PJN
ISSN 1680-5194

# PAKISTAN JOURNAL OF NUTRITION

ANSInet
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Pakistan Journal of Nutrition 8 (9): 1335-1343, 2009
ISSN 1680-5194


# Production and Evaluation of Breakfast Cereal-Based Porridge Mixed with Sesame and Pigeon Peas for Adults

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**Abstract:** Three formulations were carried out to produce a breakfast cereal-based porridge with rice and sorghum (Locally Produced Rice (LPR), Imported Polished Rice (IMPR) and Locally Produced Red Sorghum (LPRS) mixed with sesame (*Sesamum indicum L*) and pigeon peas (*Cajanus cajan*) at different percentages. The protein content for the three formulations was significantly different ($p<0.05$) from each other. Moisture and ash contents were noted to be low for all three formulations. However, the carbohydrate and energy contents were significantly higher for all three formulations, while the fat content was only significantly higher in the LPR formulation. All three formulations were rich in minerals with a significantly higher calcium and potassium contents compared to the other minerals. Oleic and linoleic acids were the main constituent fatty acids observed in all three formulations and were significantly higher compared to other fatty acids determined in the study. The results showed that the three formulations were well balanced in essential and non essential amino acids. IMPR was observed to have a significantly higher *in vitro* digestibility (96%) compared to LPR and LPRS formulations (85% and 79% respectively). The three formulations displayed different bulk densities, with high water absorption capacities and apparent viscosities. Based on standard nutritional values, a combination of either rice or sorghum with sesame and pigeon peas could be recommended as appropriate breakfast cereal-based porridges for adults.

**Key words:** Breakfast, cereal-based porridge, rice, sorghum, sesame, pigeon peas

## INTRODUCTION

In developing countries, particularly sub-Saharan Africa, breakfast meals for both adults and infants are based on local staple diet made from cereals, legumes, roots, and cassava and potatoes tubers. However, results from previous studies note that most cereals are limited in essential amino acids such as threonine and tryptophan even though rich in lysine (Anglani, 1998; Perez-Consesa *et al*., 2002; Mensa-Wilmot *et al*., 2001; Nnam, 2001; Onweluzo and Nnamuchi, 2009), while most oil seeds and legumes are rich in essential amino acid particularly the Sulphur amino acids (Radha *et al*., 2007; Kanu *et al*., 2007a,b). Thus a combination of such food stuffs will improve the nutritional value of the resulting blend that will make it better compared to the individual components alone (Mensa-Wilmot *et al*., 2001). In Sierra Leone, West Africa for example, an extensive work has been done in an effort to formulate various breakfast and infant cereal meals by combining the available local cereals and legumes (Mensa-Wilmot *et al*., 2001; Egounlety, 2002; Kanu *et al*., 2007c). One such formulation that has gained immense appreciation from within West Africa is the Bennimix trademark that is meal popular for especially infants and lactating mothers (Kanu *et al*., 2007c). These meals are usually prepared as thick porridges such as liquid gruels for adults or as pap for infants.

The suitability of cereals, oil seed and legumes blend meals for human consumption has been extensively reviewed (Kulkani *et al*., 1991; Radha *et al*., 2007) and many countries have reported success in those formulations (Anglani, 1998; Kanu *et al*., 2007c). In Sierra Leone, however, with all the attempts made, no appropriate blend had ever been formulated that meets the nutritional requirements of the old age. Thus, this research is an attempt to formulate a cereal-based porridge meal with additional constituents such as sesame seeds, pigeon peas and sugar in various

proportions for especially adults. The two cereals, rice and red sorghum are both locally produced and abundantly available. They have been reported for their suitability in food formulations (Kulkani *et al*., 1991; Choi and Sohn, 1997). Sesame has been extensively investigated and reported to possess many health benefits to humans particularly for its quality oil (Abou-Gharbia *et al*., 2000). Similar sentiments are held for pigeon peas as well.

As far as our knowledge is concerned based on literature review, no attempts have ever been made to combine the above food stuffs to obtain a blend that could be used as a cereal-based porridge meal for the aged. Thus, the objective of this work is to formulate three cereal-based blend porridges as meals for the aged and compare and report their nutritional composition.

## MATERIALS AND METHODS

**Raw materials:** The IMPR, pigeon pea and the sugar were bought from a local market in the Southern province city of Bo, Sierra Leone. The LPRS was bought from a local farmer in a near by village while the LPR identified locally as '*Kortibu*' was kindly donated by the Scot Manga Farmers Association in Bo. Three formulations were produced, one containing LPR mixed with sesame seed, conso and sugar, the second one was a mixture of IMPR with sesame, pigeon peas and sugar and the third was made of LPRS with sesame, pigeon peas and sugar at various percentages according as shown in Table 1. The production process is illustrated in Fig. 1 as a production flow chart.

