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Co-fermentation of Cassava/Cowpea/Carrot to Produce Infant Complementary Food of Improved Nutritive Quality

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Abstract: This study conducted co-fermentation of cassava 50%, cowpea 30% and carrot 20% w/w for the production of infant complementary food. Analyses on proximate, minerals, amino acids and β-carotenoid contents were carried out using standard methods. Cassava ogi had lower crude protein content than cassava/cowpea/carrot ogi. Leucine and lysine contents were comparable in both samples. Crude protein, total amino acids values increased. Cassava ogi had higher calcium, magnesium, potassium and sodium contents than cassava/cowpea/carrot ogi. The K/Na ratio was lower in both samples than recommended ratio of 0.60. Values of essential minerals in both samples met the requirement for 9-11 months. Methionine plus cystine, histidine and isoleucine values were higher in cassava/cowpea/carrot ogi than cassava ogi. The carotenoid value in co-fermented mixture was comparable to RDA from complementary food value for 11-23 months infant. Co-fermentation of cassava/cowpea/carrots gave values of improved nutritional quality than fermented cassava ogi.

Key words: Co-fermentation, cassava, cowpea, carrots, β-carotenoid, amino acids

INTRODUCTION

Children need vitamin A for physical growth, eye sight and for immunity against infection and disease. In Nigeria, cereal-based traditional infant foods do not contain enough nutrients, micronutrients and energy densities to meet infant's daily requirements. Forty- three percent of children under 5 are stunted, 10% wasted, 36% underweight and 29.5% of surveyed children were vitamin A deficient (Maziya-Dixon *et al*., 2004; Unicef, 2003). Complementary foods must have ease of preparation affordable price and meet the Infant's nutritional requirements (Wieringa *et al*., 2003). Socio-economic status mothers still see vitamin supplements as pharmaceuticals, extra-labor and cost. Nigeria is rich in cereals, cowpea and cassava but vitamin A activity of these foods in form of provitamin (β-carotene) is low (Shamin *et al*., 2003). Therefore, there is need for food-food fortification with locally available raw materials using traditional process like fermentation. Soaking of cassava at temperature between 30-35°C is reported to be best for submerging fermentation process and can be improved by co-fermenting with cowpea (Office of International Affairs National Research Council, 1992).

Nigeria is the largest consumer and producer of cassava (*Manihot esculenta Crantz*) products and it is cheap, common and easy to prepare. It can be fortified without changing the taste and texture. Research in Nigeria, had been on fortification of cassava flours and meals with micronutrients (Asonye, 2003). Traditional cassava processing is time consuming, provides low yields and lack storage capacity. Nutritionally, cassava can be processed with other protein-rich crops like cowpea and carotenoid rich foods like carrots to improve its nutritional quality.

Raw cassava is toxic therefore must be processed into various forms to increase the shelf life and improve its nutritional quality can also be improved through fortification with other protein-rich crops like cowpea and carotenoid rich vegetable like carrots. Carrots according to Tang *et al.* (2009) can provide significant amount of vitamin A even though the amount is not as great as previously proposed. Also, the roots of some cassava varieties contain significant concentrations of beta-carotene (vitamin A), co-fermenting cassava with cowpea might be a powerful way to improve the health of vast numbers of poor people at low cost. According to Livnyl *et al.* (2003) zinc plays a role in converting carotene to retinol.

Production of organic acids like lactic and formic acids and the lowering of substrate pH is associated with cassava fermentation during first stage of *gari* production. In the second stage, the acidic condition stimulates the growth of *Geotrichum candida*, causing further acidification and production of a series of aldehydes and esters that are responsible for the taste and aroma of *gari* (Odunfa, 1985). However, not much work has been done in co-fermentation of cassava with legumes and vegetables. This work investigated the co-fermentation process.

The black-eyed cowpea (Vigna unguiculata L. Walp.) is an important food legume Nigeria. Dry cowpea has little vitamin. Methionine is its most limiting amino acid. Although, fermentation improve the nutritive value of cowpea (Fields, 1980), the process is not popular in Nigeria.

Vitamin A plays on important role in light dark visions when the cells of the eyes cannot quickly readjust to dim light, this is called night blindness. Vitamin A is needed to repair mucosa damage resulting from diarrhea. Vitamin A Deficiency (VAD), predominant in preschool children in Africa (WHO, 1992), is caused by the presence of low serum levels of vitamin A and when the plasma retinol concentrations is less than <0.70 mmo L^{-1}). (Maziya-Dixon *et al.*, 2004) and can result in pathological defects of heart, lung, parasitic infestations and diarrhea disease (Grubesic, 2004). McLaren and Frigg (2001) reported a correlation between (VAD) and protein malnutrition (PEM) in malnourished children. Traditional processes like excessive cooking of vegetables may affect the stability of vitamin A and β-carotene. In traditional home preparation, loss of carotenoid and bioconversion increase during sun-drying and boiling. Increase in cis-isomer was reported during heating of carrot juice. However, Food fortification is one of the key strategies recommended by WHO, UNICEF and International Vitamin A Consultative Group) to eradicate VAD.

