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EVALUATION OF NUTRITION PROPERTIES OF CO-FERMENTED MAIZE/ CARROT/ PIGEON PEA AND MILLET/ SWEET POTATO/ PIGEON PEA AS INFANT COMPLEMENTARY FOOD

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ABSTRACT Infant Malnutrition in Nigeria can be attributed to poor nutritional quality of cereals like maize and millet that are mostly fermented and processed to gruel for infant's consumption. Nigerians under-utilize Pigeon pea, carrots and sweet-potato as in infant complementary food despite their abundance. This study evaluated the nutritional quality of co-fermented maize/carrot/pigeon pea (MACP) and millet/sweet potato/pigeon pea (MISP) in ratio 50:20:20 as infant complementary foods. Proximate chemical composition, anti-nutritional factors, protein solubility and functional properties of MACP and MISP in terms of infant complementary food after 72hours fermentation time were analyzed using standard analytical methods. Statistical analyses all experiments were conducted in triplicate. A one-way analysis of variance was performed with P 0.05) energy value than the recommended 4kcal/g (on dry matter basis). Carbohydrate and dietary fiber values met the required values based on average breast milk intake. In anti-nutritional factors: TA(2.05-1.10), Phenol(1.02-0.48), Saponin (2.25- 2.36), Alkaloid (1.15-1.12), Flavanoid (0.35-0.28) Phytin(4.35-5.03) , Oxalate (0.68-0.81) and Cyanide(1.27-1.28). The antinutritional factors significantly (p0<05) reduced in sample MISP than in MACP. MACP sample had higher PS% in the pH range of 1-4, and significantly higher (p0<05) in the pH range of 10-12. While MISP had higher PS% in the pH range of 6-9. Both samples in terms of functional properties could be useful in structural interactions in foods, flavor retention, improved palatability and shelf life extension. In terms of general acceptability sample MACP was preferred while MISP was preferred in terms of color. The sample MACP was more enhanced in amino acids except in tryptophan compared to MISP .KEY WORDS: co-fermentation, cereals, legumes, tuber, nutrients.

KEYWORDS: Nutrition Properties, Maize, Carrot, Pigeon Pea, Millet, Sweet Potato, Pigeon Pea, Infant Complementary Food

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INTRODUCTION

Physical, physiological, immunological and mental development which occur rapidly between 6 and 24 months. Infants' malnutrition from lack of inadequate quality nutrition can manifest as limited mental abilities in adulthood (Dewey, 2013). Complementary food (CF) is the food given to infants after exclusive breastfeeding for 6 months when breast-milk is inadequate to meet their nutritional needs. Complementary feeding should start at 6 months of age (PAG, 1971). In Nigeria, the infant formula is out of the financial reach of low-income mothers, who prepare CF from fermented cereal which results in thinly diluted and low nutrient density products. To meet adequate energy and nutrients, the infant would need to consume a volume beyond his or her stomach capacity.

LITERATURE REVIEW

Carrots, sweet potatoes, pigeon pea, millet and maize contain vitamins, minerals, carotene and antioxidants which are nutritionally beneficial. Their products can therefore be used in complementary food preparation. Sweet potatoes (*Ipomoeas batistes*) , though low in protein, are rich in vitamins A, C, protein, fat copper, dietary fiber, raffinose but have high anti-nutritional factors (Tomkins et al., 2012; Neela & Fanta, 2019). Carrots contain many vitamins folate, dietary fiber minerals and have high levels of beta-carotene which is converted to vitamin A within the body and prevent night blindness; while vitamin A deficiency (VAD) results in parasitic infections and diarrhea disease. Edem (2009) reported that there is a correlation between (VAD) and protein malnutrition (PEM) in malnourished children.

Millet: (*Pennistum vulgare*) is not toxic at any stage and contains higher protein content than most cereals. It is rich in minerals, vitamins and methionine which is lacking in starchy foods. contains higher protein content (8-19%) than most cereals (Khalid et al., 2017).

Maize *(Zea mays)* produced in greater quantity in Nigeria than most cereals is of good acceptability due to its low cost however it is deficient in lysine, threonine and tryptophan making it of poor nutritional quality as infant complementary food (Oyarekua, 2013).

