

Optimization of cereal-legume blend ratio to enhance the nutritional quality and functional property of complementary food

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ABSTRACT

This study investigated the effect of different cereal-legume blending ratios on nutritional quality and functional property of different blends. The legumes and steeped cereals were cleaned, minimally roasted, dehulled, milled and sifted separately. A single-factor experiment with three levels of the factor (cereal: legume ratio 85:15, 75:25 and 65:35 coded as B1, B2 and B3, respectively) with two replications were used to conduct the experiment. The collected data were subjected to analysis of variance using SPSS statistical software and compared with the recommended values for the age group of 6-24 months. Mean separation result showed that protein, fat, energy, crude fibre and ash contents were significantly ($p < 0.05$) different among the blends where B3 revealed higher values. Protein contents of B2 and B3, ash and fiber content of the three blends, as well as energy value of B3 were within the recommended levels. However, none of the blends met the recommended fat content. Calcium, zinc and iron content of the blends increase as the proportion of legumes increase, but only the iron value was within the recommended level. The molar ratio of phytate and the three minerals were within the recommended value for better absorption. Water solubility index increased as the proportion of legume increased from 15% to 25% then decreased as legume increased to 35%. B1 revealed significantly higher viscosity values (248.43 ± 3.35 cP) and viscosity decrease as the proportion of legume increased. Based on 10 nutritional and functional criteria, B3 possess the most desirable among the studied blends.

Key words: Cereal-legume blend, proximate composition, anti-nutrient, phytate/mineral molar ratio

DOI: <http://dx.doi.org/10.4314/ejst.v10i2.3>

INTRODUCTION

Malnutrition is a disparity between the amount of food and other nutrients that the body needs and the amount that it is receiving. In the developing world two-third of child mortality and morbidity is attributable to malnutrition. The prevalence of child malnutrition is extremely high in Ethiopia (38% stunted, 24% underweight and 10% wasted) (EDHS, 2016). Critically important period of tackling malnutrition is the period of complementary feeding when foods of low nutrient

density begin to replace breast milk and rates of diarrheal illness caused by food contamination are at their highest (Brown *et al.*, 1998; World Bank, 2005). Children aged 6-24 months are at the highest risk of malnutrition mainly due to sub-optimal complementary feeding practice. As a result, they fail to attain their full potential of growth and development, suffer long-term deprivation of energy, nutrients, and consequently chronic protein energy malnutrition (PEM), often accompanied by micronutrient deficiencies. The period 6–24 months of age is one of the

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most critical periods in the growth of the infant. At this age, their demand for nutrients relative to their body size is high. However, there are limitations in the quality and quantity of available complementary foods (World Bank, 2005).

Nutritionally balanced complementary feeding is an essential element in taking care of young children. However, due to high price of commercially available complementary foods families in Ethiopia habitually prepares complementary food from locally available raw materials. Traditional complementary foods in the developing countries are known to be of low nutritive value and are characterized by low protein, low energy density and high bulk, mainly because they are cereal-based (Dooshima *et al.*, 2015). Complementary foods, especially prepared for the infant, should be blended with cereal and legume in order to get high energy, protein and micro-nutrient. However, in Ethiopia more than two third (69.0%) of the complementary food is made up of wheat or *teff* and preparation of complementary foods made from mixed legumes and cereals is rare (AAU, 2010). Gibson *et al.* (2010) reported that such cereal-based complementary diets are characterized by poor micronutrient bioavailability notably of iron, zinc, and calcium as well as poor content and digestibility of protein. As a result of monotonous nature and poor texture of the complementary food during preparation as well as high content of anti-nutrient in commonly used cereals, the energy density and micronutrient content of complementary food used in Ethiopia is insufficient to cover the nutritional needs for child.

Appropriate consistency/texture of complementary foods is an important aspect of optimal infant and young children feeding. Given the low gastric capacity of children and the inability of the child to

digest viscous foods, complementary food at early period of supplementary feeding is supposed to be semi-solid (Brown *et al.*, 1998). However, the consistency of complementary food in Ethiopia is poor mainly because its preparation does not use technologic treatment. Specifically, 42.7% of all foods were identified as solid while 37.8%, 17.5% and 2.0% were described as having “thick like porridge”, “thin like gruel” and “thinner than gruel”, respectively (AAU, 2010).