Table 1: The raw material in percentages

| | Formulations (%) | | |
|---|---|---|---|
| Ingredients | LPR | IMPR | LPRS |
| Rice | 55 | 75 | - |
| Sorghum | - | - | 75 |
| Sesame | 25 | 10 | 10 |
| Conso | 15 | 10 | 10 |
| Sugar | 5 | 5 | 5 |
| Total | 100 | 100 | 100 |

LPR = Locally produced rice; IMPR = Imported polished rice; LPRS = Locally produced red sorghum

All chemicals and reagents used in this work were obtained from a local manufacturer (Sinopharm Chemical Reagent Co., Ltd. (SCRC) Shanghai People's Republic of China) and made available at Jiangnan University, Wuxi, P.R. China, chemical store and were of analytical grade

**Proximate analysis:** The protein analysis of the three formulations was determined using Micro-Kjeldahl machine (GBT5009,5-2003, Shanghai). Moisture content was determined by placing 2 g of each formulation into

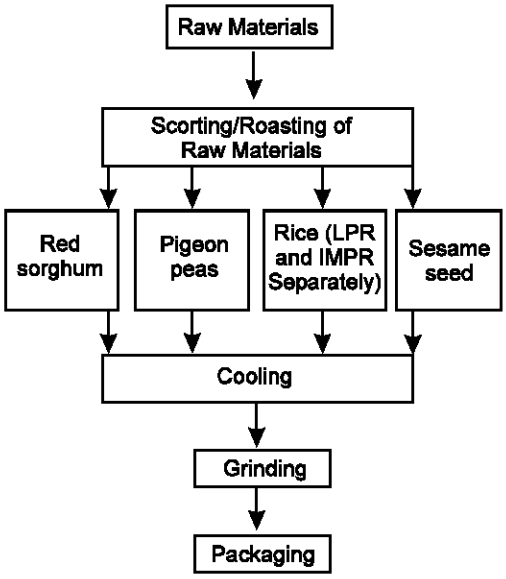


Fig. 1: Production flow chart of the breakfast cereal-based formulations

a preweighed aluminum dish and dried in a forced-air convection oven at 105°C until a constant weight was reached. Ash content was determined by combusting the samples in a muffle furnace at 550°C for 12 h according to AOAC (1995). The mineral contents were determined after the ash content determination; the residues of each formulation was dissolved in 10 mL of 50% nitric acid solution and diluted with distilled water making the final volume of 25 mL. The aliquot was used to separately determine the following mineral contents: Zn, Fe, Cu, Mn, Na, K, Mg, Ca, Ni, Cr using an Atomic Absorption Spectrometer (Spectrr AA 220, USA Varian).

**The carbohydrate content:** The carbohydrate content was estimated by subtracting the sum of percentage of moisture, fat, protein and ash contents from 100% according to AOAC (1995).

**Total energy:** The total energy value of the three formulations was determined according to the method of Mahgoub (1999) using the formula as shown in equation 1:

$$\text{Total energy (kcal/100g)} = [(\%\text{ available carbohydrates X4}) + (\%\text{ protein X4}) + (\%\text{ fat X9})]$$

Percentage protein calories were determined according to James, (1995) as shown in equation 2:

$$\%\text{ Protein calories} = \%\text{ Protein X 4/ total energy of formulation}$$

**Fatty acid:** Fatty acid for the three formulations was determined according to the method of James (1995) with slight modifications. Fat was extracted with methyl

ether by directly treatment of the fat in the samples with sodium methoxide. Gas Chromatography/Mass Spectra (GC/MS) was used to identify and determining the amounts of the various fatty acids in the formulations using FINNIGAN TRACE MS (USA) gas chromatograph/ mass spectra equipped with a 30 m x 0.25 mm Ov-1701 column. Column flow rate was 0.8 ml/min with helium as the gas carrier, split was 64 ml/min and the source temperature was 270°C. The fatty acid methyl esters were identified by comparison with the retention times of NU CHECK Inc. standards (Elysian, 1L) and amounts determined by internal normalization.

