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Original Research Article

Physicochemical, Pasting and Sensory Characteristics of Complementary Foods Formulated from Plantain, Pigeon Pea and Maize Flours

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This study was aimed at producing complementary food of good physicochemical properties from locally available crops. Complementary foods from blends of fermented maize, plantain and pigeon pea flours (MZF, PLF, PPF) were produced and evaluated for their proximate composition, physicochemical, pasting and sensory properties. The different flours were combined in ratios 23.81:48.57:32.62, 38.35:23.52:38.12, and 22.32:28.58:49.10 (protein basis) of MZF, PLF and PPF to obtain 3 diets. The diets were coded as FDI (formulated diet I), FDII (formulated diet II) and FDIII (formulated FDIII) respectively. A commercial infant formula `Nutrend' was used as control diet (CD). Proximate analyses of diets showed that the formulated diets were significantly (P<0.05) higher in protein (17.88-21.04%), moisture (4.97-5.14%) and ash (4.9-5.05) than the control sample (6.28, 4.05 and 2.31 respectively) while the control sample was significantly higher in carbohydrate (63.19%) and crude fibre (.518%). The bulk densities and pH ranged from 0.63-0.72g/ml and 4.15-6.03 for the flour samples and 0.69-0.71g/ml and 5.26-5.32 for the complementary diets. The water absorption capacity (WAC), swelling power (SP) and solubility increased with increasing temperature for all samples with control diet exhibiting the highest WAC and the formulated diets showing higher swelling power and solubility than the control diet at higher temperatures (70-90°C). The formulated diets and the control diets both formed stable gels at 11% (WIV) flour concentration. FDI had the highest peak (243.43RVU), through (191.3RVU) breakdown (52.29RVU) and setback (105.54 VU) viscosities and the values were significantly (P<0.05) different from other formulated and control diets. All the complementary food formulations were significantly (P<0.05) different from the control diet in all the sensory attributes.

Keywords: Complementary foods, Nutrient composition, Organoleptic properties, Protein.

INTRODUCTION

The transition from exclusive breastfeeding to family foods, referred to as complementary feeding, typically covers the period from 6-18 or 24 months of age, and is a very critical stage (WHO, 2003). It is most critical time for promotion of optimal health, growth and psychological development (FAO/WHO, 1991, 1998). This time is also the period when malnutrition starts in many infants, especially in developing countries, contributing significantly to more than six million of ten million annual child deaths (WHO, 2012). Hence complementary foods are foods other than breast milk or infant formula (liquids, semisolids and solids) introduced to an infant to provide nutrients (Kleinman, 2004). Infants at this stage of development require higher energy and proteins in their diet so as to meet the increasing demand of metabolic processes in the body.

In Nigeria, the cereal-based traditional infant foods such as western Nigeria maize preparation "Ogi" do not contain sufficient nutrients, micronutrients and energy density to meet infants' daily requirement (Oyarekua, 2009). For example, babies are weaned on nutritionally deficient diets as they are fed with mainly starch gruel which is cereal, root or tuber-based. These products are deficient in quality proteins (Ihekoronye and Ngoddy, 1985) which result in protein deficiency diseases such as kwashiorkor.

The composition of complementary foods should meet the specific nutritional needs of infants and young children up to 3 years of age, providing the accurate amounts of proteins, carbohydrates, lipids, fibers, minerals and vitamins with limitations for salt, sugars and saturated fat. The main concern in complementary food preparation is making sure that there is

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no gap between nutrient requirements and what a child is able to consume, absorb and utilize.

The problem of these deficiencies in local staples can be solved by adopting various approaches which include broadening the diet to incorporate a wider range of foods such as complementing cereal foods with legumes. Development of high protein infant food has been done by fortifying cereals with legumes (soybeans, cowpeas and melons) (Akpapunam and Sefa-Pedeh, 1995). Fashakin and Ogunsola (1982) formulated "Nug-Ogi" (a mixture of corn gruel and peanut). Adedoyin (2001) formulated cowpea-melon ogi (a mixture of corn gruel with defatted melon and germinated cowpea) and other useful combinations have been adopted by the food processing industries.

In addition, there is need for low cost weaning foods which can be prepared easily in home and community kitchens from locally available raw materials such as maize, pigeon pea (an underutilized legume), plantain, using simple process technology that is within the reach of the general public in developing countries and does not require sophisticated equipment and which can be served quickly and conveniently. Hence, the objective of this study was to produce complementary food by a judicious blending of maize, plantain and pigeon pea flours and to determine the proximate composition, physicochemical and sensory properties of the flours and their blends.

