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EFFECT OF CO-FERMENTATION ON NUTRITIVE QUALITY AND PASTING PROPERTIES OF MAIZE/COWPEA/SWEET POTATO AS COMPLEMENTARY FOOD

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ABSTRACT

Traditional complementary foods based on cereals have inadequate nutrients required by infants. This study developed a co- fermentation process of maize (50%), cowpea, (30%) and sweet potato (20%w/w) to produce a complementary food for infants. The control was fermented whole grain maize. Gruel of fermented cereal is called 'ogi' in Yoruba native language of south-west Nigeria. Analyses of proximate composition, minerals, amino acids and ß-carotene contents were done using standard methods. Pasting properties were determined using Rotatory Viscometer. Crude protein content was higher in maize/cowpea/sweet potato ($p > 0.05$) than fermented maize but both values were lower than Recommended Daily Allowance (RDA) for complementary infant food. Most of the amino acids (AA) analyzed were higher in co-fermented mixture. Total AA were higher in co-fermented mixture than maize but lower the standard: egg reference protein of 556mg/g crude protein (cp). Fermented maize had higher calcium, magnesium, potassium and sodium contents than co-fermented mixture: This might be due to the utilization of these minerals by the various microbes in the co-fermented mixture for their metabolic activities however the values in both samples met RDA for 9-11months old infants, and are in excess for 11-23months old. The K/Na ratio was lower in both samples than recommended ratio value of 0.61. In Mineral Safety Index (MSI); magnesium, calcium, sodium, zinc, iron and copper were comparable to recommended MSI value for infants aged 6-23 months. The calcium and iron values in both samples were lower than RDA value based on nutrient need from complementary food by level of usual breast milk intake. Co-fermentation of maize/cowpea/sweet potato reduced some essential minerals, increased crude protein and total amino acid contents. Carotenoid value in co-fermented mixture was comparable to estimated need from complementary foods level of usual breast milk intake for 11-23 months infant, while maize carotenoid value was comparable to that of 6-8 months old infant. Essential minerals values in both samples met the requirement for 9-11months.The MSI for magnesium, sodium, zinc and copper in co-fermented mixture met the RDA for 6-23 months. Co-fermentation of maize/cowpea/sweet potato resulted in a product of improved nutritional quality than fermented maize.

Key words: Co-fermentation, maize, cowpea, sweet-potato, ß-carotenoid

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INTRODUCTION

Nigeria National Food Consumption and Nutrition Status Survey (NFCNS) (2004) showed that 43% of children under 5 years of age were stunted, 10% wasted, 36% are underweight and 29.5% vitamin A deficient (VAD)[1]. Cereal-based traditional complementary foods commonly fed to infants are inadequate to meet daily nutrients and energy requirements, while infant formula foods are too expensive for mothers of low socio-economic status. [2]. Mothers also regard incorporation of vitamin A capsule as a supplement into complementary food as extra-labor. Staple foods such as maize, cowpea and white-fleshed sweet potatoes have low retinol activity [3] Vitamin A deficiency are associated with xeropthalmia, skin, hair diseases, growth retardation and impaired immune system [4, 5, 6]. ProvitaminA (carotenoid) found in colorful orange-fleshed sweet potato makes these foods a healthy complement to young children's diets. Infant food of more than 20% concentration (w/v) is too thick for an infant's gastric system while if lower than 20% (w/v), might be low in energy and nutrient densities[7].

Cowpea (*Vigna unguiculata* (L) Walp) has methionine as the most limiting amino acid. Fermentation has been reported to improve nutritive value of cowpea [8]; however, fermentation of cowpea legumes is not popular in Nigeria. Maize *(Zea mays)* is the third widely cultivated cereal produced in Nigeria. Sweet potato *(Ipomean batatas)*, another major staple Nigeria food also grows best in sub-humid regions with rainfall between 1000-2000 mm and temperature of 25-32^{o}C. It is consumed as boiled or fried chips [9]. Raw orange-fleshed sweet potatoes have anti-nutritional factors (ANF), which interferes with calcium absorption [10]. They also have predominance of *trans*-β-carotene than *cis*-β-carotene. Their tubers contain storage protein, copper, and dietary fiber. Fermentation removes the ANF because microbial phytase can hydrolyze phytate during fermentation [11].