**Total amino acids analysis:** The LPR Formulation, IMPR Formulation and LPRS Formulation (20 µg each) were dried in conventional hydrolysis tubes. To each tube 100 µL of 6 mol $L^{-1}$ HCl containing 30 mL phenol and 10 mL 2-mercaptoethanol (6 mol $L^{-1}$ HPME) were added and the tubes were evacuated, sealed and hydrolyzed at 110°C for 22 h. After hydrolysis, HCl was evaporated in a vacuum bottle heated to about 60°C. The residue was dissolved in a sample buffer and analyzed for amino acids using RP-HPLC with an Agilent 1100 assembly system (Agilent Technologies, Palo Alto, CA 94306, USA) and Zorbax 80A C18 column (4.6 id x 180 mm). The Excitation Wavelength (Ex) of 348 nm and Emission Wavelength (Em) of 450 nm were chosen. The column oven was maintained at 60°C. Amounts of amino acids were determined by calculations using the recorded chromatogram.

For cystine determination, samples (50 µg of LPR Formulation, IPR Formulation and RS Formulation) were first oxidized with 10 µL performic acid in an ice-water bath for 4 h. The mixtures were evaporated with a vacuum pump to remove performic acid before hydrolysis.

Determination of tryptophan was done by the ninhydrin method. One gram of each formulation was put into a 25 mL polypylene test tube with caps, 10 mL of 0.075 N NaOH was added and thoroughly mixed until clear solution was obtained. The dispersion was shaken for 30 min and centrifuged at 5000 rpm for 10 min and the supernatant liquid transferred into a clean test tube. 0.5 mL of the supernatants, 5 mL of ninhydrin reagent (1.0 g of ninhydrin in 100 mL mixture of 37% HCl and 96% HCOOH) in a ratio of 2:3 for all the samples were added and incubated at 35°C for 2 h. After incubation, the solution was cooled to room temperature (23-25°C) and the volumes were made up to 10 mL using diethyl ether, thoroughly mixed using a vortex mixer, filtered and the clear filtrates were analyzed with the same equipments as described above for the other amino acids.

**Determination of *in vitro* protein digestibility (IVPD):** The method of Saunders *et al.* (1973) was used with slight modifications. The formulations (5 g each) were placed in a 50 mL centrifuge tube, to which 15 mL of 0.1N HCl containing 1.5 mg pepsin-pancreatin was added and the tube was incubated at 37°C for 3 h. The suspension was then neutralized with a phosphate buffer (pH 8.0), containing 0.005 M sodium azide. 1 ml of toluene was added to prevent microbial growth and the mixture was gently shaken and incubated for an additional 24 h at 37°C. After incubation the sample was treated with 10 mL of 10% Trichloroacetic Acid (TCA) and centrifuged at 5000 rpm for 20 min at room temperature. The protein in the supernatant liquid was estimated using the Kjeldahl method. The percentage of protein digestibility was calculated using the following formula:

$$\text{Protein Digestibility (\%)} = \frac{\text{Protein in Supernant}}{\text{Protein in sample}} \text{X } 100$$

**Functional properties**

**Bulk density (BD):** BD was determined using the method described by Wang and Kinsella (1976) with slight modifications. 10 g of the test materials were placed in a 25 ml graduated cylinder and packed by gentle tapping the cylinder on the bench top ten times from a height of 5-8 cm. The final volume of the test material was recorded and expressed as g/ml.

**Water absorption capacity:** (WAC) was determined by the method of Cegla *et al.* (1977) with slight modifications. 10 g of each formulation were weighed in a 100 mL beaker. A known volume (5 mL) of water was pipetted into the beaker, carefully stirred and allowed to equilibrate for one hour at room temperature (23-25°C). After complete water absorption, the sample was further treated with 0.01 mL water portion at 10 min interval before visual observation. The volume that gave a complete absorption of water (no visible free water) was recorded. WAC was calculated as the ratio of maximum amount of water in grams absorbed by 100 g dry material.

**Apparent viscosity (AV):** AV was determined by placing 20 g of the sample in measuring cylinder of 100 mL of water in a boiling water bath of 75-80°C. The slurry was constantly stirred until boiling which was continued for five minutes. The slurry was cooled to room temperature 23-25°C and their viscosity was measured with a Brookfield Synchro-electric viscometer (Shanghai, P.R China) using RVT spindle no. 4 at a constant speed of 100 rpm. Conversion into cps units was done using the specific factor for spindle 4.

**Sensory evaluation:** Sensory evaluation was done by a trained panel of ten members. The three formulations were prepared differently into porridge and the 'Nine Point hedonic scale' was used to test the like and dislike

for the three formulations for colour taste and mouth feel attributes.

**Statistical analysis:** The results were subjected to statistical analysis of variance (ANOVA), using a Statistical Analysis System (SAS) The significant difference between means were determined by Duncan's Multiple Range Test (DMRT), at $p<0.05$.