MATERIALS AND METHODS

Materials

Mature but unripe plantain (*Musa spp*) and pigeon pea (C*ajanus cajan*) were purchased from a local market in Ile-Ife while maize (*Zea mays*) was purchased in Ilesa, both in Osun State. All chemicals used were of analytical grade.

Preparation of plantain flour

Mature but unripe plantains were washed with tap water, peeled manually with a stainless steel knife and sliced to an average thickness of 3mm. The sliced plantains were blanched at 70^{o}C for 20 minutes and then oven dried at 70^{o}C for 24 hours. The dried chips were then milled using attrition mill. The flour was then packaged in a polyethylene bag for further use.

Preparation of fermented maize flour

The method described by Essien *et al*. (2010) for the production of fermented maize flour was adopted with slight modification. The maize grains were first sorted to remove extraneous materials such as broken grains, stones, chaffs, plant debris and were subsequently rinsed with water to remove adhering dirts. This was followed with soaking of the grains in tap water (1:5 w/v) for 72hrs for fermentation. At the end of soaking period, the grains were rinsed with tap water, wet milled and sieved to get rid of shaft and then allowed to ferment for 48 hours. The fermented dough was oven dried at 60^{o}C for 24 hours and then milled into flour.

Preparation of pigeon flour

The procedure described by Akoja and Mohammed (2011) for the production of pigeon pea flour was adopted with slight modification. The pigeon pea grains were sorted manually to remove unwanted materials and dirt. Soaked in tap water for 8 hours for easy dehulling. The soaked seeds were manually dehulled and cooked for 15 minutes in boiling water, drained and then oven dried at 60^{o}C for 24 hours and then milled into flour.

Preparation of dietary samples

The diets were formulated as described by Amankwah *et al*. (2009). The diets were formulated in 18, 20 and 22% protein content with each containing 10g of sugar, 5g of vitamin mix and 5g of cod liver oil. They were mixed in Kenwood mixer and mixed for a period of 10 minutes and were labeled formulated diet FDI, FDII, and FDIII respectively. Each diet was packed in a separate polyethylene bag and stored in the refrigerator at 4^{o}C during the experimental period. Table I shows the percentage composition of the formulated diets.

Proximate Composition Analysis

The flours and diet samples were analyzed for moisture, crude fat, crude protein, ash, crude fibre and carbohydrate content (by difference) using standard methods of analysis of the AOAC (2000).

Physicochemical properties determination

The pH

The pH of the samples was measured by making a 10% w/v suspension of the sample in distilled water. The suspension was mixed thoroughly and the pH was measured with a Fisher Acumen pH meter (Model AB 15).

Bulk Density

Bulk density was determined according to the method of Okezie and Bello (1988). A 10ml graduated cylinder, was gently filled with the sample, the bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level after filling to the 10ml mark. Bulk density was calculated as weight of sample per unit volume of sample (g/ml).

Functional Properties Determination

Swelling power and solubility

Swelling power and solubility index were determined on the flour and diet samples at 25 (room temperature), 60, 70, 80 and 90^{o}C. This was determined by the modified method of Leach *et al*. (1959). It was done by weighing 1g of flour into 100ml conical flask, 15ml of distilled water was added and mixed gently at low speed for 5minutes. The slurry was added and mixed at low speed for 5 minutes. The slurry was heated in a thermostarted water bath (THELCO model 83, USA) at 60, 70, 80 and 90^{o}C respectively for 40 minutes. During heating, the slurry was stirred gently to prevent clumping of the starch.

The content was transferred into a pre-weighed centrifuge tube and 7.5ml distilled water was added. The tubes containing the pastes were centrifuged at 2,200 rpm for 20 minutes using SORVALL GLC-1 centrifuge (model 06470, USA). The supernatant was decanted immediately after centrifuging into a pre-weighed can and dried at 100^{o}C to constant weight. The weight of the sediment was taken and recorded.

$$\text{Swelling power} = \frac{\text{Weight of sediment}}{\text{Sample weight–Weight of soluble}} \quad \ldots (1)$$

$$\text{Solubility index (\%)} = \frac{\text{Weight of soluble}}{\text{Weight of sample}} \quad \ldots (2)$$

Water absorption capacity

Water absorption was determined on the flour and diet samples at 25 (room temperature), 60, 70, 80 and 90°C by a modification of the method described by Sathe and Salunkhe (1981). Briefly a 2g sample was weighed into a previously tarred 50ml centrifuge tube and approximately 30ml of distilled water with temperature ranging between 60 and 90°C were added. The mixture was stirred with a stirring rod for 60s and allowed to stand for 10minutes. The suspension was then centrifuged at 4000 rpm for 10 minutes. The suspension was decanted and the tube was allowed to drain at 45°C angle for 10 minutes and then weighed. Water absorption capacity was expressed as percentage increase of the sample weight.