Spontaneous lactic acid fermentation is an effective and convenient process for the improvement of nutritional value and viscosity reduction of cereal-based foods; it also reduces anti-nutritional factors (ANF), increasing nutrient density. The metabolic activities of enzymes and microflora of the raw materials increase the antimicrobial activities resulting in an acidic environment suppressing pathogenic bacteria and giving a product of pleasant flavor, aroma and texture (Eneche, 2009).

Pigeon pea (*Cajanus cajan L.*,) is a dry mature legume seed of the leguminosae family. It is a very drought-resistant legume and it is cultivated widely in Nigeria. About 7.8 million households produce pigeon peas in sub-Saharan Africa (Zahra et al., 2020). Pigeon peas are rich sources of essential amino acids (lysine, methionine, and tryptophan), fiber, vitamins (riboflavin and niacin), and minerals (phosphorus, iron, and magnesium) (FAO, 1985). It is normally consumed as dehulled splits, whole, canned, boiled, roasted, or grind into flour to make a variety of desserts, noodles and snacks.

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Pigeon pea contains 20 to 22% protein, 1.2% fat, 65% carbohydrate and 3.8% ash. Most products obtained from soya bean can be produced from pigeon pea yet it is underutilized due to the tough texture resulting in long cook ability, fuel and time consumption (Oyarekua, 2009; Kidanemaryam et al., 2019; Soloon et al., 2017).

None or poor combination of staples has contributed to the poor nutritional quality of traditional complementary foods. Therefore, the objective of this study is to co-ferment cereal/legume/tuber/vegetable as means of improving the nutritive value of cereal-based infant complementary food.

METHODOLOGY

Experimental Design

The design of complementary foods involved co-fermentation of substrates to:

- Improve the nutritional nutritional needs of all or part of the nutrients requirement for infants;
- the choice of raw materials are their cultivation and availability, is conditioned availability but underutilized as infants foods
- by knowledge of the levels of available nutrients and of anti-nutritional factors through the co-fermentation process.

The development of treatments was with the following objectives:

- ensuring acceptable organoleptic qualities;
- inactivating anti-nutritional factors and reducing the levels of undesirable compounds;
- ensuring nutritional quality in terms of protein, carbohydrate and amino acids.
- evaluating the sensory acceptability of the products of the products.

Sample Preparation

Mature grains of pigeon pea, maize and pearl millet were bought from a local market at the King's Market, Ado-Ekiti. They were destined, winnowed, sorted and fresh tubers of sweet potato and fresh roots of carrots were washed in clean water to remove soil before peeling and cutting into slices of about 2.0 mm thickness. Mixtures of maize/carrot/pigeon pea (MACP) and millet/sweet potato/pigeon pea (MISP) each in ratio 60:20:20 were weighed and soaked in tepid water for 72h and at every 24 hours of the fermentation, pH was measured. After 72h each mixture was wet milled and wet sieved using a cheesecloth. The shafts were then discarded. The sediment from each mixture was left in the water for 24h for further fermentation. With the supernatant discarded, the slurry was de-watered and dried at 60^{o}C. The cake was milled and sieved (300mm sieve). The final flour was stored at 4^{o}C for analysis.

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Analyses

Determination of pH, Total Titratable Acidity (TTA) during fermentation

pH was measured using standard methods of (AOAC 2005a).

Chemical analysis: Fat, carbohydrate, ash and moisture protein contents were determined using standard methods while carbohydrate was calculated by difference (Adeyeye et al, 2014).

Determination of protein solubility

Protein solubility was determined by the method of Abd El-Moneim 2012).

Determination of anti nutritional factors

According to the method described by (Oyarekua and Bankefa 2015).

Estimation of total phenols: Standard method (Whitney et al., 1990) in which total phenol is which is expressed as chlorogenic acid equivalent, was used for the estimation of total phenols. Antinutritional factors were determined by the chemical method described by (Whitney et al., 1990).

Oxalate content analyzed according to (Adeyeye et al., 2014) and phytate using the method described by (Abd El-Moneim, et al., 2012)

Phytic acid was calculated by multiplying phytin-P by a factor of 3.55.