## RESULTS AND DISCUSSION

The proximate chemical composition is presented in Table 2. The protein content for the three formulations was significantly different ($p<0.05$) from each other. LPRS has the highest protein content followed by IMPR. The result of the LPRS was significantly higher than the reported results of Egounlety (2002) for the nutritive value of protein-energy legume-fortified weaning for 'ogi'. But lower than the result reported for Binnimix (Kanu *et al*., 2007c).

Table 2: Proximate composition for the three formulations

| Proximate Composition | LPR Formulation | IMPR Formulation | LPRS Formulation |
|---|---|---|---|
| Protein (%) | 8.8 | 10.2 | 13.3 |
| Moisture (%) | 0.1±0.03 | 0.2±0.02 | 0.2±0.06 |
| Ash (%) | 2.3±0.89 | 1.3±0.64 | 2.1±0.74 |
| Fat (%) | 17.5±1.35 | 7.8±2.05 | 8.7±1.27 |
| Carbohydrate (%) | 71.3±2.03 | 80.5±2.35 | 75.8±1.78 |
| Energy(kcal/100g) | 477.8 | 433.2 | 434.9 |
| % protein calories | 7.4 | 9.4 | 12.2 |
| Minerals (µg/g) | | | |
| Zinc (Zn) | 121.11 | 119.8 | 117.9 |
| Iron (Fe) | 24.4 | 20.6 | 68.0 |
| Copper (Cu) | 17.1 | 15.80 | 16.6 |
| Manganese (Mn) | 59.3 | 49.82 | 43.0 |
| Sodium (Na) | 67.6 | 37.6 | 22.4 |
| Potassium (K) | 4500.5 | 2800.2 | 4000.1 |
| Magnesium (Mg) | 150.3 | 101.6 | 158.4 |
| Calcium (Ca) | 7500.6 | 5539.4 | 6790.6 |
| Nickel (Ni) | 0.6 | 0.3 | 0.3 |
| Chromium (Cr) | 0.7 | 0.5 | 0.6 |

Values are mean ± SEM (n = 3), significant at level ($p<0.05$)

The moisture contents for the three formulations were almost the same. The results were observed to be the same as all of the formulations were subjected to the same period of scorching/roasting during the production process. The highest was observed from IMPR with a marginal difference of 0.04% for LPR and 0.02 for LPRS. According to these results there are no significant differences ($p<0.05$) in the moisture content of the three formulations. The low moisture observed for the three formulations is a good indicator of their longer self life.

Ash, for the three formulations was also observed to be very low in the range of 1.3-2.3%. These values are similar to the values reported from the production of legumes-fortified weaning food (Egounlety, 2002).

Fat was significantly different for all the formulations. LPR had the highest fat content followed by LPRS. From the results the differences were significant ($p<0.05$). A possible reason for the high fat content in the LPR could be attributed to the large amount of sesame seed used in the formulation. The high fat content in this formulation could be a reason for its low protein content as it is known that fat from sesame has the tendency to bind with protein. It is also known that fat extraction from the seed results to an increase protein content (Kanu *et al*., 2007d).

Carbohydrate was observed to be significantly ($p<0.05$) higher for the three formulations at the range of 71.3-80.5%. This result was within the range (71.11-83.39%) of results reported by Egounlety (2002) for nutritive value of high-protein-energy legume-fortified weaning flours. The high carbohydrate content of the formulations is attributed to the high carbohydrate content in the cereals that are the principal ingredients in the formulations. A marginal difference was observed when the results are compared with the results Mahgoub (1999) reported for cerelac proximate composition of weaning food formulations.

Energy was observed to be high for all the three formulations. Significantly higher ($p<0.05$) than the results reported by Mahgoub (1999) and Kulkani *et al*., (1991) who studied sorghum malted-based weaning food formulation: Preparation, functional properties and nutritive value. However, the results corroborated those of Egounlety (2002). Energy content is a parameter used to determine the quality of food especially for formulations designed for adult with high energy requirements.

However percentage protein calories were lower than those reported by Mahgoub (1999) and also lower for required amounts for children in Sierra Leone but, however, higher then the required amounts for adult as reported by Robbin-Coker and Jalloh (1975) in infant feeding and protein-calorie malnutrition in Freetown. According to the Indian Council of medical research, the required optimal protein-calorie requirement for pre-school children for India is 7.1% (Mahgoub, 1999). Protein-energy ratio gives the protein content of a food or diet expressed as the proportion of the total energy provided by protein (17KJ, 4kcal/100 g). The average requirement for percent protein is about 7% of total energy intake. Average Western diets provide about 14% for children and half of it for adults (Bender, 2005).