FAO/WHO/UNICEF (1971) emphasised the use of local foods formulated at home guided by the following principles: (i) High nutritional value to supplement breastfeeding, (ii) Acceptability, (iii) Low price, and (iv) Use of local food materials (Dewey and Brown, 2003; Peltó *et al.*, 2003). Moreover, for effective use and acceptance of complementary foods by consumers, it is desirable to study the impact of the process and blends on functional property of the products (Brou *et al.*, 2013).

Therefore, this research was conducted to investigate the effect of different cereal-legume blending ratios on nutritional quality (proximate, mineral, anti-nutritional factors and phytate/mineral molar ratio as a proxy indicator of mineral bioavailability) and functional property of the different blends, to choose the best blend based on selected nutritional profiles.

MATERIALS AND METHODS

Sample Preparation and Experimental Design

The cereal (maize, wheat and barley) and legume (chick peas, soybean and lentil) were cleaned manually and washed in 5% (w/v) sodium chloride (NaCl). The cereal was steeped in potable water

at room temperature in grains to water ratio of 1:3 (w/v) in a plastic container by changing the water in every 3 hours for a total period of 9 hours. After which the cereal was drained. The cereal and legume were cleaned, minimally roasted (until it develops a golden colour), dehulled, milled and sifted through a fine mesh separately.

A single-factor experiment with three levels of the factor (cereal: legume ratio 85:15, 75:25 and 65:35 coded as B1, B2 and B3 respectively) selected from the most commonly used cereal: legume ratios used by different projects was used to prepare complementary foods. The experiment was completely randomized with two replications. The study was conducted at food research laboratory of Bahir Dar Institute of Technology, Ethiopia.

Analysis and Measurement

Proximate, mineral, anti-nutritional factor composition analysis and phytate/mineral molar ratio determination

Proximate composition (namely; moisture content, crude fat, fibre and ash content, crude protein content) analysis was determine in duplicate by using standard procedures of Association of Official Analytical Chemists (AOAC, 2005) and total carbohydrate was calculated by difference i.e. Total carbohydrates [%] =100- [%Moisture + % Protein+ % Fat + % Ash]. Gross energy was determined by calculation from fat, carbohydrate and protein contents using the Atwater's conversion factor with the following equation: (9 * % fat) + (4*% protein) + (4*% carbohydrate) and expressed in kilocalories (kcal) (Atwater and Benedict, 1902).

Calcium, iron, and zinc content were determined in duplicate using an Atomic Absorption

Spectrophotometer. After removal of organic materials by dry ashing, the residue was dissolved in dilute sulphuric acid. The solution was sprayed into the flame of Atomic Absorption Spectrophotometer (ICP-Spectroscopy: "ULTIMA-2") and the absorption of the metal to be analyzed was measured at a specific wavelength.

$$\text{Mineral content } \left(\frac{\text{mg}}{100\text{g}} \right) = \frac{[(a-b)+v]}{10W}$$

Where: W = weight (g) of samples; V= volume (V) of extract; a = concentration ($\mu\text{g/ml}$) of sample solution; b = Concentration ($\mu\text{g/ml}$) of blank solution.

Phytic acid content was determined as described by Wheeler and Ferrel (1971). Briefly, the sample (0.2 g) was extracted four times for 40 min with 3% Trichloroacetic acid (TCA) and then centrifuged for 30 min at 5000 rpm. Aliquot (10 mL) of the supernatant was precipitated with 4 mL FeCl_3 solution containing 0.2% FeCl_3 in 3% TCA. The solution was heated for 45 min in a water bath (Aston VII) at 100°C and centrifuged at 5000 rpm for 15 min. The $\text{Fe}(\text{OH})_3$ obtained was dissolved in 40 mL of hot 3.2 N HNO_3 and the Iron determined calorimetrically (Jenway Ltd Felsted, Dunmow, Essex CM6 3LB model 6051). The absorbance of the solution was read in a spectrophotometer (Jenway Ltd Felsted, Dunmow, Essex CM6 3LB model 6300) at 480 nm against a reagent blank for each set of sample. The iron content was calculated from a standard curve. Phytate phosphorus was calculated from determination assuming 4:6 Iron: Phosphorus molecular ratio. Phytic acid content was determined by multiplying the phytate phosphorus content by a constant factor of 3.55 based on the empirical formula $\text{C}_6\text{P}_6\text{O}_{24}\text{H}_{18}$.