Least gelation concentration

The method of Sathe and Salunkhe (1981) was used to determine the least gelation concentration. Sample suspension of 1, 3, 5, 7, 9, 11, 13, 15, 17 and 19% were prepared in 5ml distilled water and the test tubes were heated in a boiling water bath for 1hour followed by rapid cooling under running tap water. The test tubes were further cooled for 2 hours at 4°C. Least gelling concentration was determined as that concentration when the sample from the inverted tube did not fall down or slip.

Pasting properties determination

Pasting properties were determined with a Rapid Visco (RVA, Model 3C, Newport Scientific PTY Ltd., Sydney, Australia). First flour samples (3.0g) were weighed into a dried empty canister; then 25ml of distilled water was dispensed into the canister containing the sample 3.0 g. The solution was thoroughly mixed and the canister was well fitted into the RVA as recommended. The slurry was heated from 50 to 95°C with a holding time of 2 minutes followed by cooling to 50°C with 2 minutes holding time. The rate of heating and cooling were at a constant rate of 11.25°C per minute. 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, 1995).

Sensory Evaluation

The formulated diets were reconstituted by adding water to the diets to form a slurry then cooked for about 20 minutes. The samples were coded and presented randomly to a 15 – member panelists who were nursing mothers to evaluate the organoleptic attributes of the reconstituted diets and Nutrend (control diet) for colour, taste, flavour, mouth feel and overall acceptability. The assessors were requested to physically examine the samples and score according to their respective degree of likeness using a 7-point hedonic scale with scores from 1 to 7 (1=dislike extremely, 7=like extremely), (Goimero *et al*., 2003). The data obtained were analyzed by analysis of variance (ANOVA) and Duncan's test for the least significant difference ($p \leq 0.05$).

Statistical Analysis

All data were subjected to Analysis of Variance (ANOVA) using SPSS (version 16.00, SPSS Incorporation, Chicago, Illinois, USA) and means were separated using Duncan's Multiple Range Test (DMRT). The level of significance was at 5%.

RESULTS AND DISCUSSION

Proximate Composition

The proximate composition of the flour samples, formulated diets and the control diet are shown in Table 2. Amongst the flour samples, pigeon pea flour (PPF) had the highest protein value of 20.94%; plantain flour (PLF) had the lowest protein value of 3.14% while maize flour (MZF) had a protein content of 11.14%. The protein contents of PLF and MZF were relatively low compared to those reported for pra seed flour (16.01%) and hazelnut flour (14%) and PPF had a higher protein content compared to walnut (6%) but compared favourably with the reported value for almond (21%) by Choonhahirun (2010).

In the formulated diets, the protein content ranged between 17.88% – 21.04%. The protein content of the formulated diets compared favourably with the protein content of soy-ogi (17.6 – 18.6%) reported by Oluwamukomi et al. (2005). The formulated diets had significantly ($p<0.05$) higher protein contents than the control diet (16.28%). However, the flour samples and formulated diets were all significantly different ($p<0.05$) from each other. The protein content of FD II was within the recommended value of 20% (PAG, 1971).

The moisture content of the flour samples ranged from 4.33 – 7.06% with PLF having the highest moisture content and MZF exhibiting the lowest moisture. There was no significant difference ($p>0.05$) between PPF and MZF while PLF exhibited a significant difference ($p>0.05$) from the other flour samples. Soybean and maize flours are reported to have moisture content of 8.4% and 9.9% respectively (Ibanga and Oladele, 2008) which were higher than the moisture content obtained in the study.

The moisture content in the formulated diets and control diet ranged between 4.05 – 5.14% with the control diet having the lowest moisture content of 4.05% and FDIII having the highest moisture content of 5.14%. Low residual moisture content is advantageous in that microbial proliferation is reduced and storage life is enhanced and prolonged (Kuye and Sanni, 1999). There was no significant difference at 5% level between FDI and FDII while FDIII and CD were observed to be significantly different ($p<0.05$) from FDI and FDII. The moisture content of the formulated diet is within the recommended standard (5–10%) of the Protein Advisory Group PAG (1971).

The crude fat content of the plantain flour (PLF) was 5.36% and was the highest while maize flour (MZF) had the lowest (3.22%). The crude fat obtained for maize flour in this study was close to the fat content (4.00%) of maize flour reported by Fasasi *et al*. (2007). No significant difference ($p>0.05$) was observed between PPF and PLF while MZF was observed to be significantly different ($p<0.05$) from the other flour samples. Amongst the diets, FD II had the highest mean value of 9.23% while FDI exhibited the lowest value of 8.70%.