The objectives of this study were to enrich nutrient contents and improve the nutritional quality of the traditional infant complementary food by co-fermenting maize, cowpea and sweet potatoes tubers in ratios of 60:20:20, respectively; compare nutritional values and pasting qualities of the co-fermented mixture with that of fermented maize and also to assess the nutritional quality of the co- fermented mixture as a complementary infant food.

MATERIALS AND METHODS

Biological materials

Dry grains of maize, cowpea and orange-fleshed tubers of sweet potatoes were obtained at a local market in south-west, Nigeria. The research analyses were performed at the laboratories of Institute of Agricultural Research and Training, Ibadan and University of Jos, Nigeria.

Samples Preparation

Maize and cowpea grains were sorted and winnowed. Five hundred grams maize was mixed with 300g cowpea and 200g of longitudinally-quartered small pieces of sweet potato. The mixture was soaked in water1:3 w/v for 72 hours milled using Semotec mill Model 900, dispersed in water, sieved with Muslin cloth of about 300µm pore size; left in water for 24 hours and filtered. Filtrate was dried at 60°C for 12hr, milled and sieved to obtain flour. One kilogram of maize grains were subjected to same treatment as above. Both samples were stored at -4°C before proximate, carotenoid and pasting properties analyses. Values reported for each test were mean averages of duplicates.

METHODS

pH and Titratable Acidity (TA)

pH and TA of fermenting samples were monitored at every 24 hr till 72hr of fermentation as described by Official Analytical Chemists(AOAC) [12], by mixing100ml Millipore water mixed with 10 ml of fermentation aliquot and pH measured with pH meter (Model HM-305, Tokyo, Japan). In TA determination, another 10 ml of fermenting aliquot was titrated against 0.1M sodium hydroxide to phenolphthalein end point. The TA was calculated as mg lactic acid/100g.

Proximate Composition

Crude fiber, lipid and moisture contents were determined using the method described by AOAC, 2005 numbers 962.09 and 920.39, 925.10, respectively [13].Carbohydrate was calculated by difference by subtracting the sum of percentage moisture content, crude fiber, lipid and ash from 100.

Moisture content (MS)

One gram of sample in pre-weighed crucible was placed in oven (105°C) for 24hr, cooled and reweighed. The Percentage moisture was calculated thus:

$$\text{Moisture (\%)} = \frac{W_2 - W_3}{W_2 - W11} \times 100$$

where: W_1 is weight of crucible W_2 the weight of crucible after drying at 105 °C and sample W_3 the weight of crucible and sample after cooling in an airtight desiccators.

Crude Protein

Crude protein was determined using micro-Kjeldahl method as described by Pearson [14]. Ten ml H_2SO_4 added to 3g of sample was digested with Kjeldahl digestor (Model Bauchi 430) for $1^1/_2$ hr. Forty ml water was added and distilled using Kjeldahl distillation Unit (Model unit B – 316) containing 40% concentrated sodium hydroxide and Millipore water. Liberated ammonia was collected in 20 ml boric acid with bromocresol green and methyl red indicators and titrated against 0.04N sulphuric acid. A blank (without sample) was likewise prepared. Percent protein was calculated as:

$$\frac{\text{Sample titre - blank titre} \times 14 \times 6.25 \times 100}{\text{Sample weight}}$$

Where 14 is nitrogen molecular weight and 6.25 is the nitrogen factor.

Crude Fiber

One gram of defatted sample in a weighed crucible was attached to the extraction unit (in Kjeldahl, D-40599,behr labor-Technik GmbH, Dusseldorf, Germany) into this 150 ml of hot 1.25% sulphuric acid and digested for 30 min**,** the acid was drained and sample washed with hot distilled water for $1^{1}/_{2}$h. Crucible was removed and oven dried overnight at 105°C, cooled, weighed and ached at 550°C in a muffle furnace (MF-1-02, PCSIR labs. Lahore, Pakistan) overnight and reweighed after cooling. Percentage extracted fiber is calculated as:

$$\frac{\text{Weight of digested sample} - \text{Weight of ashed sample x 100}}{\text{Sample weight}}$$