Gruel of each sample was served to trained panelists of twenty-five infant mothers. Each panelist was made to assess each product based on the 9-point Hedonic scale (9=like very much, 1=dislike extremely) and the attributes to be tested are: * appearance-colour. *texture-smoothness. * softness-soft. *taste-sweetness- too bitter. *mouth feel *aroma. *general acceptability.

Statistical Analysis

All analyses were carried out in duplicates and the data collected were analyzed using Plot IT software (SPE Scientific 1993). Data were subjected to analysis of variance (ANOVA) and Tukey's test was used for comparison of means. Significance was accepted at $p = 0.05$.

RESULTS AND DISCUSSION

The comparison of nutrients values in this work were based on recommended nutrient intakes required for infant complementary foods and complementary guidelines of IOM (2003), WHO (2002), WHO/FAO/UNU (1998) and Dewey (2003). It was estimated that a daily ration of 40 g for infants aged 6 to 11 months (mo) and 60g for young children aged 12 to 23 mos is recommended. The pH of MACP as shown in Fig.1 was higher than MISP at the first 24h of fermentation. The pH of MACP however reduced to 4.00 by 72 h and later rose to 4.5 by 96h whereas the pH of MISP was higher at 48h till 96 h. The increase in pH by MISP might be due to increased activity of protease which would have hydrolyzed protein to

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amines resulting in an alkaline condition of the fermenting medium. The ash content in both mixtures was comparable MACP (0.81%) and MISP (0.97%). The ash content of samples met both the RDA1 and PAG2 requirements.

Table 1 showed proximate chemical composition (%) for MACP and MISP Ash (0.82-0.97), moisture content (10.77-18.14), crude protein (21.14-15.19), lipid (1.95-5.92), fiber (3.59-5.42), carbohydrate (61.74- 54.37) and energy (2738-2424). Results showed comparable ash content in both samples (MACP and MISP Ash (0.82-0.97). Low moisture content is an important preservative factor. The lower moisture content of MACP is indicative of higher dry matter which might be due to increase in soluble solids. Soluble solids are desirable as the food is effectively digested prior to consumption. Also relatively high dry matter (DM) content of both samples might be due to relative hardness and impermeability of the seed coats of pigeon pea present in both mixtures. Except for water, dry matter is positively correlated to starch content and other food elements (Kaguongo et al., 2012). However, the values were significantly (P>0.05) higher than (WHO/FAO/UNU1998) recommended dietary allowance (RDA1) for infants and babies (Kaguongo et al., 2012).

The protein requirement of infants and children is the minimum intake that will allow nitrogen equilibrium (Haque et al., 2013). Proteins are for cell repairs, cellular integrity and function, growth and development and energy reserve in times of energy deprivation. Protein deficiency symptoms manifest as marasmus, kwashiorkor or marasmus-kwashiorkor (Oyarekua, 2013c). Proteins content in sample MACP was 20.36g/100g and significantly (p0>0.5) higher than that of sample MISP with 15.19g/100g. The crude protein in both samples were higher than proposed value for fortified complementary foods of 9.1- 9.9g/100g for 6 to 8mo, and 9.6- 9.9g/100g for 9 to 11 mo and 10.9g/100g for 12 to 23 months (WHO, 1998; WHO, 2000; IOM, 2003).

Crude Fiber: was significantly (p0>0.5) higher in MISP with 5.42% than MACP with 3.58%. Increase in the intake of dietary fibers may increase stool bulk, can cause flatulence and decrease appetite. Fiber load can negatively affect the absorption efficiency of important nutrients from diets (PAHO/WHO, 2003). The dietary fiber which is 1/7 of the crude fiber content and should not exceed 5 g/ 100 g on a DM basis of complementary food (Dewey & Huffman, 2009). Therefore, both mixtures MISP might be desirable in terms of dietary fiber content where MACP had 0.511g/100g and MISP, 0.774g/100g.