Table 1: Percentage (%) composition of the formulated diets

Samples	MZF	PLF	PPF
FDI	23.81	43.57	32.62
FDII	38.35	23.52	38.12
FDIII	22.32	25.58	49.10

PPF – Pigeon pea flour
MZF – Maize flour
PLF – Plantain flour
FDI – Formulated diet I
FDII – Formulated diet II
FDIII – Formulated diet III

Table 2: Proximate compositions of the flour samples, formulated diets and control diet

Samples	PPF	PLF	MZF	FD I	FD II	FD III	CD
Protein	20.94±0.05[b]	3.14±0.11[g]	11.14±0.08[f]	17.88±0.03[d]	19.10±0.16[c]	21.04±0.08[a]	6.28±0.04[e]
Moisture	4.51±0.3[d]	7.06±0.10[g]	4.33±0.12[c]	4.97±0.01[c]	5.05±0.5[c]	5.14±0.02[b]	4.05±0.07[e]
Fat	5.15±0.03[d]	5.36±0.01[d]	3.22±0.06[e]	8.70±0.11[c]	9.23±0.07[a]	8.99±0.01[bc]	9.00±0.14[ab]
Ash	1.79±0.07[c]	0.36±0.01[d]	1.67±0.85[c]	5.05±0.01[a]	4.92±0.08[a]	4.93±0.04[a]	2.31±0.01[b]
Fibre	2.67±0.08[d]	1.95±0.01[e]	2.48±0.13[d]	4.79±0.11[b]	4.20±0.03[c]	4,23±0.04[c]	5.18±0.11[a]
CHO	64.94±0.10[c]	82.13±0.01[a]	77.16±0.18[b]	58.62±0.20[d]	57.51±0.08[d]	55.42±0.13[e]	63.19±0.37[c]
Energy (kcal)	392.12±0.06[b]	389.32±0.43[b]	382.12±0.97[c]	384.30±0.14[c]	389.51±0.29[b]	386.75±0.29[c]	398.88±0.12[a]

PPF – Pigeon pea flour
MZF – Maize flour
PLF – Plantain flour
FDI – Formulated diet I
FDII – Formulated diet II
FDIII – Formulated diet III

The mean value of all the formulated diets compared favourably with the control diet (9.00%). The crude oil contents of the formulated diets were within the range of values (8.33 – 10.60%) reported for crude fat contents of diets formulated from maize, bambara, soybean and sesame by Okafor *et al.* (2008). Fats play a vital role in maintaining healthy skin and hair, insulating body organs against shock, maintaining body temperature and promoting healthy cell function (Donatelle, 2005). The values obtained were within the recommended value for fat content in complementary foods which should not be more than 10% by PAG (1971).

Ash content represents the total mineral content in foods (Nielson, 2002). It was observed that the ash content of the flour samples ranged from 0.36 – 1.79% with the plantain flour (PLF) exhibiting the lowest mean value of 0.36% and PLF, showing the highest mean value of 1.79%. There was no significant difference at 5% level between PPF and MZF but PLF exhibited a significant difference ($p<0.05$) when compared to the other flour samples. Amongst the diets, the ash content ranged from 2.31 – 5.05%. The formulated diets had higher ash values than the control diets (CD) having the least value of 2.31% while FD I had the highest value of 5.05%.

The ash contents of the formulated diets were observed to be higher than the ash contents (2.01 – 2.80%) of complementary food prepared from maize, bambara nut, soybean and sesame flours reported by Okafor *et al*. (2008) and also higher than ash contents (2.37 – 2.75%) obtained from complementary food processed from maize and soybean flours reported by Oluwamukomi *et al*. (2005) and 2.25 – 2.30% from maize and Nile Tilapia flours reported by Fasasi *et al*. (2007). The ash content can provide an estimate of the quality of the product, since high levels may indicate contamination. There was no significant difference at 5% level amongst the formulated diets. However, the ash content of the formulated diets is within the 5 – 10% value recommended by PAG (1971).

The crude fibre values amongst the flour samples ranged between 1.95 – 2.67%. PLF had the lowest mean value of 1.95% and PPF had the highest mean value of 2.67%. There was no significant difference ($p<0.05$) between PPF and MZF but PLF exhibited a significant difference at 5% level when compared to PPF and MZF. Fibre helps prevent constipation and acid digestion. Amongst the diets, the fibre values ranged between 4.20 – 5.18% with FD II exhibiting the lowest value of 4.20% while CD exhibited the highest value of 5.18%. FD I and FD III had mean values of 4.7% and 4.23% respectively and were not significantly different ($p<0.05$) from each other. These values are higher than the fibre content of Soy-ogi (1.85 – 2.88%) as reported by Oluwamukomi *et al*. (2005).