Lipid

Lipid was estimated using TecatorSoxtec (Model 2043(20430001), 69, Slandegarupgade, DK-3400, Hilleroed, Denmark). A 1.5 g sample mixed with 2.3g anhydrous sulphate was weighed into thimble and covered with absorbent cotton; while 40 ml of petroleum ether (40° C - 60° C Bpt) was added to pre-weighed cup. Both thimble and cup were attached to the Extraction Unit. Sample was extracted using ethanol for 30 min and rinsed for $1^{1}/_{2}$hr. Thereafter, the solvent was evaporated from the cup to the condensing column. Extracted fat in the cup was then placed in oven at 105°C for 1hr cooled and weighed. Percent fat was calculated as:

$$\frac{\text{Initial Cup Weight} - \text{Final Cup Weight}}{\text{Sample weight}} \times \frac{100}{1}$$

Ash

Ash and Mineral contents were determined according to AOAC numbers 923.03 and 984.27 [15].

Two gram of sample added into pre-weighed crucible was incinerated in muffle furnace at 600°C.

$$\text{Moisture (\%)} = \frac{W_2\text{-}W_3}{W_2\text{-}W11} \text{ x } 100$$

where: W_1 is the weight of cleaned, dried, ignited and cooled crucible W_2 the weight of crucible and sample after incinerating at 600 °C and W_3 the weight of crucible and sample after cooling in an airtight desiccator.

Minerals (Cu, Zn, Mn, Mg and Fe)

One gram of sample was digested with nitric/ perchloric/sulphuric acids mixture in ratio 9:2:1 respectively and filtered. Filtrate was made up to mark in a 5 ml in volumetric flask. Filtered solution was loaded to Atomic Absorption Spectrophotometer, (model703 Perkin Elmes, Norwalk, CT, USA). The standard curve for each mineral was prepared from known standards and the mineral value of samples estimated against that of standard curve. Sodium and potassium values were determined using Flame photometer (Sherwood Flame Photometer 410, Sherwood Scientific Ltd. Cambridge, UK).

Mineral Safety Index (MSI)
MSI is a numerical statement of the minimum toxic doses of minerals. The MSI for Na, Ca, Mg, Fe, Cu, Zn are 4.8, 10, 15, 6.7, 33 and 33, respectively while the Recommended Infant Intake (RII) are 400, 400, 80, 10, 0.65 and 6, respectively.

MSI Calculation:

$$\frac{\text{MSI X Value of mineral in sample}}{\text{RII}} = \text{MSI}$$

Amino acids (AA)
AA of sample each was determined according to the method of FAO/WHO [16].In which about 5-10 µl of defatted and vacuum-dried residue was analyzed using Technicon Sequential Multisample Amino Acid Analyser (TSM), (Technicon Instruments Corporation, New York) was used for the analysis. Analysis period was 76 min and column flow rate was 0.50 ml/min at 60^{o}C with reproducibility consistent within ±3%. Net height of each peak produced by the chart record of TSM was measured and calculated for the amino acid it represented. Tryptophan was not determined.

AA quality parameters
Calculations of AA, total AA, predicted protein efficiency ratio (P-PER); Ratio of total essential AA (TEAA) to the total AA (TAA), (TEAA/TAA); total aromatic AA (TArAA) were as described in [17].

Carotenoid Analysis
Carotenoid analysis was carried using the method of Rodriguez-Amaya and Kimura [18]. This involved extraction with cold acetone using a mortar and pestle, partitioned to petroleum ether and taking the absorbance at 450 nm.

Calculation

$$\text{Total carotenoid content } (\mu g/100g) = \frac{\text{A x Vol. (ml) x}10^4 \text{ X } 100}{A^{1\%}_{1cm} \text{ x Sample wt (g)}}$$

Total carotenoid content (µg/100)/6 = µg RE/100g

Where: A= absorbance, Vol. = 50ml $A^{1\%}_{1cm}$=Absorbance co-efficient of β-carotene in PE (2592)

Viscosity
A 3g sample dissolved in 25ml distilled water was heated steadily from 25°C to 95°C, held for 15 minutes and cooled to 50°C. The cooked paste viscosity of the slurry was determined using Rapid Visco Analyser (RVA) (Model TM Super-3 Analyzer Newport Scientific PTY Ltd. 1998 ½ -Apollo st., Warriewwood MXW 21-02 Australia). Pasting temperature, peak paste, viscosity, time to peak, temperature at

peak, hot and cold paste viscosity, breakdown, set back and final viscosity were recorded.