Dietary fats provide the infant with energy and essential fatty acids. Fatty acids are essential for adequate growth, immune function, and child development (Dewey, 2005). The crude ether extract content in MISP was significantly (p0>0.5) higher (5.92g/100g) than MACP (1.96g/100g) increased activities of lipolytic enzymes can hydrolyze fat to glycerol and fatty acids (Chapero and Dewey 2010). The amount of fat needed from CF (assuming average breast milk intake) is zero at 6–8 mo, 3 g/day at 9–11 months and 9–13 g/day at 12–24 mo (WHO/FAO/UNU, 1998). The fat content of the two samples were significantly (P0<0.5) lower than RDA for infants (WHO/FAO/UNU1998). Dietary fats are essential for adequate growth, immune function, and child development and provide the infant with energy and essential fatty acids (Suhasini & Malleshi, 2003b).

Carbohydrate value was significantly (p0>0.5) higher in MACP than in MISP. The total carbohydrate content of MACP (62.51%), as shown in Table 1, was significantly (p0>0.5) higher than that of MISP of 54.3%, however, both values met the requirement for infants and

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babies (Kaguongo, 2012). The apparent decrease in carbohydrate of MISP could be due to increased activity of amylolytic enzymes that hydrolyzes carbohydrates to simpler sugars that are easily available to the infant digestive system.

Energy: Energy density from complementary food should be 4 kcal/g on dry weight basis (PAHO/WHO 2003). Low energy density of infant complementary foods has been implicated in protein-energy-malnutrition (PAHO, 2003). Both mixtures have significantly higher ($p>0.05$) energy value than the recommended energy content. The new energy requirements from complementary food are 200, 300 and 550 kcal/100g for ages 6 to 8, 9 to 11 and 12 to 23 mos respectively (WHO/FAO/UNU, 1998). In this study as shown in Table 1, MACP had a value of 2738kcal/100g and MISP, 2416 kcal/100g; these values were significantly higher ($p>0.05$) than the recommended energy content of 400 kcal/100g (on DM basis) required from complementary food (WHO/FAO/UNU, 1998).

Antinutritional factors as seen in Table 2; phytic acid found primarily in unrefined cereals, grains, legumes, are potent inhibitors of these minerals absorption. Phytate: iron molar ratio should be less than one and less than 0.17 for phytate: calcium (Mendoza, 2002). Sample MISP showed a significant increase ($p < 0.05$) in phytic acid than sample MACP; this might be due to increased activities of phytase during fermentation. About 80% of the phosphorus in cereal diet is bound up in phytic acid (the storage form of phosphorus for the plant) and excreted unabsorbed (Golden, 2009). Therefore, the low values of phytic acid in MACP and MISP samples may enhance bioavailability of phosphorus.

MACP had a Phytic acid value of 4.35mg/g and MISP 5.03 mg/g. Phytic acid is a potent inhibitor of some essential minerals (Fries et al., 2004; Torres et al., 2006). The slight increase in phytic acid of MISP might be due to increased phytase activities during fermentation.

Phenols chelate with dietary proteins and iron thereby decreasing protein digestibility and iron absorption. The values of phenols in samples MACP and MISP were lower than that reported for mucuna by (Vadivel & Janardhanan, 2000).

Oxalate contents in MACP and MISP had comparable oxalates values of 0.81mg/g and 0.86 respectively. Oxalates form complexes with dietary calcium.

As shown in Table 2, Tannins differ from other phenols because they precipitate proteins and other macro and micro elements, particularly iron. Tannins interact with saliva proteins giving an astringent sensation which influences palatability. Sample MACP had a value of 2.05% and MISP 1.05%. Excessive consumption of tannins may also lead to anemia (Oyarekua, 2013c).

The values of saponin, alkaloids and flavonoids were all comparable in the two samples.

Gelation Capacity (GC): Ability to form gel is an important factor in viscosity of complementary food processing (Fasasi et al., 2007). In this study, the gelation power decreased more with mixture MACP. The variation in the gelling properties of MACP and MISP may be due to the interactions of different constituents that make up each mixture which may also affect the functional and hydrophobic properties.