The mineral composition for the three formulations is presented in Table 1. The three formulations were rich in calcium followed by potassium with LPR having the highest amount for the two minerals compared to the other two formulations with a significant difference at ($p<0.05$). The results were within the range of those reported by Kulkani *et al*. (1991). The high amount of calcium observed from LPR was attributed to the ingredients as LPR had the highest proportion of

sesame and it has been reported that sesame seeds have significantly higher amounts of calcium (Ünal1 and Yalçın, 2008). Since the sesame seeds were not hulled, it is possible that the present of the seed coat from the sesame could be another reason for the high mineral content as it has been reported that the sesame seed coat contain higher mineral content (Johnson *et al*., 1979).

Calcium is by far the most important mineral that the body requires and its deficiency is more prevalent than many other mineral. The adult body contains three to four pounds of calcium, 99% of which are in bones and teeth. Since it is so concentrated in the bones and teeth, only 1% of our calcium circulates in body fluids and tissues. When calcium intake is inadequate, some of it is stored at the ends of bones. Under stress situations, this reserve storage could be used. If the body has no reserve calcium, then it is taken from the bone structure, usually the spinal and pelvic bones (Ishitani *et al*., 1999). For the three formulations to have a significant amount of calcium makes them very good sources of the element, thus making them ideal for adult consumption. The three formulations also have significant amount of other minerals determined as shown in Table 2. The results were within the range reported by Annan-Prah and Agyeman (1997) in nutrient content and survival of selected pathogenic bacteria in kenkey used as a weaning food in Ghana.

**Fatty acids:** The fatty acid composition of the three formulations is shown in Table 3. As shown in the table there are no significant differences ($p<0.05$) among the formulations with oleic and linoleic acids being the main fatty acid constituents in the three formulations accounting for about 80.0% put together of the total fatty acids. The high amount of the fatty acids could also be attributed to the sesame ingredient as it has been recently reported to have a high content of oleic and linoleic acids (Ünal1 and Yalçın 2008). Other fatty acids like palmitic and stearic acids were also observed to be in significant amount for the three formulations. The two highest fatty acids have been reported to have several health benefits. Oleic acid is a monounsaturated fatty acid found naturally in many plant sources and in animal products and it is an omega-9 fatty acid and considered as one of the healthier sources of fat in diets (Moreno and Mitjavila, 2003). It is commonly used as a replacement for animal fat sources that are high in saturated fat. As a replacement for other saturated fats, it can lower total cholesterol level and raise levels of High-density Lipoproteins (HDLs) while lowering Low-density Lipoproteins (LDLs), also known as the "bad" cholesterol. From a health standpoint, oleic acid exhibits further benefits (Quinlan *et al*., 1996; Moreno and Mitjavila, 2003). It has been shown to slow the development of heart disease and promoting the production of antioxidants. Numerous studies indicate that a diet rich in olive oil decreases the development of atherosclerosis and lowers serum cholesterol by diminishing oxidative stress and inflammatory mediators while promoting antioxidant defenses (Moreno and Mitjavila, 2003). The human body can produce all but two of the fatty acids it needs. These two, Linoleic Acid (LA) and alpha-linolenic acid (LNA), are widely distributed in plant oils (Quinlan *et al*., 1996). In addition, fish oils contain the longer-chain omega-3 fatty acids Eicosapentaenoic Acid (EPA) and Docosahexaenoic Acid (DHA). Since they cannot be made in the body from other substrates and must be supplied in food, they are called essential fatty acids. Mammals lack the ability to introduce double bonds in fatty acids beyond carbon 9 and hence linoleic acid and linoleinic acid are essential fatty acids for humans (Quinlan *et al*., 1996). In the body, essential fatty acids are primarily used to produce hormone-like substances that regulate a wide range of functions, including blood pressure, blood clotting, blood lipid levels, the immune response and the inflammation response to injury infection (Quinlan *et al*., 1996).

