly different (*P* ≥ 0.05). Values are mean ± standard deviation from triplicate determinations.
Ogi = 100% Maize, 0% African yam bean and 0% Pigeon pea.
MAP$_1$ = 90% Maize, 5% African yam beans and 5% Pigeon pea.
MAP$_2$ =80% Maize, 10% African yam beans and 10% Pigeon pea.
MAP$_3$ = 70% Maize, 15% African yam beans and 15% Pigeon pea.
Nutrend = Control.

Table 3: Anti-nutritional content (mg/ 100 g) of complementary diets formulated from African yam beans and Pigeon pea.

Antinutrients	MAP$_1$ (mg/ 100 g)	MAP$_2$ (mg/ 100 g)	MAP$_3$ (mg/ 100 g)
Phytate	11.67^{a} ± 0.06	10.27^{b} ± 0.02	10.05c±0.00
Tannin	0.24^{c} ± 0.01	0.28^{b} ± 0.17	0.32^{a} ± 0.23
Oxalate	0.08^{b} ±0.11	0.08^{b} ± 0.15	0.12a ± 0.11

Mean values with the same superscript in a row are significantly different (*P* ≥ 0.05).Values are mean ± standard deviation from triplicate determination.
MAP$_1$ = 90% Maize, 5% African yam beans and 5% Pigeon pea.
MAP$_2$ =80% Maize, 10% African yam beans and 10% Pigeon pea.
MAP$_3$ = 70% Maize, 15% African yam beans and 15% Pigeon pea.

Pasting characteristics of African yam bean-pigeon pea complementary diet

Table 5 showed that the pasting characteristics of Maize-African Yam Bean- Pigeon pea diets were generally lower in peak, trough, breakdown and final viscosity values when compared with the control sample (ogi) and nutrend. While setback, peak time and pasting temperature values of the control and nutrend values were lower than the values from maize- African yam bean and Pigeon pea values. Peak viscosity is the maximum viscosity developed during or soon after the heating aspect of the test. High peak viscosity has been attributed to be significant in the preparation of stiff dough products [41]. The apparent gelatinization (pasting) temperature is the temperature were viscosities first increases by at least 2 RVU over a 20 sec period. This may be due to the buffering effect of fat (from African yam bean and Pigeon pea) on starch which interferes with the gelatinization process [42]. The pasting temperature is one of the characteristic which provide an indication of the minimum temperature required for sample cooking, energy cost involved and other components stability. The peak viscosity of Ogi and Nutrend were 166.25 RVU at a temperature of 81.45°C in 4.77 min and 175.67 RVU at a temperature of 82.35°C for 5.18 min respectively. The Maize- African yam bean – Pigeon pea flours had lower values in the range of (128.30 RVU at a temperature of 82.55°C for 5.35 min to 161.11 RVU at a temperature of 82.18°C for 5.05min. However, lower peak viscosity may be attributed to difference in protein content [43]. This suggests that the presence and interaction of components like fats and protein (from African yam bean and Pigeon pea) with maize starch lowers the peak viscosity of the blends [42]. The holding period is usually accompanied by breakdown viscosity which could also be referred to as shear thinning, hot paste viscosity, paste stability or trough. It is regarded as the measure of the degree of disintegration of the granules or "paste stability" [44]. Trough and breakdown are pasting properties which indicate the ability of a food material to remain undisrupted when subjected to long periods of constant

Table 4: Mineral composition (mg/100 g) of complementary diets formulated from Maize, African yam bean and Pigeon pea flour.

Sample (mg/100g)	Calcium (mg/100g)	potassium (mg/100g)	sodium (mg/100g)	magnesium (mg/100g)	Phosphorus (mg/100g)	iron (mg/100g)	Zinc (mg/100g)	Copper (mg/100g)
Ogi	73.2 ± 0.01	1247.2 ± 0.02	8.57 ± 0.01	120.8 ± 0.01	466.36 ± 0.01	4.58 ± 0.01	1.17 ± 0.01	0.23 ± 0.01
MAP$_1$	73.66 ± 0.17	1258.6 ± 0.03	7.74 ± 0.03	121.48 ± 0.01	455.57 ± 0.01	4.26 ± 0.01	1.23 ± 0.02	0.24 ± 0.03
MAP$_2$	74.47 ± 0.01	1328.2 ± 0.03	7.13 ± 0.11	123.26 ± 0.02	444.50 ± 0.01	4.17 ± 0.01	1.26 ± 0.01	0.25 ± 0.02
MAP$_3$	77.25 ± 0.01	1333.4 ± 0.03	6.95 ± 0.02	128.46 ± 0.01	438.49 ± 0.01	3.96 ± 0.01	1.27 ± 0.01	0.28 ± 0.01
Nutrend	70.11 ± 0.11	1289.0 ± 0.02	7.13 ± 0.11	122.35 ± 0.01	428.4 ± 0.02	4.56 ± 1.74	1.06 ± 0.01	0.27 ± 0.04