Statistical analysis

Comparisons of data between samples were subjected to analysis of variance [19] with a probability level of $p \leq 0.05$.

RESULTS

pH and Titratable Acidity (TA)

pH of co-fermented mixture dropped from about 7.0 to 3.8 within the first 24hr then rose to 5.0, 4.5 at 48 hours and 72 hours respectively (Table 1), that of fermented maize decreased from about 6.5 to 5.0, 5.5 and 4.0 at 24hours, 48hours and 72hours respectively. Decrease in pH of co-fermented maize/cowpea with fermentation time had been reported [20]. Titratable acidity (TA) increased from 0.0135mg/g to 0.17mg/g for fermented maize and that of co-fermented samples increased from 0.014 mg/g to 0.153mg/g. Acidity of the fermenting medium of each sample was affected by fermentation.

Proximate Composition

Table 2, the ash content of co-fermented mixture (0.50g/100g) was higher than that of fermented maize (0.32g/100g). Protein content of the mixture was significantly higher ($p > 0.05$) with a value of 10.7g/100g than fermented maize of 6.7g/100g.

Lipid content was significantly ($p > 0.05$) higher in fermented maize with a value of 2.30g/100g than in co-fermented mixture (0.75g/100g). Crude fiber value was also higher in fermented maize with 3.42g/100g compared to co-fermented mixture of 1.74g/100g. Generally, moisture, lipid and fiber contents were higher in fermented maize than in co-fermented mixture. See Table 9.

Minerals: In Table 3, co-fermented mixture had significantly ($p > 0.05$) higher content of calcium (60.7 mg/100g), sodium (10.1 mg/100g) than fermented maize. However, fermented maize had higher magnesium (12.4 mg/100g), potassium (8.7 mg/100g) and zinc (0.85 mg/100g).The values of manganese, iron and copper were comparable in both samples. See Table 9.

AA profile

In Table 4, AA values of phenylalanine, leucine, isoleucine, valine, cystine methioninie, alanine and threonine, arginine, lysine and histidine were better concentrated in co-fermented mixture while fermented maize had higher contents of aspartic and glutamic acids. However, Glu and Asp were the two most concentrated AA in both samples. Isoleucine value was 149 mg/g crude protein (cp) in maize/cowpea/sweet potato which was higher than RDA value of 46 mg/gcp and that of fermented maize. The values of leucine in both samples were higher than the recommended dietary allowance (RDA) value of 93 mg/g cp. Methionine plus

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cystine values in both samples were lower than RDA values of 42 mg/gcp; the value was significantly ($p > 0.05$) higher in the co-fermented mixture. See Table 9.

In Table 5, the PER of co-fermented mixture was 131.7mg/g cp was significantly ($p > 0.05$) higher than 73.73mg/g cp. Total Essential Amino Acids (TEAA) calculated includes histidine and arginine (essential for infants growth) and excluded cysteine and tyrosine. TEAA in co-fermented sample was 823mg/g cp and was lower than ($p \leq 0.05$) 841mg/g cp fermented maize. TArAA was 129mg/g cp in co-fermented mixture significantly ($p > 0.05$) higher than 51mg/g cp. The AA score as shown in table 6 showed co-fermented mixture having higher scores in all the amino acids except in acidic amino acids and serine where fermented maize had higher scores. See Table 9.

Carotenoid

Co-fermented mixture had a significantly ($P<0.05$) higher value of 297.0 µRE/100g than that of fermented maize of 164.3 µRe/100g (table 7). Orange-fleshed sweet potato is rich in carotene (mainly trans-beta-carotene**)** and might have contributed to higher value of carotenoid in the co-fermented mixture. Since the value in the co-fermented mixture met the RDA for 11-23 months old, it might be desirable as a vitamin A source for infants. See Table 9.