Malnourished infants can be expected to have multiple deficiencies (Wieringa *et al.*, 2003). It is necessary to choose an appropriate food vehicle and to set safe and adequate levels of the nutrients and micronutrients to be added. In this study traditional co- fermentation of cassava with cowpea and carrots might be a powerful way to improve the health of vast numbers of infants at low cost. This might offer a significant low cost and sustainable food process to reduce micronutrient deficiency . This research also evaluated the nutritional, antinutritional and micronutrients adequacies expected from complementary foods.

MATERIALS AND METHODS

Materials

Fresh cassava tubers, dry grains of cowpea and fresh carrots were obtained from a local market in Ado-Ekiti, South-West area of Nigeria. The study was conducted at the Laboratories of Federal Polytechnic, Ado-Ekiti, University of Jos, Jos and the Institute of Agricultural Research and Training, Ibadan all in Nigeria: in July to September 2008.

Sample Preparation

Raw cassava and carrots were peeled and cowpea (*Vigna unguiculata*) grains were winnowed. Five hundred grams of the peeled cassava was mixed with 300 g cowpea and 200 g peeled carrots (*Daucus carota*), soaked in water in ratio 1:3 for 3 days and there after milled using clean grinding machine. Ground fermented mixture was later sieved. Filtrate was left for 24 h for further fermentation. During fermentation process, physicochemical parameters were monitored with time. At the end of fermentation, sediment was dried at 60°C and subjected to proximate composition, minerals, amino acids, tannin content and carotenoid analyses. Peeled cassava, serving as control, was subjected to the same treatment as co-fermented mixture.

Determination of Dry Matter and Proximate Composition

Standard methods of the Association of Official Analytical Chemists (AOAC, 2005a) were used to determine the dry matter and proximate composition of the samples. The analyses were done in triplicates. The pH of the slurry mixed was noted and recorded. Titrable Acidity (TA) was according to AOAC (2005b). Determination of minerals was determined according to AOAC (2005a).

Amino acids profile was determined by using the method described by Speckman *et al.* (1958) done using Amino Acid Analyzer: Tecnicontsm-1 Model dns 0209.

Determination of Antinutritional Factors

Tannin was determined according to AOAC (2005a).

Determination of Vitamin A

Determination of Vit. A was determined according to standard method AOAC (2005b).

$$\beta\text{-Caortenoid}\left(\frac{\text{ug}}{100\text{g}}\right)=\frac{\text{Absorbance of sample}\times\text{gradient factor}\times 10}{\text{Wt. of sample}\times 1000}$$

Conversion

- 6 mg of β-carotene = 1 retinol equivalent = 1 mg retinol
- 12 mg of other biological active carotenoids = 1.1 retinol equivalent

Viscosity Measurement

A 3 g of sample on (dry matter basis) was dissolved with 25 mL distilled water, the slurry was heated uniformly from 25 to 95°C, held for 15 min and cooled at the same rate to 50°C. Cooked paste viscosity of the slurry was determined with the Rapid Visco Analyzer (RVA). Sample was assessed for pasting temperature, peak paste, viscosity, time to peak, temperature at peak, hot and cold paste viscosity, breakdown, set back and final viscosity. The precise linear ramped heating and cooling abilities of the RVA along with steady state temperature control allow careful control of cooking environment whilst changes in viscosity were continuously recorded.

Statistical Analysis

Comparison of data between samples among the means of triplicates readings of experimental results obtained were subjected to Analysis of Variance (ANOVA) with a probability level of (p>0 .0 5 using Statistical computer program (StaSoft Inc., 1999).

RESULTS

The co-fermented mixture had its pH value drop from about 6.35 to 3.83 within the first 24 h to 3.88 at 72 h. For fermented cassava the pH of the fermented product also from about 6.30 to 5.4 at 24 h and at 48 h and to 4.7 at 72 h. Analysis of variance of the data indicates that fermentation time and nature of raw materials affect their pH. The Titratable Acidity (TA) increasing from 0.047(g lactic acid/100 g dry sample) to 0.17(g lactic acid/100 g dry sample) for co-fermented samples and fermented cassava increased from 0.023 to 0.14 mg g^{-1}. Analysis of variance of the data showed that fermentation and co-fermenting maize with cowpea and sweet potato affect the acidity of the fermenting medium (Table 1).