Carbohydrates are the most important and readily available source of energy, they are also important in the functioning of the brain, heart and nervous, digestive and immune system. The carbohydrate (estimated by difference) content in the flour samples ranged between 64.94 – 82.13%. PLF recorded the highest mean value of 82.13% while PPF recorded the lowest mean value of 64.94%. There was a significant difference ($p<0.05$) amongst the flour samples. Among the diets, CD had the highest carbohydrate content (63.19%) than the formulated diet. FD I, FD II, and FD III were observed to have 58.62%, 57.52% and 55.42% respectively. The carbohydrates contents of the formulated diets were of lower values compared to the carbohydrate content of diet formulated from Nile Tilapia and maize flour (65.91 – 69.83%) by Fasasi *et al*. (2007).

The mean energy value of the flour samples ranged from 392.12 – 389.87 kcal. PPF had the highest value of 389.87 kcal while MZF had the lowest value of 382.12 kcal. Amongst the diets, the energy values ranged from 384.30 – 398.88 kcal with CD having the highest value of 398.88 kcal and FD I exhibited the lowest value of 384.30 kcal. FD II and FD III were observed to have 389.51 and 386.75 kcal respectively. FD I and FD II were not significantly different ($p>0.05$) from each other at 5% level.

Physicochemical Properties

The result of bulk density, pH, water absorption capacity (WAC) swelling power and solubility (at room temperature) are shown in Table III.

Bulk density

In flour samples, maize flour (MZF) recorded the highest bulk density (0.72 g/ml) and it is significantly different ($p<0.05$) from the other flour samples (PPF and PLF) which had bulk densities 0.63g/ml and 0.63g/ml respectively. These values were high compared to 0.47g/ml and 0.38g/ml reported for maize and soybean flours by Edema et al (2005). Bulk density is important in determining packaging requirement, material handling and application in wet processing in the Food industries (Karuna *et al*., 1996). It is a function of particle size and particle size is inversely proportional to bulk density (Perez, 1997). Amongst the formulated diets, FD II recorded the highest bulk density (0.71 g/ml) while FD I and FD III have the same bulk density (0.69 g/ml) and are not significantly different ($p>0.05$) from each other.

The CD recorded the lowest density (0.55 g/ml) when compared to the flour sample and formulated diet; this demonstrates a reduced compactness of the particles. The values of the formulated diet compared favourably with the values (0.58 – 0.77 g/ml) obtained by Adebowale *et al*. (2008). The advantage of low bulk density of this complementary diet (FD I, II and III) is that the gruel or porridge made from this diet will have a lower dietary bulk (Omueti *et al*., 2009). This is important in complementary foods because high bulk limits the caloric and nutrient intake per child and infant are sometimes unable to consume enough to satisfy their energy and nutrient requirements (Nnam, 2000).

pH

The pH of flour suspension is important since some functional properties such as solubility, emulsifying activity and foaming are affected by pH (Adepeju *et al*., 2011). Amongst the flour samples, the pH ranged from 4.15 – 6.03. MZF, PPF and PLF had pH values of 6.03, 5.56 and 4.15 respectively. There was a significant difference ($p<0.05$) amongst the flour samples. The pH values of the formulated diets are acidic ranging from 5.26 – 5.32 with FDI having the highest pH of 5.32.

Acidic conditions are known to be used in food preservation (Leistner, 1995). It was also reported by Adebowale *et al*. (2008) that low pH also limits the microbial growth of food. The control diet (CD) recorded a pH of 6.02 which was also acidic. The pH of the flour samples were also acidic ranging from 4.15 – 6.03 with MZF having the highest pH.

Water absorption capacity

Amongst the flour samples, at room temperature, pigeon pea flour (PPF) exhibited the highest water absorption capacity (258%) while maize (MZF) flour recorded the least capacity to absorb water (103%). The water absorption capacity of plantain flour (PLF), though slightly higher than that of maize flour (MZF) was however not significantly different ($p<0.05$) from it. The water absorption capacity of pigeon pea flour was higher than that of Pra seed flour (187.5%) and comparatively lower than 512% recorded for full-fat cassia fistula seed flour by Choonhahirun (2010) and Akinyede and Amao (2009) respectively.