Viscosity

Values obtained for setback, peak 1, setting, breakdown, setback temperature viscosity at 95°C, final viscosity, viscosity at 50°C as shown in table 8, were higher for fermented maize than that of co-fermented mixture. Co-fermentation of maize with sweet potato and cowpea reduced to 145.25 RVU (RVU is the unit measurement in using Rapid Visco Analyser) compared to that of fermented maize of 192.33 RVU. See Table 9.

DISCUSSION

The Recommended Daily Allowance (RDA) referred to in this work was based on complementary food consumption of 275ml/day, 450ml/day for between 6-8months, 9-11months and 11-23 months old, respectively [21].

The rapid decrease within the first 24 hours in the pH of co-fermented mixture may be due to availability of more nutrients for microbial proliferation and enhanced metabolic activities, (Table 1) and also cultivation and hybrid of maize, cowpea grains and sweet potato tubers used. The acidic nature of the products of both samples could be due to the production of lactic acid by microorganism associated with maize dough fermentation [22]. In this study, co-fermented mixture increased the acid production which is desirable for souring and acceptability of product. Early production of acid and the consequent rise in TA is important to avoid proliferation of undesirable organisms. The increase of TA with fermentation time is in agreement with the report that TA increased with fermentation time in co-fermentation of maize/cowpea using starter cultures [20].

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Cowpea must have been a major contributor of higher protein content increase of the co-fermented mixture as shown in Table 2.The values of proteins in all the samples however did not meet the 14g/100g protein recommended for complementary foods for 6-12 month old infants. There is a correlation between VAD and protein malnutrition (PEM) because the transport of retinol across different organ is made possible by retinol-binding protein (RBP) [23]. Therefore, β-carotenoid from sweet potato in this work may increase RBP synthesis. Protein deficiency, therefore, may lead to decreased synthesis of RBP.

The higher lipid content in fermented maize as indicated in table 2 might be due to greater water absorption capacity in the matrix of maize, which could have reduced in co-fermented mixture. This reduction might also be due to the presence of cowpea and sweet potato. The absorption of vitamin A and its precursors is conditioned by fats therefore in fermented maize there might be more emulsified particles of β-carotene in the intestine's microvillus for absorption [24].

Table 3 indicates that values of calcium and iron in both samples were comparable to RDA for 9-11 months infants on low breast milk intake. Calcium is needed for bone and teeth formation while iron is needed in blood cells formation proper growth and oxygen circulation. Retinol alone or with retinoic acid is required for the synthesis of the iron transport protein transferring. Deficiency of calcium leads to rickets in infants while deficiency of iron, may lead to anemia, depressed growth and neuro-psychomotor development [25], the values of both minerals in this work might be desirable for infants. The manganese levels in both samples met the RDA for 6-23 for infants at low to high breast milk intake. Consumption of any of the two samples might help in proper functioning of the spinal cord because manganese deficiency leads to defective growth of central nervous systems. Magnesium value of fermented maize compared favorably with the nutrient need of 6-23 months at low to high breast milk intake, contrary to the low value in the co-fermented mixture. Zinc value in fermented maize met the desired nutrient density for 6-8 months old) on low breast milk intake while that of co-fermented mixture that of 12-23 months based on average breast milk intake. Zinc is necessary for protein and blood formation and to maintain vitamin A concentration in plasma. Values of sodium and potassium in both samples were 4-8foldslower than the RDA average of 44.3mg/100g.Therefore the products of this work might not meet the electrolyte balance in infants' plasma, if no additional supplement like fruit, salt, honey or milk is added. The calculation of MSI based on the values in Table 3, Showed that the MSI of sodium, calcium, magnesium iron, copper and zinc were comparable to the MSI value for infants.

Amino Acids

The lower values of these acidic amino acids in co-fermented mixture may be due to buffering action of alkaline condition which might have been from cowpea.

Methionine + cysteine are the limiting amino acids in legumes thus sweet potatoes or/and maize must have contributed to the level of increasing methionine + cysteine contents in the co-fermented mixture. Cystine, which acts as a sparring partner in methionine synthesis has positive effect on zinc absorption thus making consumption of the mixture desirable.