For the determination of tannin content, 0.2g of the milled sample was weighed into a flask and 10ml of 4% methanol was pipetted and the flask was closed with paraffin. The sample was shake for 20 minutes on a wrist action Shaker, centrifuged for 10 minute (4500 revolution per minutes). Absorbance of the standard solution, sample extract and sample blank were taken 20 minutes after incubation in the spectrophotometer at 500nm.

$$\%Tannin = \frac{AU * Cstd}{Astd}$$

Where: AU= Absorbance of unknown; Cstd = Concentration of Standard and AStd = Concentration of Standard.

Among the techniques used to determine the bioavailability of minerals in the human body, measuring the molar ratio of phytate and minerals in the food is suggested by Morris and Ellis (1989). The suggested desirable molar ratios for mineral absorption are phytate:iron < 1 (Hallberg *et al.*, 1989), phytate:zinc < 15 (Turnlund *et al.*, 1984; Sandberg *et al.*, 1987; Morris and Ellis, 1989); phytate:calcium < 0.24 (Morris and Ellis, 1985). The mole of phytate and minerals was determined by dividing the weight of phytate and minerals with its atomic weight (phytate: 660g/mol; Fe: 56g/mol; Zn: 65g/ mol; Ca: 40 g/mol). The molar ratio between phytate and mineral was obtained after dividing the mole of phytate with the mole of minerals.

Functional properties

Water absorption index (WAI) of the sample flour was determined in duplicate as per the method of Anderson (1969). Sample of 1.25g was placed in 40 ml centrifuge tube and suspended in 15ml distilled water. The sample was incubated by using

a shaker water bath (DKZ-1) at about 25°C for 30 minutes and was centrifuged at 3000rpm for 5 minutes. Mass of the sample was determined before and after the decantation of the clear supernatant of centrifugation (L-530 tabletop). The WAI was calculated as grams of absorbed water per gram of dry sample mass (1.25g). The clear supernatant of the centrifugation was transferred into pre-dried (105°C) and weighed glass baker (about 50ml) for the estimation of the water solubility index (WSI).

The supernatant preserved from WAI measurement was evaporated at 105°C overnight. The WSI was calculated as a ratio of dry residue to the original mass (1.25g) used to estimate WAI and the result was expressed as percentage.

The viscosity of cooked paste was determined with a VISCO STAR PLUS H model. A 10% slurry (dry matter basis) of each flour was prepared with 200 ml distilled water and the slurry was heated uniformly from 25°C to 95°C and held for 15 min and cooled to 50°C. Then viscosity was determined after cooling to 50°C (Mbata *et al.*, 2009).

Data handling and statistical analysis

Summary statistics (mean and standard deviation) was computed for dependent variables. In order to find differences between blends, the proximate composition, mineral content, anti-nutritional composition, functional properties (WAI, WSI and Viscosity) were determined and Phytate/Mineral molar ratio were calculate in duplicate per sample (Four times per treatment) and submitted to General Linear Model (GLM) procedure using SPSS 20.0 statistical software package. ANOVA was used for comparison of means. Significance

was accepted at 0.05 level of probability ($p < 0.05$). Mean separation was performed by least significant difference (LSD) for multiple comparisons of means.