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Functional Properties:

Table 4 Proteins and starch are the main contributors in functional properties such as foaming, protein solubility, oil and water absorption and emulsification while fat absorption and emulsion are influenced by protein and fat interaction. Globulin interaction with carbohydrates and lipids is responsible for the gelation capacity (Kerr et al., 2015). WAC: Sample MACP flour had a higher value of WAC (280) than MISP (230) flour. Sample MACP had a higher WAC than that reported for *mucuna veracruz*, and higher LG than *Mucuna rajada* (Adebowale & Lawal, 2004). Fermentation of cereal-legume blend can reduce water absorption capacity which can make gruels prepared from them to have free-flowing consistencies even with a high flour concentration (Oyarekua, 2013c). Thus sample MISP will be more desirable in terms of this attribute.

OAC

The OAC value of samples MACP and MISP were higher than that reported for soybean flour (Mizubuti et al., 2000). The result of this study shows that MACP has more hydrophobic interaction sites than MISP; the difference might be due to disparity in non-polar side chains that bind the hydrocarbon side chains of oil (Adebowale & Lawal, 2004). The flours of MACP and MISP might be useful for favor retention, improved palatability and shelf life extension.

EC: The Emulsion capacities were comparable in both samples. The emulsifying properties are the result of soluble and insoluble protein fractions and like polysaccharides (Torres, 2009). The emulsifying capacity of MISP flour (47.37%) MACP (45.50%) were similar to that reported for sorghum (49%) (Elkhalifa et al., 2005), but lower than that reported for *Brassica carinata* (75.6%) (Pedroche et al., 2004), *Sesamum indicum* (83.0%) and *Vigna subterranean* (78.5%) (Yusuf et al., 2008).

The Emulsion Stability of proteins is related to their ability to reduce the interfacial tension between oil and water in the flour due to increased hydrophobicity. The ES of both MACP (50.0%) and MISP (50.0%) were comparable.

Gelation capacity

The Least Gelation (LG): Sample MACP was 6.0 and MISP 4.0. Variation in may be due to the sizes of proteins, carbohydrates, and lipids. The values of this study were lower than values reported for *Canavalia ensiformis*, *Voandzeia subterranean* and *Mucuna pruriens* by Adebowale and Lawal (2004). Gelation capacity is important in the development and acceptability of many foods.

Protein Solubility

Fig. 2 showed the comparable solubility curve of MACP and MISP. The protein of MACP has highest PS at pH 1-3 and 10-12 while sample MISP has highest PS at pH 6-9. The protein of MACP had higher solubility at acidic pH range of 0-4, and at alkaline region of pH 10 – 12; while that of MISP had higher solubility at pH 5–9, this might be due to higher proteolytic activity during fermentation due to hydrolysis of the storage proteins resulting in increase in PS.

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Amino acids as shown in Table 5. CODEX Alimentarius recommended that the amino acid score should not be less than 70% of that of casein for infants' 6-12 mos old. Methionine, a limiting amino acid in legumes, and lysine, the limiting amino acid in cereals with increase during fermentation (Paredes-Lopez & Harry, 1988). Proteolytic activity of bacteria in traditional fermentations hydrolyze proteins into peptides and amino acids; these are used for protein synthesis therefore while crude protein may not increase during fermentation, but protein quality in the form of amino acids may increase.

Amino Acids values (mg/g-^{1}cp):Arg (MACP 39.00, MISP-33.00), His(MACP 21.00-MISP16.00) Cys (MACP 21.00, MISP-13.00), Trp (MACP 6.00, MISP-7.00) Val (MACP 36, MISP 26) Leu(MACP 77, MISP 26) Met (MACP61.00, MISP-42.00) Phe (MACP 56.00, MISP-3.00)Tyr (MACP-39.00, MISP- 31.00), Isoleu (MACP-48.00- MISP -30.00 respectively.

The most concentrated amino acid was leucine in both MACP and MISP 77.00-62.00 mg/g $^{-1}$cp respectively. The first limiting amino acid in both mixtures was tryptophan while the second was Cysteine for MACP and phenylalanine for MISP.