In table 4, the high values of glutamic and aspartic acids in both products showed that the two acids might be by-products of microbial fermentation which might affect the flavour of the products. Arginine, histidine and lysine which are essential amino acids for a child's growth [26] were higher in co-fermented sample than fermented maize. However, arginine, histidine and lysine in both values were lower than 6.3g/100g of reference egg protein and RDA value of (6.6g/100g). Leucine constituted the highest single essential amino acid (EAA) in both samples, this finding agrees with the report that leucine content had highest values of EAA compared to other amino acids in raw, roasted and cooked groundnut (*Arachis hypogaea*) seeds[17].

The higher P-PER value in co-fermented mixture than fermented maize this might make the co-fermented mixture to be superior in terms of protein quality and bioavailability to the fermented maize. Total essential amino acids (TEAA), contents in both samples were lower than the value for egg reference protein (56.6 g/100 g cp) [17], although they will need to be supplemented when used as gruels. Total amino acids, (TAA) of co-fermented mixture (2135 mg/g cp) was lower than that of fermented maize (2273mg/g cp), and both higher than in dehulled African yam beans (AYB) with values of 703-918mg/ g cp [17].

The ArAA of co-fermented mixture 129mg/g cp was close to range suggested for ideal infant protein (68-118m g/ g cp). The ArAA are precursors of epinephrine and thyroxin. The percentage ratios of TEAA to TAA in the samples were 38.5% (in co-fermented mixture) and 37.0% (in fermented maize) respectively. The TEAA/TAA values in both samples were close to 39% considered to be adequate for ideal protein food for infants [17]. The TEAA in both samples had a value greater than 1 when compared to recommend of 350mg [16]; this imply that there was no limiting amino acids in both samples based on these results**.**

The Results of the amino acid scores of both samples were compared suggested patthen of requirement on preschool children (2-5 yeas). Lysine had the least % CV while valine had the highest. Threonine and Met + Cys had similar values; histidine had comparable value to leucine.

Results of the amino acid scores of both samples are shown in Table 6. Lysine had the least %CV while valine had the highest. Threonine and Met+Cys had similar values; histidine had comparable value to leucine.

Carotenoid: The co-fermented mixture in table 7 had a significantly ($P<0.05$) higher value of 297.0 µRE/100g than that of fermented maize of 164.3µRe/100g. Orange-fleshed sweet potato, which is rich in carotene (mainly *trans*-beta-carotene**)** must have contributed to the higher value of carotenoid in the co-fermented mixture. Since the value in the fermented mixture met the RDA for 11-23months old, it will be desirable as vitamin A source for infants. Carotenoids susceptibility to degradation during the drying process of the fermented products might have caused reduction in carotenoids content of the co-fermented mixture because of isomerisation from *trans*-carotenoids (normal configuration in nature) to *cis*- carotenoids may have occurred[27].

WHO/FAO/UNU 1998 recommended 300 µgRE, 400 µgRE and 500 µg RE for 1-3years, respectively and nutrient needs from complementary foods by level of usual breast milk intake in µg RE are as follows: Low (164), Average (13), High (0) for 6-8months old; for 9-11months Low (214), Average (42), High (0); for 12-23months old at Low (313), Average (126) and High (0). From this study, co-fermented mixture might meet the vitamin A need for 12-23 months old children based on low breast-milk intake while fermented maize had comparable value for that of 6-8 months old children based on low breast-milk intake. (The categories Low, Average and High correspond to breast-milk intake (g/d).

From table 8, it can be deduced that fermentation increased the swelling capacity of starch component and hot paste viscosity of the fermented maize. [28].The diameter and covalently bonded phosphate monoester groups of potato starch granule could have given a higher paste viscosity. In this study, fermented maize gruel had higher peak viscosity and final viscosity than co- the co-fermented mixture. Reduction in viscosity of co-fermented gruel could be due to a slightly greater breakdown of the paste during cooking, protein-starch interaction and amylose-lipid formation or due to differences in starch granules, size and composition of the co-fermented raw materials with the protein part contributing to giving lower paste viscosity. This agrees with the finding that supplementation of maize flour with bambara ground nut (*Vigna subterranean* L.) reduced the peak viscosity of the product [29].