Additionally, a ranking system using ten nutritional and functional criteria's related with appropriate complementary food characteristics and major forms of malnutrition (namely, protein energy malnutrition and micronutrient deficiency) was devised to determine the optimal blend combination according to the modified method of Griffith *et al.* (1998) (Table 4). Based on the relative importance and interrelationship of those criteria, ranking was reported on an equal weight basis. The three blends were ranked from 1 (best) to 3 (worst) to objectively determine the best complementary blend. The blend yielding the lowest score was considered to possess the most suitable nutritional and functional characteristics.

RESULTS AND DISCUSSION

Effect of different Cereal: Legume Blending Ratio on Proximate Composition of Complementary Food

Mean and standard deviation (SD) of the proximate composition measurements of the complementary food products at different blending ratio and recommended proximate composition values as per FAO/WHO (1991) are given in Table 1.

The three blending ratios didn't show significant difference with respect to moisture content. The moisture content of the formulated complementary food samples was 6.51 ± 0.08 (B₁), 6.54 ± 0.06 (B₂) and the highest value 6.58 ± 0.08 (B₃) was observed as the proportion of legume increase. In all blending ratios, the value was higher than the recommended value of Codex Alimentarius ($\leq 5\%$) but within the recommended moisture content range (5-10) recommended by Protein Advisory

Table 1: Effect of blending ratio on proximate compositions of formulated product

Proximate compositions	Samples (mean \pm SD)			*Recommended values (g/100gm)
	B ₁	B ₂	B ₃	
Moisture content (%)	6.51 ± 0.08^a	6.54 ± 0.06^a	6.58 ± 0.08^a	≤ 5
Ash content (%)	2.04 ± 0.03^a	2.18 ± 0.02^b	2.27 ± 0.04^c	≤ 3
Crude Protein (%)	14.64 ± 0.02^a	15.73 ± 0.03^b	16.50 ± 0.02^c	≥ 15
Crude fat (%)	5.80 ± 0.06^a	6.16 ± 0.11^b	8.22 ± 0.07^c	10-25
Crude fiber (%)	2.01 ± 0.02^a	2.24 ± 0.03^b	2.61 ± 0.01^c	≤ 5
Carbohydrate (%)	71.00 ± 0.08^a	69.39 ± 0.08^b	66.43 ± 0.15^c	64 ± 4
Energy (kcal/100g)	394.77 ± 0.48^a	395.94 ± 0.27^b	405.76 ± 0.12^c	400-425

Means followed by different superscripts within a row show statistically significant ($p < 0.05$) differences.

*FAO/WHO (1991) (CODEX CAC/GL 08. 1991): Codex Alimentarius: Guidelines on formulated supplementary foods for older infants and young children.

Group (PAG, 2002) and Standard Organization of Nigeria (SON, 1989). In the present study, the moisture content of the blends was similar to the finding of Mohamed and Huiming (2007). Scientific studies reported on the importance of low moisture content in complementary foods, especially to increase the nutrient composition (Amankwah *et al.*, 2009) and shelf life of the product (Kikafunda, 2006). It is evident that the low moisture content of food products inhibits biochemical activities of invading microorganisms, and thereby prevents food spoilage during storage (Kikafunda, 2006).

Mean separation result showed that there was a significant difference in protein content among all blends where B3 (16.50 ± 0.02) revealed significantly ($p < 0.05$) higher content as compared to B2 (15.73 ± 0.03) and B1 (14.64 ± 0.02). This observation could be attributed to the fact that protein content of cereal-legume combination or blending of two or more plant-based food materials is better than those produced from a single plant based food materials (Achi, 2005; Solomon 2005; Wakil and Onilude, 2009). Protein contents of formulated complementary food with 25% and 35 % legume were within the recommended level of FAO/WHO (1991). Whereas complementary food formulated with 15% legume didn't meet the protein requirement of formulated complementary foods for older infants and young children. However, WHO (2009) suggested that while protein is needed for growth, high protein levels above 15% may increase renal solute load and interfere with appetite.