Table 3: Fatty acids for the three formulations

| ---------- Fatty Acids ---------- | | LPR Formulation | IMPR Formulation | LPRS Formulation |
|---|---|---|---|---|
| Common Names | Scientific names | (%) | (%) | (%) |
| Palmitic acid | Hexadecanoic acid | 9.8 | 9.7 | 10.7 |
| Palmitoleic Acid | 9-Hexadecenoic acid | 0.2 | 0.4 | 0.3 |
| Capric acid | Decanoic acid | 0.2 | 0.3 | 0.1 |
| Stearic acid | Octadecanoic acid | 6.3 | 5.6 | 5.0 |
| Vaccenic acid | 11-Octadecenoic acid | 1.3 | 0.3 | 0.1 |
| Linoleic acid | 9,12-Octadecadienoic acid | 39.0 | 38.4 | 36.7 |
| Linolenic Acid | 9,12,15-Octadecatrienoic acid | 0.2 | 1.1 | 1.3 |
| Oleic acid | 9-Octadecenoic acid | 40.0 | 41.0 | 42.8 |
| Elaidic | 9-trans Octadecenoic acid | 0.62 | 0.31 | 0.46 |
| Lauric acid | Dodecanoic acid | 0.9 | 0.5 | 0.9 |
| Behenic acid | Docosanoic acid | 0.7 | 0.7 | 0.6 |
| Ricinoleic acid/Nutmeg | 12-Hydroxy-9-octadecenoic acid | 0.8 | 0.3 | 0.3 |
| Arachidic acid | Eicosanoic acid | 0.1 | 1.1 | 0.5 |
| Gadoleic Acid | 9-Eicosenoic acid | 0.1 | 0.3 | 0.3 |

Values are mean±SEM (n = 3), significant at level ($p<0.05$)

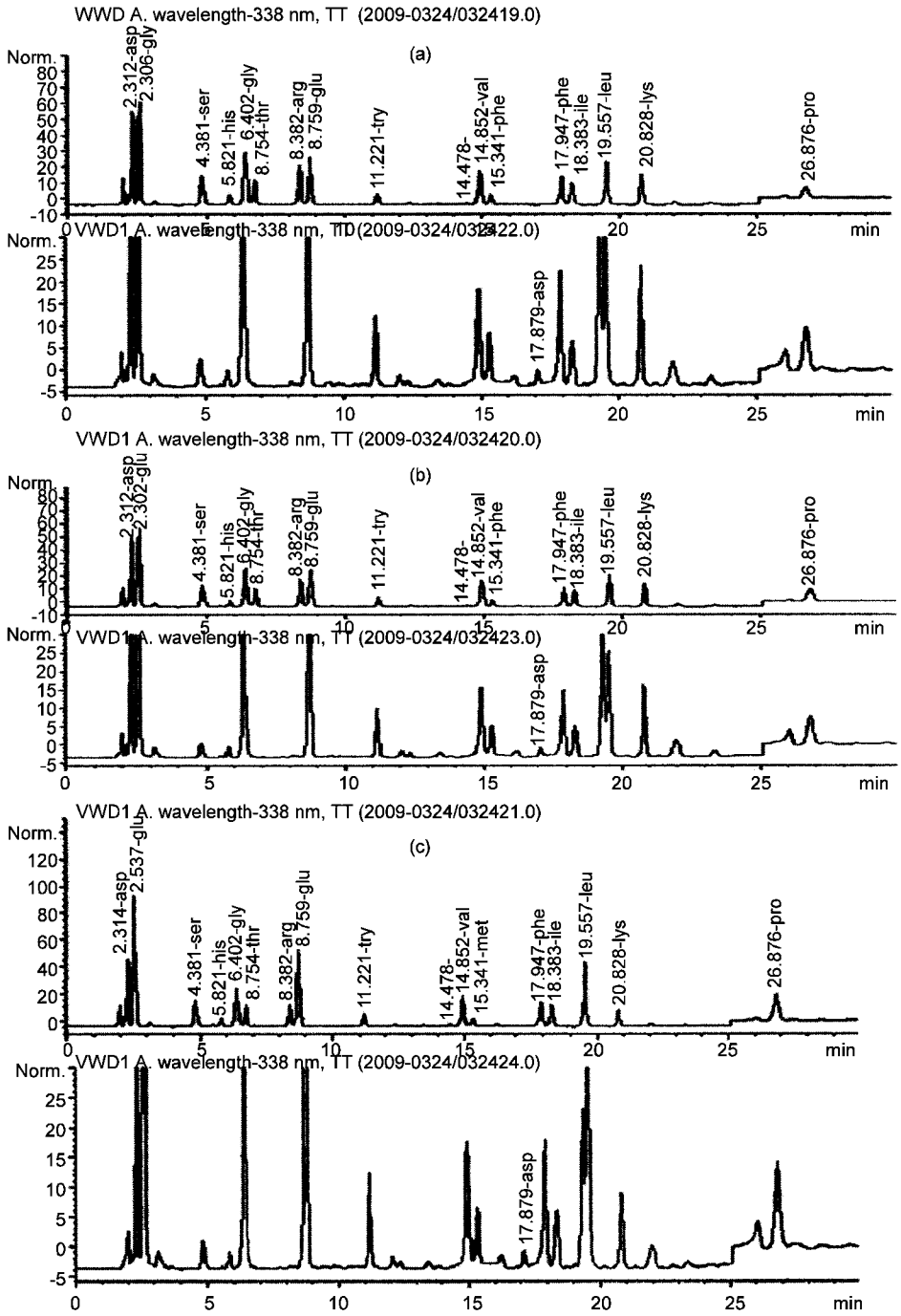


Fig. 2: (Ai) Amino acid chromatogram for LPR, (B) Amino acid chromatogram for IMPR, (C) Amino acid chromatogram for LPRS