Ash content of both samples were comparable and both values lower than 5% recommended by FAO (1992). The dry matter contents were also comparable in both samples. Co-fermented mixture had a value of 9.88 g/100 g while fermented cassava had 9.86 g/100 g. Values of proteins in all the samples did not meet the 14 g/100 g digestible protein per liter recommended for complementary foods in 6-12 months infants. Co-fermentation did not increase the crude protein of the ogi mixture compared to fermented cassava.

The values of crude fiber in this study were comparable in both samples; 1.63 g/100 g in co-fermented mixture and 1.48 g/100 g in fermented cassava. But both lower than 4 mg/100 g recommended for 6-12 months infants (Table 2).

In Table 3, Cassava ogi had higher values of calcium, magnesium, sodium and manganese than co-fermented sample. While the values of Zinc and copper were comparable in both samples.

Tannin value was low and comparable in both samples. Fermentation might have significantly reduced the tannin content.

Some minerals especially when taken in large amount can result in abnormally high levels in the blood. The values of calcium were lower than recommended MSI in both samples; while the values of magnesium, sodium zinc and copper were comparable to recommended MSI values (Table 4). However, iron values were comparable in fermented cassava and cassava/cowpea/carrot; both were lower than MSI values.

$$\text{Mineral safety} = \frac{\text{Tabulated mineral safety index}}{\text{Index}} \times \text{Value of mineral in sample}$$

Recommended Adult Intake of Mineral

Co-fermented mixture had higher values of essential amino acids like histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine and valine

Table 1: Changes in pH and titrable acidity (g lactic acid/100 g dry sample) of co-fermented cassava/cowpea/carrot and cassava *ogi* over fermentation time

		Fermentation time (h)			
Fermented sample	Parameter	0	24	48	72
Cassava/cowpea/carrot	pH	6.35	3.83	3.88	3.84
	Titrable acidity	0.047	0.036	0.028	0.18
Cassava	pH	6.30	5.40	4.50	4.70
	Titrable acidity	0.023	0.010	0.011	0.14

Table 2: Chemical proximate composition of cassava ogi and cassava/cowpea/carrot ogi (g/100 g)

Sample	Ash	Moisture	Protein	Fat	Fiber
Cassava/cowpea/carrot ogi	0.559	5.66	9.88	3.12	1.63
Cassava ogi	0.343	1.21	9.86	9.59	1.48

Table 3: Minerals and tannin contents of cassava and cassava/cowpea/carrot *ogi* (mg/100 g)

Sample	Ca	Mg	K	Na	Mn	Fe	Zn	Cu	Tannin
Cassava/cowpea/carrot ogi	44.9	3.8	2.8	7.5	1.4	2.1	0.11	0.054	1.2
Cassava ogi	53.4	4.9	3.8	9.8	2.0	2.9	0.17	0.073	1.1

Table 4: Mineral Safety Index (MSI) of cassava and cassava/cowpea/carrot ogi (mg/100 g)

	Ca			Mg			Na			Fe			Zn			Cu		
Sample	Tv	Cv	D	Tv	Cv	D	Tv	Cv	D	Tv	Cv	D	Tv	Cv	D	Tv	Cv	D
A	10	1.1	8.9	15	0.71	14.3	4.8	0.09	4.7	6.7	1.4	5.3	33	0.61	32.9	33	2.7	30.1
B	10	1.3	8.7	15	0.92	14.1	4.8	0.12	4.7	6.7	1.9	4.8	33	0.94	32.1	33	3.7	29.3

A :Cassava/cowpea/carrot ogi, B: Cassava ogi, TV: Tabulated value, CV: Calculated value, D: Difference between calculated value and tabulated value

Table 5: The amino acids profile of cassava and cassava/cowpea/carrot ogi (mg g^{-1} Cp)

Amino acid	Cassava ogi	Cassava/cowpea/carrot ogi
Lysine	92	
Histidine	79	
Arginine	207	285
Aspartic acid	205	316
Threonine	80	135
Serine	30	60
Glutamic acid	1007	863
Proline	41	183
Glycine	89	149
Alaninie	44	204
Cystine	46	73
Valine	90	156
Methionine	47	81
Isoleucine	89	149
Leucine	158	254
Tyrosine	64	79
Phenylalanine	77	111

and also had higher values of non-essential amino acids like alanine, arginine, glycine, proline, serine, tyrosine. However, fermented cassava glutamic and aspartic acids (Table 5).