Ash content represents the total mineral content in foods. All blends varied significantly ($P < 0.05$) in ash content resulting from differences in amount among individual ingredients. Ash

content was significantly higher in B3 (2.27 ± 0.04) than B2 (2.18 ± 0.02) and B1 (2.27 ± 0.04) and the values were within the reference value for all the blends. This high concentration of ash in B3 could be linked to the addition of legumes during formulation. Gibson *et al.* (1998) also demonstrated that legumes are rich in minerals. Therefore, supplementing cereals with these foods could lead to higher mineral content.

The crude fibre content of the three blends also showed significant difference where the highest value was observed in B3 (2.61 ± 0.01). The crude fibre content of infant food is supposed to be low (Amuna, 2000; Olorunfemi *et al.*, 2006), as food with high fibre content tends to cause difficulties in digestion of protein and mineral absorption. The observed low fibre content of the three blends were within the recommended values of FAO/WHO (1991) which enable the children to consume most of the food samples so as to meet their daily energy and other vital nutrient requirements (Eka and Edijala, 1972).

The difference in fat content among the three blends were significant ($P < 0.05$). And the highest value was observed for B3 (5.80 ± 0.06) with high proportion of legume (35%) than B2 (25%) and B1 (15%). However, the fat content in all the three blends do not meet the recommended value 10 – 25 % of FAO/WHO (1991). Comparatively higher fat content of formulated samples was reported by Lalude and Fashakin (2006) for sorghum and oil seeds blend (9.87%) and by Amankwah *et al.* (2009) for fermented maize, rice, soybean and fishmeal blend (8.75–9.38%). This finding signifies the importance of including legumes and oil seeds which are rich in fat content to meet the fat requirement of infants and young children living in resource-poor households in low income countries

where consumption of animal-source foods is often low due to economic or religious reasons.

The carbohydrate content of the three blends showed significant ($P < 0.05$) difference where the highest value was observed in B1 (71.00 ± 0.08) but it decreased with an increase in legume ratio. However, all the blends met the recommended value ($64 \pm 4\%$) by FAO/WHO (1991).

The energy in an infant's diet is provided by protein, fat and carbohydrates (Amankwah *et al.*, 2009). There was significant ($P < 0.05$) difference in the energy content of the three blends where the highest ($405.75 \pm 0.13 \text{ kcal/100gm}$) was measured in B3. This could be probably due to the relatively high fat and protein content of the legumes blended in greater proportion (35%). Among the blends only B3 met the recommended value of 400-425 kcal by FAO/WHO (1991). Brown *et al.* (1998) recommended that foods fed to infants and children should be energy-dense as low-energy foods tend to limit total energy intake and the utilization of other nutrients.

Effect of different cereal: legume blending ratio on mineral content, anti-nutritional factors and phytate: minerals molar ratio of complementary foods

Table 2 summarizes data on the iron, zinc, calcium, tannin and phytate concentrations of the three complementary food blends. Corresponding phytate/mineral molar ratios are also given.

All blends significantly ($p < 0.05$) varied in Ca^{+2} , Fe^{+3} and Zn^{+} content. Calcium and zinc content of the blends increased as the proportion of legumes in the blend increases. The finding also showed that the calcium and zinc content of the three

blends didn't meet the recommended value by FAO/WHO (1991) for infant formulas. In contrast, iron content of the blend decreased in response to an increase in the proportion of legume and the iron content of the three blends was within the recommended value (16 mg/100g) of FAO/WHO (1991). Gibson *et al.* (2010) also reported these same mineral deficits earlier for infants and young children consuming the indigenous complementary foods. Such deficits in iron, zinc, and calcium can have far-reaching adverse consequences on growth, health, and cognitive development during childhood. The present study demonstrated the importance of fortification of cereal: legume based complementary foods with calcium and zinc or enriching the diet with animal source ingredients during preparation of the food to ensure it meet the FAO/WHO (1991) estimated needs for zinc and calcium for infants and young children.

Anti-nutrient composition result showed that phytate and tannin concentration of the three blends didn't show significant difference ($p > 0.05$). Poor mineral content of plant-based complementary diets exacerbated in part by poor bioavailability, especially when the complementary foods are based on unrefined cereals and legumes which have a high content of phytate, a potent inhibitor of mineral absorption (Gibson *et al.*, 2006). As a result, interpreting the level of phytate as phytate/mineral molar ratio (proxy indicator of bioavailability) is suggested by most studies.