The statistical results on Table 9 showed that, all parameters in both samples except Beta-carotene, pH & TTA were significantly different $P < 0.05$.
The co-fermented '*ogi*' gruel in this work could be desirable as infants' complementary food in terms of its low viscosity which by implication might be high in nutrients and energy density.

CONCLUSION

The co-fermentation of maize/cowpea/sweet potato had significant influence on the acid production, crude protein content and amino acids profile and also led to reduction in viscosity which might give higher energy and nutrient densities. The β-carotenoid level improved in co-fermented mixture than fermented maize. The co-fermentation process in this study is easy and cost-effective and can be applied locally especially by low-socio economic mothers to improve the nutritive quantity and quality of infant complementary food. The co-fermented product compared well with RDAs and thus can contribute to reduction of malnutrition in infants.

RECOMMEDATION

Although the mixture gave higher values of some amino acids needed for child's growth, there is need for its fortification with foods that are rich in vitamins and minerals like ground crayfish or milk without compromising the low viscosity and nutrient density of the co-fermented mixture.

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Table 1: Changes in pH and Titratable Acidity during the steeping stages of fermented maize and co-fermented maize/cowpea/sweet potato

	pH changes		Titratable Acidity changes	
Time (h)	Maize/cowpea/sweet potato	Fermented maize	Maize/cowpea/sweet potato	Fermented maize
0	7.0	6.5	0.0135	0.014
24	3.8	5.0	0.011	0.0126
48	5.0	5.5	0.0143	0.0163
72	4.5	4.0	0.017	0.0153

Table 2: Proximate composition (g/100g DM) of co-fermented maize/cowpea/sweet potato and fermented maize

Fermented sample	Ash	Protein	MS	lipid	Fiber	Carbohydrate (by difference)
Maize/Cowpea/ sweet potato	0.50	10.7	6.51	0.75	1.74	79.54
Maize	0.32	6.7	87.20	2.30	3.42	78.54
Mean	0.41	8.7	90.35	1.525	2.58	79.04
S.D	0.127	2.828	4.448	1.096	1.188	1.41
CV %	30.975	32.505	4.923	65.573	73.178	1.783

Key: S.D = Standard Deviation, C.V = Coefficient of variation

Table 3: Minerals (mg/100g content of co-fermented maize/cowpea/sweet /potato and fermented maize

Fermented Samples	Ca	Mg	K	Na	Mn	Fe	Zn	Cu
M/C/ S P	60.7	5.2	3.8	10.1	2.2	3.2	0.19	0.07
M	29.6	12.4	8.7	5.6	1.7	3.8	0.85	0.077
Mean	45.15	8.8	6.25	7.85	1.95	3.5	0.52	0.078
S.D	21.99	5.09	3.46	3.18	0.35	0.42	0.47	0.001
CV (%)	48.70	57.84	55.36	50.51	17.95	12.00	9.04	1.28

KEY: Ca=Calcium; Mg= Magnesium; Na=Sodium; Mn =Manganese; Fe= Iron; Zn=Zinc Cu=Copper

M/C/SP= Maize/Cowpea/Sweet Potato; M= Fermented Maize; SD Standard Deviation

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Table 4: The amino acid profile of co-fermented maize/cowpea/sweet potato and fermented maize (g/100gcp)

Amino acid	Co-fermented Maize/Cowpea/Sweet potato	Fermented Maize	Mean	S.D	CV (%)
Lysine	1.03	0.82	9.25	1.485	16.054
Histidine	1.21	0.85	10.3	2.546	24.718
Arginine	2.19	1.89	20.4	2.121	10.397
Aspartic Acid	2.70	3.57	31.35	6.152	19.623
Threonine	1.13	0.61	8.7	3.677	42.264
Serine	0.30	0.41	3.55	0.778	21.915
Glutamic Acid	7.80	9.54	86.7	12.30	14.186
Proline	0.61	0.51	5.6	0.707	12.625
Glycine	1.25	1.15	12.0	0.707	5.891
Alaninie	2.32	0.80	15.6	10.70	68.589
Cysteine	0.79	0.33	5.6	3.253	50.089
Valine	1.30	0.61	9.55	4.879	51.089
Methionine	0.50	0.36	4.3	0.990	23.023
Isoleucine	1.78	1.01	13.95	5.445	39.032
Leucine	3.06	1.75	24.05	9.263	38.515
Tyrosine	0.64	0.50	5.7	0.990	17.368
Phenylalanine	1.29	0.51	9.0	5.515	61.277