Leucine might depress isoleucine which with other factors is a contributor to pellargra disease resulting from consumption of cereals like sorghum. The values of leucine in both co-fermented samples were higher than the recommended dietary allowance (RDA) value of 93 mg g^{-1} Cp from infant complementary food. Isoleucine value was 149 mg g^{-1} Cp in cassava/cowpea/carrot and higher than RDA value of 46 mg g^{-1} cp and than that of fermented cassava. Methionine and cystine values were higher in co-fermented cassava/cowpea/carrot than that of fermented cassava.

The histidine value was higher in co-fermented cassava/cowpea/carrots than in fermented cassava.

Arginine which is an essential amino acid for child's growth, had comparable values in both samples. The lysine contents were also comparable.

In Table 6 the values of carotenoid (RE) were higher in co-fermented sample with 10.12 μg RE than in fermented cassava ogi with 6.50 μg RE. The value of co-fermented mixture was comparable to the recommended value of 8.2 mg/100 kcal for 12-23 months while that of fermented cassava was comparable to RDA (for 6-12 months) from complementary foods.

Values obtained for set back, peak 1, trough 1 (setting), breakdown, set back (gelatinization) temperature viscosity at 95°C, Final Viscosity, Viscosity at 50°C were

Table 6: β-carotenoid value of cassava and cassava/cowpea/carrot ogi

Sample	Value 1 mg/100 g	Value 1×6 (RE)
Cassava/cowpea/carrot ogi	1.687	10.12
Cassava ogi	1.084	6.50

Table 7: Pasting properties of fermented cassava and co-fermented cassava/cowpea/carrot ogi

Sample	Peak1	Trough1	Breakdown	Final viscosity	Setback	Peak time	Pasting temp
A	159.917	106.25	53.667	171.75	65.5	5.133	93.65
B	162.833	112.5	50.333	186.17	73.667	5.333	94.55

A:Fermentred cassava ogi, B:Co-fermented cassava/cowpea/carrot ogi

lower for fermented cassava than that of co-fermented mixture (Table 7). Starch stability reduction in co-fermented samples indicates a slightly greater breakdown of the paste during cooking. The final viscosity of fermented cassava reduced to 171.75 compared to that of co-fermented mixture of 186.17CFU.

DISCUSSION

The Recommended Daily Allowance (RDA) in this work was based on complementary food consumption of 275 mL day^{-1} for 6-8 months old; 450 mL day^{-1} for 9-11 months old and 750 mL day^{-1} for 11-23 months old WHO (1998).

The pH of all samples decreased with fermentation time and nature of raw materials. The decrease was more significant ($p<0.05$) in co-fermented mixture within the first 24 h as compared to that of fermented cassava. This might be due to the production of lactic acid produced and type of microorganism associated with the fermentation. In this study co-fermented fortified mixture increased the acid production. This was also probably due to availability of more nutrients for microbial proliferation and enhanced metabolic activities. This early production of acid and the consequent rise in TA is important to avoid proliferation of some pathogenic micro-organisms.

However, the titrable acidity increased with fermentation time. Increase was more pronounced in co-fermented after 72 h. The pH of fermented cassava was 0.023 g/100 g lactic acid at pH of 6.3 and 0.14 g/100 g lactic acid at pH of 4; this was contrary to the finding of Oyewole and Odunfa (1992) who reported 0.08 g 100 g lactic acid at pH of 6.3 and 0.36 g/100 g lactic acid fermented cassava at pH of 4.0. It has been reported that titrable acidity of co-fermented cereal/cowpea mixture increased with fermentation time (Oyarekua *et al*., 2008).

The dry matter of co fermented mixture (100-9.88 moisture content) was 94.3 g 100 g which was higher than the value (93.34 g 100 g) reported for co-fermented pearl millet/cowpea blend by Zanna and Milala (2004) and for co-fermented maize, soybean, cowpea, ground bean and melon seeds (Egouinlety, 2002). There was no significant difference in protein value in this study and this is contrary to the finding of Uche *et al*. (2009) who reported that fortification of cassava with soybean extract increased the protein content of cassava.

Lipid content was significantly ($p>0.05$) higher in fermented cassava than co-fermented cassava/cowpea/carrots ogi this might be due to greater water absorption capacity in the matrix of cassava. The absorption of vitamin A and its precursors is conditioned by fats (Ribaya-Mercado, 2002). Therefore, the low fat content in co-fermented mixture in this study, might lead to low absorption and limited bioconversion which may limit the vitamin A activity.