As indicated in Table 2 the three blends had phytate/zinc molar of 6.8 (B1), 6.3 (B2) and 5.8 (B3). Considering phytate/zinc molar ratio < 15 as desirable limit for absorption, phytate:zinc molar ratios of all the blends were low thus met the desired level. The contribution of the low phytate/zinc molar ratio to bioavailability of Zinc was

Table 2: Iron, zinc, Calcium, Phytate, Tannin content and Phytate/Mineral Molar Ratios of the three blends

Mineral, Phytate, tannin content and phytate/mineral molar ratio	Cereal: Legume Blending Ratios			Recommended values (mg/100gm)
	B1	B2	B3	
Ca (mg/100g)	32.81±0.04 ^a	43.8±0.02 ^b	54.75±0.01 ^c	500*
Fe (mg/100g)	35.17±0.02 ^a	27.04±0.01 ^b	24.69±0.04 ^c	16*
Zn (mg/100g)	1.92±0.05 ^a	2.06±0.06 ^b	2.25±0.04 ^c	3.2*
Phytate (mg/100g)	132.34 ±0.15 ^a	132.38 ± 0.12 ^a	132.39 ± 0.25 ^a	----
Tannins(mg/100g)	4.57±0.56 ^a	4.56 ±0.25 ^a	4.52±0.09 ^a	----
Phytate/Zn*	6.8	6.3	5.8	<15**
Phytate/Fe*	0.32	0.4	0.45	<1**
Phytate/Ca*	0.23	0.18	0.14	<0.24**

All values are means of four measurements (n=4) ± standard deviation.

Means followed by different superscripts within row show statistically significant (p<0.05) differences.

*FAO/WHO (CODEX CAC/GL 08. 1991)

** Gibson *et al.* (2010)

justified by Hotz and Brown (2004), who reported zinc absorption to be 18% and 25% for adult males and females, respectively if the phytate/zinc molar ratio is >18, whereas for diets with phytate/zinc molar ratios between 4 and 18 the corresponding estimates for adults are 26% and 34%, respectively. Gibson *et al.* (2010) explained the reduction in Phytate/zinc molar ratio is due to the degradation of phytate in cereal and/or legume and linked with significant increases of Zinc. Similarly, all the complementary food blends had phytate/iron molar ratios < 1 and phytate/calcium molar ratio <0.24, which is desirable for better iron and calcium bioavailability respectively. Phytate/mineral ratio of the three minerals indicates that zinc, iron and calcium absorption was unlikely to be markedly compromised by phytate. The probable reason for these low phytate/ mineral molar ratios may be the effect of soaking, roasting, dehulling used in

the processing of the three blends. Gibson *et al.* (2006) reported that molar ration between phytate and mineral improved by enriching complementary foods with animal-source foods or practice processing methods such as roasting, germination and fermentation.

Effect of blend ratio on functional property of complementary foods

The functional properties of the food materials are very important for the suitability of the diet, particularly, for the growing children. Functional properties (WAI, WSI and Viscosity) of the formulated complementary foods are presented in Table 3. Water absorption index gives an indication of the ability of flour to absorb water and the amount of water available for gelatinization depends on the availability of hydrophilic groups which bind water molecules (Kulkarni *et al.*,

2002). The water absorption index of B3 (1.64 ± 0.01) was significantly ($p < 0.05$) higher than B2 (1.59 ± 0.01) and B1 (1.60 ± 0.04) but there was no significant difference between WAI values of B1 and B2. As cited in Brou *et al.*, 2013; Gamel *et al.* (2006) explained that an increase of WAI could be attributed to an increase in protein content and Kinsella (1976) explained that, the polar amino acid residues of proteins have an affinity for water molecules that explained easily water absorption of products having high amount of protein. According to PAHO/WHO (2003), 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 foods for making semi-solid porridge with high caloric density per unit volume.