The total sulfur AA (TSAA) of MACP was 8.2g/100g-^{1}cp and MISP 5.5gg/100g-1cp. MISP had a comparable value 5.8 g/100g-^{1}cp recommended for infants while MACP had a value of 2.68 g/100 g-^{1} cp which is about one-half of the 5.8 g/100g -^{1}cp recommended for infants (FAO/WHO/UNU, 1985).

In MACP the TAA with histidine was 83%, without histidine 77% whereas for MISP with histidine was 37% and without histidine 34%. The value in MACP was well above the 39% considered adequate for infants' complementary food while that of MISP was comparable (FAO/WHO/UNU, 1985).

The suggested patterns of total EAA requirement from literature were (mg/g-^{1}cp): including His: 460 (infant), whereas our own values with Histidine were 305mg/g-^{1}cp for MACP; and MISP 186 mg/g-^{1}cp). The suggested patterns without Histidine were: 434 (infant), whereas our own values without Histidine were for MACP 284mg/g-^{1}cp and MISP 170mg/g-^{1}cp. These values were lower to the required daily intake of amino acids. Histidine is a semi-essential amino acid particularly useful for children's growth. It is a precursor of histamine present in small quantities in cells (Adeyeye et al., 2012).

The values of isoleucine ranged from MACP 48.0 and in MISP 30.0 mg/g crude protein in the samples. Isoleucine and EAA for infants had higher than required values in both samples.

Methionine is an EAA needed for choline synthesis ranging from 61.0 for MACP to 42.0 for MISP mg/g samples respectively. MACP had 21.0 and MISP 13.0 mg/g of cysteine; these values would satisfy the infant's requirement. Phenylalanine, a precursor of some hormones and pigment melanin in hair, eyes and tanned skin was high in MACP with a value of 56.0mg/g and significantly ($P<0.05$) lower in MISP with3mg/g. Valine's value was high in both mixtures MACP, 36 and in MISP 26(mg/g) respectively. The Cys /Cys + Met (%) values were high in the samples MACP was 62% and MISP was 42%. Generally, MACP was more enhanced in amino acids (except in tryptophan) scores than MISP. Cys has positive effects on mineral absorption, particularly Zn (Mendoza 2002).

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The values of histidine in this study were significantly (p0<0.5) lower than RDA of 460 $mg/g^{-1}cp$ with sample MACP having ($21mg/g^{-1}cp$) and MISP (16 $mg/g^{-1}cp$). Valine value of $36mg/g^{-1}cp$ in MACP was comparable to recommended maintenance value of $39mg/g^{-1}cp$ for infants (WHO/FAO.UNU 2007); but lower in MISP with value of 26 $mg/g^{-1}cp$. The Cys/Cys + Met (%) values were high in the samples: MACP and (82), MISP (55), Cys has positive effects on mineral absorption, particularly Zn (Mendosa 2002). Generally, sample MACP was more enhanced in amino acids scores than MISP.

In MACP the TAA with histidine was 83%, without histidine 77% whereas for MISP with histidine was 37% and without histidine 34%.

Table 6 Sensory evaluation is a unique discipline that makes use of experimental design and statistical analysis concepts to human senses, with the aim of evaluating consumer products (Kuenzel et al., 2011).

Sensory Attributes

Sample MISP had the highest score for appearance, which may be explained by the fact that these products experienced the lowest degradation or fermentation, as suggested by the low level of acidity and higher accompanying pH values.

Sensory evaluations use experimental design and statistical analysis concepts to human senses, to evaluate consumer products in terms of aroma, flavor, texture, after taste, and sound properties (Kuenzel et al., 2011). Analysis therefore showed the panelists' scores on the basis of their acceptability and preference for the selected attributes.

Correlation analysis, as well as the Principal Component Analysis (PCA), has been used to measure linear variations between sample variables and reduce a large number of variables to two or three principal components respectively (Panda et al., 2007).

The panelists preferred both the taste and flavor of the fermented products but significantly disliked both on acceptability. In co-fermented samples, there was no significant difference in the test scores on taste, color, texture, aroma and acceptability at $p<0.05$ level of significance. This may be explained by the fact that these products experienced structural degradation through the fermentation process, by expected low levels of acidity. The difference in acceptability recorded here may be a clear pointer to the fact that respondents were not familiar with multiple substrates fermentation products as seen in co-fermented mixtures.