Values are mean ± standard deviation from triplicate determination.
Ogi = 100% Maize, 0% African yam bean and 0% Pigeon pea.
MAP$_1$= 90% Maize, 5% African yam beans and 5% Pigeon pea.
MAP$_2$ =80% Maize, 10% African yam beans and 10% Pigeon pea.
MAP$_3$ = 70% Maize, 15% African yam beans and 15% Pigeon pea.
Nutrend = Control

Table 5: Mean pasting properties of Maize-African yam beans-Pigeon pea flour blends.

Samples	Viscosity (RVU) Peak Viscosity (Vp)	Final Viscosity(V)	Peak time (min)	Pasting Temp (°C)	Through at (95°C)	Break down (Vp-Vi)	Setback (Vf-Vi)
Ogi	166.25^b	293.33^a	4.77^d	81.45^d	115.67^b	50.58^b	60.17^d
MAP_1	161.11^c	247.33^b	5.05^c	82.18^c	123.25^a	37.92^d	122.92^c
MAP_2	133.50^d	145.25^d	5.18^b	82.35^c	85.08^e	48.42^c	124.08^b
MAP_3	128.30^e	229.33^c	5.35^a	82.55^a	100.42^d	22.08^e	177.67^a
Nutrend	175.67^a	106.58^e	5.18^b	82.35^b	101.08^c	74.58^a	59.50^e

Means with different superscripts in a row are significantly different ($P \geq 0.05$)
Ogi = 100% Maize, 0% African yam bean and 0% Pigeon pea.
MAP_1= 90% Maize, 5% African yam beans and 5% Pigeon pea.
MAP_2 =80% Maize, 10% African yam beans and 10% Pigeon pea.
MAP_3 = 70% Maize, 15% African yam beans and 15% Pigeon pea.
Nutrend = Control.

high temperature and ability to withstand breakdown during cooking [45]. The breakdown viscosity of Ogi and nutrend were 50.58 and 74.58 RVU respectively. The blend samples had lower values in the range of 22.08-48.42 RVU at varying levels of African yam bean and Pigeon pea addition. Adebowale, et al. [23], reported that the higher the breakdown in viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking. Therefore, with this report sample MAP_3 might be able to withstand heating and shear stress compared to other samples because of its low breakdown value. Shimels, et al. [46] reported that final viscosity is used to indicate the ability of starch to form various paste or gel after cooling and that less stability of starch paste is commonly accompanied with high value of breakdown. The final viscosity is the most commonly used parameters to determine a particular starch based sample quality. It gives an idea of the ability of a material to gel after cooking. The final viscosity ranged from 106.58 - 293.33RVU and the Ogi sample had the highest 293.33 RVU final viscosity. The difference between final viscosity and trough give rise to a pasting property known as setback viscosity. Setback values have been reported to correlate with ability of starches to gel into semi solid pastes. It is the phase of the pasting curve after cooling the starches to 50°C. This stage involves re – association, retrogradation or re – ordering of starch molecules. It has been correlated with the texture of the food products [47]. High setback viscosity is associated with weeping or syneresis. Among the maize diets studied, MAP_3 had the highest retrogradation tendency of 177.67 RVU setback viscosities, followed by MAP_2 124.08 RVU while MAP_1 had the lowest value 122.92 RVU. It is clear from the results that the Ogi sample will cook faster with less energy, thereby saving cost and time compared to other samples because of its lower pasting temperature. The ability of starch to imbibe water and swell is primarily dependent on the pasting temperature. Hence in the presence of water and heat, starch granules swell and form paste by imbibing water [48].

CONCLUSION

This work shows the nutritional status of maize– based staple food which was enhanced by the addition of African yam beans and Pigeon pea Flour. It was observed that the formulated diets, particularly *Maize, African yam beans and P*igeon pea at ratio 70:15:15 blends, had a better result in proximate composition, antioxidant property and mineral content when compared to the local complementary diet (Ogi) and commercially available food i.e. Nutrend. The pasting property of 70:15:15 blends were also the best. Hence, the70:15:15 blends formulation could be used as infant food, particularly for underprivileged children, who cannot have access to qualitative complementary diets.

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