Water solubility index (WSI) is used as a measure for starch degradation; it means that at lower WSI there is minor degradation of starch and such condition leads to less numbers of soluble molecules in the formulate (Hernandez-Diaz *et al.*, 2007). The WSI of complementary food with cereal legume blending ratio of 85:15 (B1), 75:25

(B2) and 65:35 (B3) were 8.85 ± 0.05 , 8.91 ± 0.08 and 8.29 ± 0.04 , respectively. WSI increase as the proportion of legume increase and blend with cereal:legume ratio of 75:25 (B2) revealed significantly higher WSI and WSI decreased as the proportion of protein increased to 35% (B3) of the blend. This finding concedes with Brou *et al.* (2013) who reported an increase in WSI as the proportion of legumes increased from 0 to 30 followed by a decrease when the proportion of legume increased to 45% of the blend.

The viscosity characteristics of the complementary foods blended at different cereals to legumes ratio shows that, the blend with high carbohydrate content B1 revealed significantly higher viscosity values (248.43 ± 3.35) and viscosity decrease as the proportion of legume in the blend increased. This relation suggests a higher viscosity can be expected from blends with a lower fat and protein content. Hellström *et al.* (1981) showed a similar correlation in complementary gruels made from wheat and field pea flour. A larger percentage of fat decreases the carbohydrate content, reducing the amount of starch available for gelatinization. Jacobs *et al.* (1995) related viscosity to the extent of starch granule swelling. Low viscosity

Table 3: Effect of blending ratio on functional properties (WAI, WSI and Viscosity) of complementary foods

Blends	Functional properties		
	WAI	WSI	Viscosity
B1	1.60 ± 0.04^a	8.85 ± 0.05^a	$248.43 + 3.35^a$
B2	1.59 ± 0.01^a	8.91 ± 0.08^a	$232.12 + 2.81^b$
B3	1.64 ± 0.01^b	8.29 ± 0.04^b	$228.45 + 3.15^b$

All values are means of four measurements ($n=4$) \pm standard deviation

Means followed by different superscripts within column show statistically significant ($p < 0.05$) differences

of a cereal-based gruel is advocated for infant feeding. The low viscosity allows flexibility for manipulating the product consistency by increasing the solids concentration. This also provides a simple, inexpensive means for increasing the product's nutrient density.

Determining optimal complementary food blend

legumes. There was statistically significant difference among the Cereal: legume blends nutritional and functional qualities. The study revealed the protein, carbohydrate, iron and the energy content of the complementary food blend from 35% cereal and 65 % legume is in the range of FAO/WHO recommended daily intake for 6-23 months. However, the fat, calcium and zinc

Table 4: Ranking of complementary food blends for determining optimal nutritional and functional profile

Nutritional Profile	Cereal: Legume blending ratio		
	B1(85:15)	B2(75:25)	B3(65:35)
Protein (%)	3	2	1
Energy (kcal/100gm)	3	2	1
Ash (mg/100gm)	3	2	1
Fiber	1	2	3
Tannin (mg/100gm)	3	2	1
Phytate:Zinc Molar Ratio	3	2	1
Phytate:Iron Molar Ratio	1	2	3
Phytate:Calcium Molar Ratio	3	2	1
WSI	2	1	3
Viscosity	3	2	1
Total Score	25	19	16

*Most desirable (1) to least desirable (3).

As indicated in Table 4 complementary food blended from 65% cereal and 35% legume (B3) yielded the lowest total ranking scores. This blend was concluded to possess the most desirable nutritional and functional profiles among the blends studied.

CONCLUSION

The present study demonstrated that complementary food of high nutrient profile can be formulated from mixture of cereals and

content of the selected blend is relatively low to meet the daily intake of infants and older children and this calls enriching infant foods such as porridge during preparation with ingredients rich in fat, calcium and zinc to benefit fully from the complementary food. As indicated in the ranking of the formulation, a blend containing the highest proportion of legume resulted in better nutritional and functional profile that could help to tackle the two major forms of malnutrition in developing countries namely, protein energy malnutrition and micronutrient deficiency.

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