The water absorption capacity of food materials is an index of the maximum amount of water that it can take up and retain (Levin *et al*., 1993; Pinstrup-Anderson *et al*., 1995; Milward and Jackson, 2004). The high water absorption capacity recorded by pigeon pea (PPF) flour may be explained by the content of hydrophilic constituents such as proteins which was higher in pigeon pea than in maize and plantain.

Amongst the diets, the control diet (CD) demonstrated significantly high water absorption capacity absorbing 324% water. The formulated diets did not exhibit much significant difference ($p<0.05$). The high water absorption capacity of CD may be attributed to their protein content; this is because proteins are hydrophilic in nature and will make the diet to absorb more water (Badries and Mellowes, 1992 and Oyegbayo *et al*., 2000) than the formulated diets which were purely formulated from vegetable proteins. The significance of a lower water absorption capacity of the formulated diets compared to CD is that it has a lower water absorption capacity which is desirable for making thinner gruels with high caloric density per unit volume (Omueti *et al*., 2009).

Swelling power and solubility index

Table 3 shows the swelling capacity and solubility index of the flour samples, formulated diets and control diet. Swelling capacity is an important parameter used in determining the amount of water the diet will absorb and the degree of swelling within a given temperature. Swelling power could also be used to demonstrate differences among various types of starches and to examine the effect off starch modification (Crosbie, 1991).

According to Kinsella (1976), swelling causes changes in hydrodynamic properties of the food thus impacting characteristics such as body, thickening and increase in viscosity to foods. This implies that amongst the formulated diets FD I with the highest swelling power will produce a thick viscous gruel compared to FD II and FD III and the CD. Swelling power is an indication of water absorption index of the granules during heating (Loos *et al*., 1981).

Swelling power which is a starch property is related to binding within the starch granule and apparently the strength and character of the micellar network is related to amylose content of the starch (Calzetta *et al*., 2000) as low amylose content produces high swelling power (Wootton and Tumaali, 1984). The variation in swelling power indicates the degree of exposure of the internal structure of the starch present in the flour to the action of water (Raules *et al*., 1993).

Solubility is an index of protein functionality such as denaturation and its potential application, the higher the solubility, the higher the functionalities of the protein in a food (Omueti *et al*., 2009).

Least gelation concentration

Table 4 shows the least gelation concentration (LGC) of the diets. Least gelation concentration is a measure of the minimum amount of flour/blends of flour that is needed to form a gel in a measured volume of water (Adebowale *et al*., 2005). It is an index of water absorption capacity and it is important to complementary foods (Chukwu *et al*., 2000).

The LGC indicates that all diets did not form gel at 1% (w/v) and all diet samples were slightly gelled at 3 – 9% (w/v). All the diets formed a stable gel at 11% (w/v) which is within the same range (9 – 12% w/v) that cooking banana based weaning food samples formed stable gels (Chukwu *et al*., 2000).

Table 3: The physicochemical and functional properties of the flour samples and the diets

Diet	Bulk density (g/ml)	pH	WAC	Swelling power	Solubility index
MZF	0.72±0.01[a]	6.03±0.01[a]	103.00±2.82[e]	2.07±0.01[g]	0.70±0.01[g]
PPF	0.69±001[b]	5.56±0.02[b]	258.50±4.95[b]	4.35±0.00[a]	6.06±0.00[a]
PLF	0.63±0.00[c]	4.15±0.01[e]	109.32±1.41[e]	2.81±0.00[f]	3.88±0.01[e]
FD I	0.69±0.01[a]	5.32±0.01[c]	135.82±0.71[d]	3.01±0.00[e]	4.94±0.01[d]
FD II	0.71±0.01[a]	5.26±0.02[d]	144.41±0.71[c]	3.12±0.00[c]	5.11±0.01[c]
FD III	0.69±0.01[b]	5.29±0.01[cd]	137.23±2.83[cd]	3.07±0.02[d]	5.24±0.01[b]
CD	0.55±0.00[d]	6.02±0.06[a]	324.18±4.95[a]	3.33±0.11[b]	3.75±0.04[f]

Values with the same superscript in a column are not significantly different ($p<0.05$)

WAC – Water absorption capacity
CD – Control diet
PPF – Pigeon pea flour FD I – Formulated diet I
MZF – Maize flour FD II – Formulated diet II
PLF – Plantain flour FD III – Formulated diet III

Table 4: The least gelation concentration (%) of the diets

Samples	1	3	5	7	9	11	13	15	17	19
FD I	–	±	±	±	±	+	+	+	+	+
FD II	–	±	±	±	±	+	+	+	+	+
FD III	–	±	±	±	±	+	+	+	+	+
CD	–	±	±	±	±	+	+	+	+	+

– – No gel CD – Control diet
± – Slightly gel FD I – Formulated diet I
\+ – Gelled FD II – Formulated diet II
FD IIII – Formulated diet IIII

The LGC of heat processed jackfruit flour was 18% (w/v) as reported by Odoemelam (2005) and was higher than the range of values obtained in this study.