The data in Table 6 rated the products and their control and thus showed the panelists' scores based on their preference on aroma, flavor, texture, after taste and general attributes.

In texture MISP was preferred followed by MACP, the values in unfermented mixtures were low but comparable. This showed that the fermentation process which involved soaking in water, milling, sieving and dewatering might have given a smooth texture which would give a smooth texture for the infant's mouth-feel.

In taste and aroma MACP and MISP had comparable values which were higher than those of those of their unfermented analogues; the higher score of MACP and MISP might have been due to the effect of the metabolic activities of fermenting micro-flora. Generally the panelists

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showed no significant difference in aroma, taste, color and acceptability in MACP and MISP. However the unfermented MACP and MISP had the highest score in acceptability.

The respondents used in this case had a lower appreciation of the product in this regard. This, however, provides an avenue for improving the product by adding sugar.

CONCLUSION

In terms of general acceptability sample MACP was preferred while MISP was preferred in terms of color. Anti-nutritional factors were significantly (p0<05) lower in MISP than in MACP. MISP had higher Protein Solubility (PS%) in the pH range of 1-4, and significantly higher (p0<05) in the pH range of 10-12. MACP had higher PS% in the pH range of 1-4, and significantly higher (p0<05) in the pH range of 10-12. The sample MACP might be useful as infant complementary food.

RECOMMENDATION

Due to the high cost of commercial infant formula, it is important to prepare complementary foods from locally available raw materials with a simple co-fermentation process. The results from this work showed that complementary foods can be prepared from co-fermented maize/carrots/pigeon pea or millet/sweet potato/pigeon pea to meet the macro nutritional needs of infants. However, certain aspects like the detailed genetic microbial activities during co-fermentation and bio-availability of nutrients needs investigation.

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APPENDIX

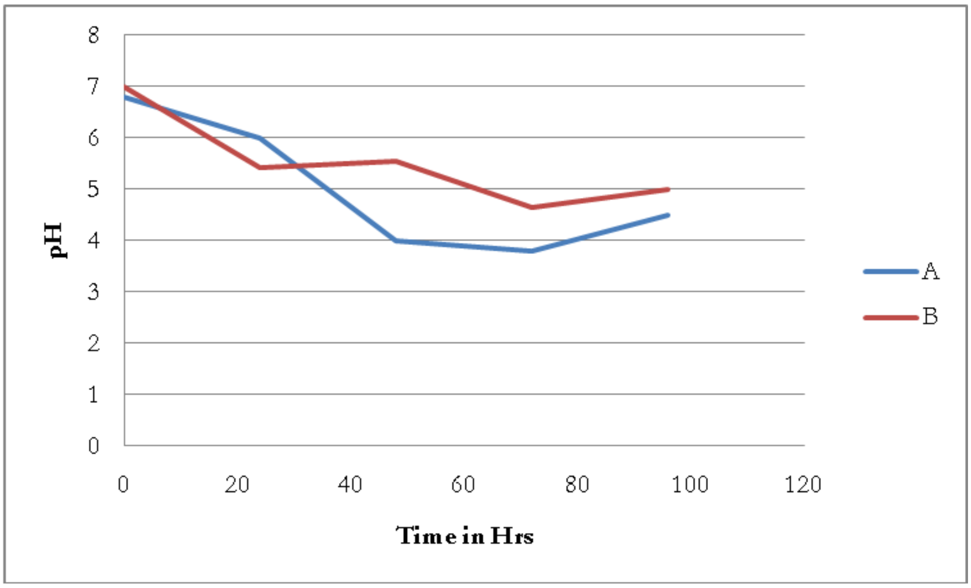

Fig 1: pH changes during co-fermentation involving components of MACP (A) and MISP (B).