Key: SD = Standard Deviation

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Table 5: Determination of amino acids quality parameters (g/100 g) of co-fermented maize/cowpea/ sweet potato and fermented maize

Sample	P-PER	%*TEAA	%TAA	TEAA/TAA	%TArAA
Co-fermented Maize/cowpea/sweet potato	0.854	92.10	299.0	0.499	3.14
Fermented maize	0.274	14.90	251.9	0.344	1.93

Key: P-PER = Predicted protein efficiency ratio; *TEAA = total essential amino acids including arginine; TAA = total amino acids; TEAA/TAA = ratio of total essential amino acids to total amino acids; TArAA = total aromatic amino acids.

Table 6: The amino acid scores of co-fermented maize/cowpea/sweet potato and fermented maize (mg/gcp) using the standard for pre-school children 2-5y

Amino acid	Co-fermented Maize/Cowpea/Sweet potato	Fermented Maize	Mean	STD	%CV
Lysine	0.178	0.141	0.1595	0.026	16.4
Histidine	0.637	0.447	0.542	0.134	24.79
Threonine	0.332	0.179	0.256	0.108	42.26
Valine	0.371	0.174	0.273	0.139	51.03
Met+Cyst	0.516	0.276	0.396	0.169	42.86
Isoluecine	0.640	0.361	0.500	0.197	39.46
Leucine	0.463	0.301	0.382	0.115	29.99
Phenyl +Tyr	0.290	0.160	0.450	0.092	20.43

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Table 7: Beta-carotenoid content (µgRE/100g of co-fermented maize/cowpea/ sweet potato and fermented maize

Fermented Sample	β-Carotene (µg/100g)	β-Carotenoid (µRE/100g)
Maize	986.3	164.3
Maize/Cowpea/Sweet Potato	1782.5	297.0
Mean	**1384.4**	563.0
S.D	**230.65**	93.83
CV %	16.660	**16.630**

Key: SD = Standard deviation

Table 8: The pasting properties of co-fermented maize/cowpea/sweet potato and maize 'ogi'

S/N	Peak 1	Trough 1	Breakdown	Final Viscosity	Setback	Peak Time	Pasting Temperature (^{0}C)
M	138.667	127.417	11.250	192.333	64.917	6.066	93.500
M/C/SP	100.83	94.917	5.917	145.250	50.333	6.733	95.000
Mean	119.75	111.17	8.584	168.79	57.63	6.399	94.25
S.D	26.75	22.98	3.771	33.29	10.31	0.472	1.061
CV (%)	22.338	20.67	43.931	19.722	17.889	7.376	1.125

Key:M= Fermented maize; M/C/SP = Co-fermented maize/cowpea/sweet potato

Table 9: Statistical Analysis of the results

Results source	r_{xy}	r_{xy}^2	C_A (%)	IFE (%)	Table value	Remark
Table 1 (pH Changes)	0.7980	0.6369	60.26	39.74	0.950	NS
Table 1 (Titratable Acidity)	0.7477	0.5590	66.41	33.59	0.950	NS
Table 2 (Proximatecomposition)	0.9973	0.9947	7.30	92.7	0.811	S
Table 3 (Minerals)	0.9303	0.8654	36.69	63.31	0.707	S
Table 4 (Amino Acid profile)	0.9572	0.9162	28.93	71.07	0.482	S
Table 5 (Quality parameters of AA)	0.9995	0.9990	3.24	96.76	0.878	S
Table 6 (Amino Acid Scores)	0.9370	0.87787	34.95	65.05	0.514	S
Table 7 (Beta carotenoid content)	0.3587	0.1287	93.34	6.66	0.997	NS
Table 8 (Pasting properties)	0.9825	0.9653	18.61	81.39	0.754	S

Key:P= 0.05 and n-2 degree of freedom or simply put $r_{0.05,\ n-2}$

NS = Not Significant, S = Significant, C_A = Co-efficient of Alienation, IFE = Index of Forecasting Efficiency.

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