The formation of stable gels by the formulated diets at higher concentration implies that the diets have poor gelating ability, hence will not form a thick gel (low dietary bulk) at lower concentration which is a desirable functional property for a complementary diet. High gelation value implies that the diet would require more energy consumption to cook and hence the gel strength of the diets would be weak and desirable (Enujiugha, 2006).

Variations in the gelling properties of different flours may be due to variations in the ratio of the different constituents such as carbohydrate, lipids and protein that make up the flour (Abbey and Ibeh, 1998).

Pasting properties

Table V shows that the peak viscosity, trough, breakdown, final viscosity, setback and peak time values were higher in the formulated diets than the control diet. FD I has the highest peak viscosity (243.42 RVU), trough (191.13 RVU), breakdown (52.29 RVU), final viscosity (296.67 RVU), Setback (105.54 RVU) and pasting temperature (61.45^{o}C) and differs significantly ($p<0.05$) from other diets except in the pasting temperature.

Pasting properties are important indices in determining cooking qualities of flours (PBIP, 1995). Pasting is the result of a combination of processes that follows gelatinization from granule rupture to subsequent polymer alignment due to mechanical shear during the heating and cooling of starches. Starch when heated increases in viscosity as a result of the swelling of the starch granules and in their difficulty in moving past one another (Adeniji *et al*., 2010).

Peak viscosity is the ability of the starch to swell freely before their breakdown and it is an indicator of the strength of the paste formed during processing. It was observed that all the formulated diets had higher peak viscosity than the control diet. The lower peak viscosity value in the CD suggests the presence and interaction of components, such as fats and proteins, with starch which lowers its peak viscosity (Svanberg, 1987; Egounlety and Aworh, 1991).

Low peak viscosity of a diet implies that the weaning diet will form a low viscous paste rather than a thick gel on cooking and cooling (Otegbayo *et al*., 2006). This means that the gruel will be a high caloric density per food unit volume (Desikachar, 1980) rather than a dietary bulk (high volume/high viscosity) (Ikujenlola and Fashakin, 2005). The trough measures the ability of the paste to withstand breakthrough during heating (Adebowale *et al*., 2008). It is the minimum viscosity value in the cooking temperature phase of the RVA profile and ranges between 4.59 RVU and 191.13 RVU with the formulated diets having higher values.

The breakdown is the difference between the peak viscosity and trough viscosity. Breakdown values were also observed to have higher values in the formulated diets than the control diet. Breakdown values of FD II and CD did not exhibit any significant difference ($p>0.05$) from each other while FD III and CD are not also significantly different ($p>0.05$) from each other. The breakdown viscosity value is an index of stability of starch (Fernandez and Berry, 1989). The higher the breakdown, the lower the ability of the starch to withstand heat and shear stress during cooking (Adebowale *et al*., 2005). This implies that the formulated diets are more stable to heat and mechanical shear (Oladele and Aina, 2007) compared to the CD. The final viscosity ranged from 10.05 RVU to 296.67 RVU with the formulated diets having their values compared to the CD and the diets are all significantly different ($p<0.05$) from each other.

Table 5: The pasting properties of the diets

Samples	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Setback (RVU)	Peak time (minutes)	Pasting temperature (^{o}C)
FD I	243.43^{a}	191.13^{a}	52.29^{a}	296.67^{a}	105.54^{a}	5.28^{b}	61.45^{a}
FD II	98.21^{c}	90.05^{c}	8.17^{c}	145.59^{c}	55.54^{b}	4.97^{c}	61.55^{a}
FD III	128.29^{b}	118.09^{b}	10.21^{b}	173.00^{b}	54.92^{b}	6.51^{a}	61.83^{a}
CD	14.04^{d}	4.59^{d}	9.46^{b}	10.05^{d}	5.46^{c}	3.88^{d}	61.68a

Means in a column with the same letter are not significantly different (p<0.05)

CD – Control diet
FD I – Formulated diet I
FD II – Formulated diet II
FD IIII – Formulated diet IIII

Table 6: The sensory properties/acceptability of the diets

Samples	FD I	FD II	FD III	CD
Colour	4.86^{b}	4.94^{b}	5.00^{b}	6.60^{a}
Tastes	4.71^{b}	4.81^{b}	4.60^{b}	6.40^{a}
Flavour	4.50^{b}	4.56^{b}	4.67^{b}	6.67^{a}
Mouth-feel	5.00^{b}	5.13^{b}	5.00^{b}	6.53^{a}
Overall acceptability	5.00^{b}	5.00^{b}	5.00^{b}	6.67^{a}

Means in a row with the same letter are not significantly different (p<0.05)

CD – Control diet
FD I – Formulated diet I
FD II – Formulated diet II
FD IIII – Formulated diet IIII

Final viscosity indicates the ability of the material to form a viscous paste or gel after cooking and cooling as well as the resistance of the paste to shear force during stirring (Adeyemi and Idowu, 1990).