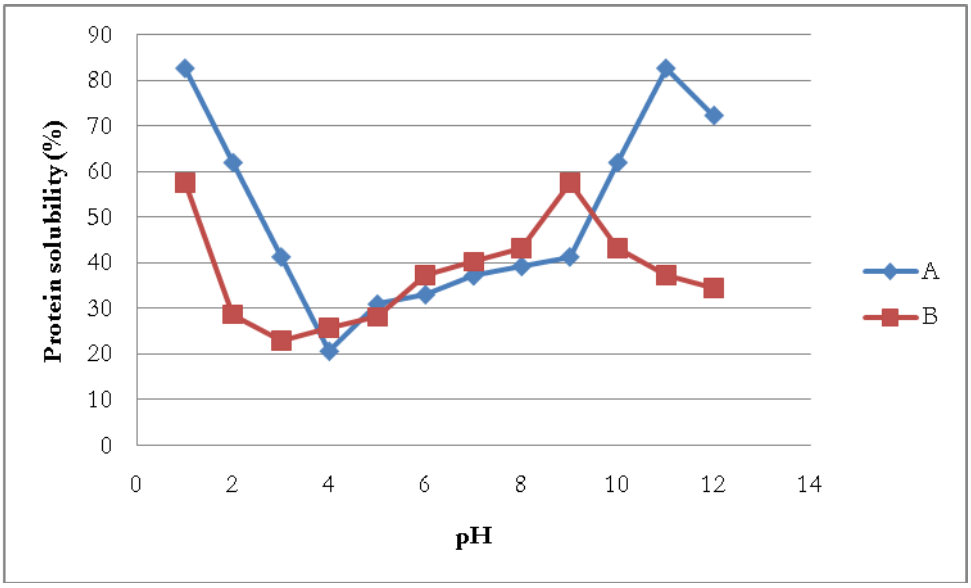

Fig 2: Protein Solubility Curve of MACP (A) and MISP (B)

Key: A=MACP, B=MISP

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Table 1: Proximate Composition of MACP and MISP.

Sample	%Ash	%Moisture content	%Crude protein	% fat	% Fibre	Dietary Fibre	%CHO	Energy KCal/ 100g
MACP	0.81	10.78	20.36	1.96	3.58	0.511	62.51	2738
MISP	0.97	18.14	15.91	5.92	5.42	0.774	54.37	2416

Table 2: Antinutritional Factors Contents of MACP and MISP

Sample	TA	Phenol	Saponin	Alkaloid	Flavanoid	PA	Oxalate	CN mg/kg
MACP	2.05	1.02	2.25	1.15	0.35	4.35	0.81	1.27
MISP	1.10	0.48	2.36	1.12	0.28	5.03	0.68	1.28

Table 3: Value of Functional Properties (%) of MACP and MISP

Sample	WAC (%)	OAC (%)	FC (%)	FS (%)	EC (%)	ES (%)	Least Gelation (W/W)
MACP	280	279.30	ND	45.50	45.50	50.0	6.0
MISP	230	255.5	ND	47.37	47.37	50.0	4.0

Table 4. Amino acids profile of MACP and MISP

Amino Acids	MACP	MISP	Mean	Standard Deviation
Arg	39	33	36	4.24
His	21	16	18.5	3.54
Cys	21	13	17.0	5.7
Trp	06	07	6.50	0.71
Val	36	26	31.00	7.07
Leu	77	62	69.50	10.61
Met	61	42	39.00	12.73

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Ile	48	30	51.50	13.44
Phen	56	03	29.50	37.48
P-PER 1	35.07	31.65		
P-PER 2	34.38	30.96		
TAA	365.00	498.50		
TEAA with His	305.00	186.00		
TEAA without His	284.00	170.00		
Cys/cys +Met (%)	62	42		
TSAAA/% Met +cys	8.2	5.5		

Table 5: Sensory Evaluation for Scores for MACP and MISP

Sample	Colour	Texture	Taste	Aroma	Acceptability
MACP	5.12^{a}	5.90^{b}	6.60^{c}	7.10^{c}	4.60^{b}
MISP	5.30^{b}	6.40^{c}	6.70^{c}	7.60^{d}	4.11^{a}
MISP = Control)	5.90^{c}	4.10^{a}	5.80^{b}	6.10^{b}	5.40^{c}
MACP= Control)	5.10^{a}	4.11^{a}	5.30^{a}	5.90^{a}	6.00^{d}

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