**Total amino acids:** The essential amino acid composition of the three formulations shown in Table 4 are in accordance with the FAO/WHO (1990) recommended requirements for both infants and adults. The LPR contains all the essential amino acids in significant ($p<0.05$) proportion as compared to the two formulations with the exception of valine and isoleucine which are higher in LPRS (4.7 and 5.7 respectively). It is also comparable with the FAO requirement of amino acids. The results in Table 4 indicate that the amino acid composition for the three formulations exceeds especially that of lysine which is in low quantity in sesame and pigeon peas (Obasa *et al*., 2006; Kanu *et al*., 2007d). It is noted that mixing the ingredients with

Table 4: Amino acid profile of the three formulations along side the FAO/WHO requirements for infants and adults

| Amin Acids | LPR Formulation (g/100 g) | IMPR Formulation (g/100 g) | LPRS Formulation (g/100 g) | FAO/WHO[a] Infant (g/100 g) | FAO/WHO[a] Adult (g/100 g) |
|---|---|---|---|---|---|
| **EAA** | | | | | |
| Histidine (His) | 4.1 | 2.7 | 3.6 | 1.9 | 1.6 |
| Threonine (Thr) | 4.8 | 3.6 | 4.7 | 3.4 | 0.9 |
| Valine (Val) | 7.1 | 5.8 | 7.3 | 3.5 | 1.3 |
| Lysine (Lys) | 4.3 | 3.3 | 2.5 | 5.8 | 1.6 |
| Leucine (Leu) | 9.9 | 7.8 | 1.7 | 6.6 | 1.9 |
| Isoleucine (Ile) | 5.3 | 4.0 | 5.7 | 2.8 | 1.3 |
| Tryptophan (Try) | 1.7 | 1.1 | 1.5 | 1.1 | 0.05 |
| Methionine (Met) | 7.6 | 5.5 | 7.5 | 2.5[b] | 1.7[b] |
| **nEAA** | | | | | |
| Tyrosine (Tyr) | 3.9 | 3.2 | 4.2 | | |
| Phenylalanine (Phe) | 9.0 | 6.5 | 8.7 | | |
| Alanine (Ala) | 6.8 | 5.5 | 1.2 | | |
| Arginine (Arg) | 1.1 | 8.3 | 6.9 | | |
| Serine (Ser) | 6.2 | 4.9 | 6.3 | | |
| Glycine (Gly) | 6.4 | 4.9 | 5.1 | | |
| Proline (Pro) | 4.0 | 4.5 | 1.0 | | |
| Aspartic acid (Asp) | 1.2 | 9.8 | 1.1 | | |
| Glutamic acid (Glu) | 2.3 | 2.0 | 3.1 | | |

[a]Suggested profile of essential amino acid requirement for infant and adult by FAO/WHO (1990), [b]Methionine + Cysteine
EAA = Essential amino acid, nEAA = Non essential amino acid, Values are mean ± SEM (n = 3), significant at level ($p<0.05$)

Table 5: Functional properties of the three formulations

| Property | LPR Formulation | IMPR Formulation | LPRS Formulation |
|---|---|---|---|
| Bulk Density (g/ml) | 0.55±0.02 | 1.53±0.04 | 0.56±0.01 |
| Water absorption capacity (g/100g) | 375±3.74 | 400±2.57 | 358±2.86 |
| Apparent viscosity (cps) (20 g/100 ml gruel concentration) | 4645±8.75 | 5147±6.58 | 4200±8.89 |

Values are mean ± SEM (n = 3), significant at level ($p<0.05$)

cereal increases the lysine content. Cereals have been reported to have higher quantity of lysine (Perez-Consesa *et al*., 2002). Lysine contents in the formulations, however, exceed the FAO/WHO recommended standards for adults. The results show that the three formulations were well balanced in essential and non essential amino acids. 18 amino acids were analyzed as shown in Fig. 2 (a, b, c). Since tryptophan was analyzed separately, it is shown in a different chromatogram below each of the respective formulation. Methionine and cystine (which are sulphur amino acids) were combined in our report as it will allow the results to be compared with the FAO/WHO standards. Our results corroborated those of Mensa-Wilmot *et al*. (2001) in the evaluation of protein quality of cowpea-based extrusion cooked cereal/legume weaning mixtures.