The setback values are all significantly different (p<0.05) from each other except FD II and FD III and the values are higher for all the formulated diets compared to the CD. Anonymous (2003) also reported that low setback is an indication that the starch has a low tendency to retrograde or undergo syneresis during freeze-thaw cycles. The peak time is a measure of the cooking time. The result shows that the value of the peak time ranged between 3.88 minutes (CD) and 6.51 minutes (FD II) and they all exhibited significant difference (p>0.05) from each other.

The pasting temperature is an indication of the minimum temperature required to cook the sample (Kim *et al*., 1995). From the result, the pasting temperature of the formulated diets and the control diet were of the same range (61.45^{o}C to 61.68^{o}C) which indicates that all he diets have low gelatinization temperatures and hence a shorter cooking time (Kim *et al*., 1995) and they are not significantly different (p>0.05) from each other. CD has the lowest values in peak viscosity, trough, final viscosity and setback and peak time.

Sensory properties

Table 6 shows the results of sensory analysis of the reconstituted formulated complementary foods with respect to colour, taste, flavour, mouth-feel and overall acceptability using a 7 point hedonic scale. The sensory properties of the formulated and commercial products (CD) indicate that all the complementary food formulations were significantly different (p<0.05) from the CD in all the sensory attributes. Mean score ranges of attributes evaluated were colour (4.86 – 6.60), taste (4.60 – 6.40), flavour (4.50 – 6.67), mouth feel (5.00 – 6.53) and overall acceptability (5.00 – 6.67).

Colour has a prominent effect on sensory scores of complementary foods (Chukwu *et al*., 2000). The colour of the formulated diets were not different (p>0.05) from each other while the colour of the CD was significantly different (p<0.05) from the formulated diets. The major complaint of the mothers was the light brown colour of the formulated diet after reconstitution which was quite glaring when compared to the CD which had a milky colour. This was so because mothers are accustomed to the milky colour of the commercial complementary foods and so it was not strange that they were hesitant to score high a product with a different colour (Chukwu *et al*., 2000).

The product might be appealing and having high energy density but without good taste, such a product is likely to be unacceptable. Sample FD III received the lowest mean score while the CD received the highest score. The formulated diets were not significantly different (p>0.05) from the CD. The inclusion of legume flour with a characteristic beany flavour may have informed the panelists' decision to return lower scores for the formulated diets. The favourable taste of the formulated diets was probably enhanced by the addition of sugar.

The flavour of the formulated diets were not significantly different (p>0.05) from each other while the flavour of the CD was significantly different (p<0.05) from the formulated diets. This may be due to the similar flour composition of the formulated diets and additional flavourant added to the CD (Nzeagwu and Nwaejike, 2005). The disparity between flavour of the control and formulated diets may be attributed to the characteristic beany aroma of the legume (Ijarotimi and Famurewa, 2003).

The sensory scores of mouth-feel revealed that no significant differences (p>0.05) were observed in mouth-feel by all panelists between the formulated diets but there was a significant difference (p<0.05) between the formulated diets and the CD. The mean score for the mouth-feel was above average indicating that from this test parameter, the formulated diets were liked moderately by the panelists. The low mouth-feel (compared to the CD) might be presumably due to the processing method of the commercial brand that involved drum drying with improved the mouth-feel (texture) and also taste of the product (Okafor *et al*., 2008).

The lower ratings of the formulated diets samples in terms of colour, taste, flavour, mouth-feel and overall acceptability compared with the CD could also be attributed to the familiarity of the panel of judges to the taste, flavour, and colour of the CD and also because the CD was industrially prepared with additional sweeteners and flavourings.

CONCLUSION

This investigation has revealed that the inclusion of protein from sources like pigeon pea combined with maize and plantain produced complementary food with high proximate composition values with acceptable organoleptic characteristics. The nutrient composition of the mixtures provided adequate protein, fat, ash, fibre, and energy content. The preparation of the complementary foods is simple; the foods are physically and economically accessible and can be easily prepared in the home and community kitchens.

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