***In vitro* Protein Digestibility (IVPD):** The pepsin-pancreatin in vitro protein digestibility of the three formulations is shown in Fig. 3. The highest digestibility among the formulations was that of IMPR (96%) followed by LPR (85%) and LPRS (79%) with significant difference ($p<0.05$) among them. The amount of digestibility displayed by IMPR is due to the fact that polished rice was used in this formulation while locally

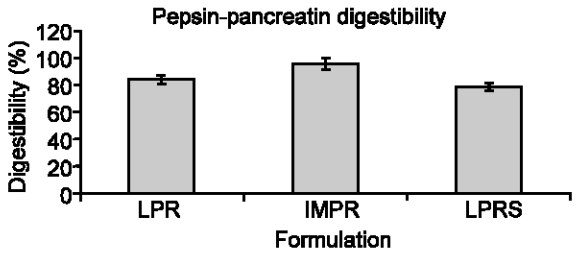


Fig. 3: *In vitro* protein digestibility of the three formulations

produced unpolished rice was used for the other formulations. The presence of the bran on the unpolished rice prevented complete digestibility of the two formulations. Nonetheless, our results are within the range of those reported by Mahgoub (1999).

**Functional properties:** Results of the functional properties studied for the three formulations are presented in Table 5. The bulk density of IMPR was significantly ($p<0.05$) different from the bulk density of LPR and LPRS. The bulk density of LPR and LPRS was not significantly ($p<0.05$) different from each other sowing 0.55 g/ml and 0.56 g/ml respectively. Water absorption capacity was observed to be in the same

trend like the bulk density. IMPR recorded the highest (400 g/100 g) than the other formulations (LPR and LPRS) and the difference was significant ($p<0.05$). Water absorption capacity gives an indication of the amount of water needed to form a gruel that results to gelatinization. Lower water absorption is desirable for making thinner gruels that will enhance more in-take of nutrients (Kulkani *et al*., 1991). The water absorption capacity of LPR was higher than LPRS and the difference was significant ($p<0.05$). The high water absorption capacity observed from the three formulations was because of the high percentage of carbohydrate in the form of starch and starch granules absorb a lot of water to reach gelatinization peak (Perez-Consesa *et al*., 2002). The small particle size of the formulation is also a contributing factor for their high water absorption capacity since smaller sized particles with greater surface area have more micro-spaces for water absorption. For apparent viscosity, IMPR again showed a higher value (5147 cps) which was significantly different at ($p<0.05$) in comparison to the other two formulations. LPR and LPRS had apparent viscosities of 4645 and 4200 cps respectively. However, the results are within the range of those reported by Kulkani *et al*. (1991). The high viscosity of a gruel prepared from cereal-grain and oil seed and legume flours is due to the presence of starch and proteins which are predominant nutrients in such ingredients. Starch in particular, absorbs water on cooking forming a gelatinous mass while proteins will denature and expose more hydrophilic sites that will take up more water (Mensa-Wilmot *et al*., 2001). These mechanisms increase the viscosity of formulations that contain significant amounts of them. Since the three formulations followed the same trend for the three functional properties considered, any modification to make them suitable for infants should target the lowering of lower their values.

**Sensory evaluation:** The data on sensory evaluation obtained by the panel of ten members showed that IMPR was rated to be more favorably (appealing) in terms of color and mouth feel (taste). While a non significant difference ($p<0.05$) was reported between the LPRS and LPRS for sensory evaluation attributes.

**Conclusion:** The production of a cereal-based porridge was achieved by mixing rice and sorghum, sesame and pigeon peas. The results observed gave a good indication that the three formulations could provide the nutrients needed by adults. The results show that foodstuff blends can be of high nutritional value and a balanced status than their individual components. They can also be used to meet specific nutritional requirements of different classes of people. Due to the simplicity of production, poor communities can use such formulations based on the local foodstuffs available.

## ACKNOWLEDGEMENT

This work was financially supported by the Government of Sierra Leone, the Government of People's Republic of China through the Chinese Scholarship Council (CSC) (No 2005694011) and Marz Chemicals Ltd, 44 Bathurst Street, Freetown, Sierra Leone. The Authors are very grateful to the two governments, Marz Chemicals Ltd and the Bennimix Food Company SL Ltd, Bo, Sierra Leone for allowing us to use their facilities to produce the food.

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