The decrease in tannins is desirable in view of its ability to adversely affect protein digestibility. Even though tannin has antioxidant activity and can be of potential health benefits.

Lysine content was higher in co-fermented mixture than fermented cassava but both were lower than RDA value (66 mg) for infant complementary food. Histidine which is essential for infant growth, was higher in co-fermented cassava/cowpea/carrots ogi (164 mg g^{-1} Cp) than in fermented cassava ogi (82 mg g^{-1}Cp). When allergens enter the tissue histidine is liberated in large quantities (Adeyeye and Faleye, 2004). However, the value of histidine in cassava/cowpea/carrots 164 mg g^{-1} Cp was comparable to RDA value from complementary food for 11-23 months old infants; while that of fermented cassava ogi (85 mg g^{-1} Cp) was lower.

High values of glutamic and aspartic acids in both products were by-products of microbial fermentation which might affect the flavour of the products. The values were higher in fermented cassava ogi than in co-fermented mixture this might be due to the alkalinity effect from the protein analogue of cowpea in the co-fermented mixture. Values of leucine in co-fermented (254 mg g^{-1} Cp) and fermented cassava (175 mg g^{-1}Cp) ogi samples were higher than the Recommended Dietary Allowance (RDA) value of 93 mg g^{-1} Cp from infant complementary food. Isoleucine, Methionine plus cystine value was 154 mg g^{-1} cp in cassava/cowpea/carrot, ogi and was higher than RDA value of 46 mg g^{-1} cp and fermented cassava of 69 mg g^{-1} Cp. Methionine and cystine are considered the limiting amino acids in legumes thus carrot or/and cowpea must have contributed in increasing methionine contents. However, methioninie plus cystine values in both co-fermented mixtures were higher than RDA values of 42 mg g^{-1} cp required for infant complementary foods. Methionine is needed for lecithin formation when diet is low in protein resulting in Protein Energy Malnutrition (PEM). Thus consumption of both products may result in excess methionine in relation to the RDA value. Cystine can act for part requirement of methionine. Arginine which is an essential amino acid for child's growth, was higher in co-fermented ogi mixture 285 mg g^{-1} Cp than fermented cassava of 189 mg g^{-1} Cp.

Protein energy malnutrition is increasingly being regarded not as deficiency of protein and energy only, but of some nutritionally important minerals which are components of key enzymes. The body uses mineral ions as electrolytes to help regulate, the distribution, composition and acidity of its fluids. Of these ions are sodium and chloride found outside the cells. While potassium, magnesium and phosphorus are found inside the cells (Whitney *et al*., 1990). Several researchers had reported loss of minerals during the fermentation production of ogi (Akingbala *et al*., 1981). Vitamin A or β-carotene may form a complex with iron, zinc, copper, lipids and proteins.

Zinc is necessary to maintain normal concentration of vitamin A in plasma. Zinc deficiency impairs efficiency of vitamin A from liver. Zinc also contribute to the synthesis of Retinol Binding Protein (RBP) which is responsible for transport of vitamin A (Livnyl *et al*., 2003). Zinc is one of the metalloenzymes in the metabolism of vitamin A. Zinc deficiency diminishes the activity of retinol oxidase (which converts retinol to retinoic acid). Zinc is a limiting factor in the growth of severely malnourished infants.

Since, the micronutrients are incorporated from the raw material during the processing, iron will not have any inhibitory effect on zinc absorption since inhibitory effect may be significant if micronutrient is in form of supplement. The value of zinc in this study which ranged between 0.11-0.17 mg g^{-1} may not lead to significant increase in length of 3-5 year old within 6 months as reported by Rosaldo *et al*. (1997). The deficiency can lead to loss of appetite, failure to grow. In this study showed the zinc values were comparable in co-fermented carrot/mixture ogi and fermented cassava ogi as control. Wieringa *et al*. (2003) and Livnyl *et al*. (2003) observed zinc plays a role in converting carotene to retinol.

Infants needs about 10 mg/100 g of iron. Non heme iron is provided from plant and animal and it is less efficiently absorbed than heme iron. The values of zinc in the two samples were lower than average RDA (4.7 British or 2.08 Krebb's standards) from complementary foods for 11-23 months.

Infants need iron to meet the need for red blood cells synthesis, respiration and growth. Deficiency of iron can be mild when iron store is low in the body, can be severe when it is low in the blood levels of heamoglobin resulting in anemia or the deficiency can be extended if the iron is depleted from the iron store in the bone marrow and liver resulting in anaemia. Among the symptoms of iron deficiency are depressed growth and neuro-psychomotor development. Excessive high levels of iron (not in plasma) can cause toxic damage to tissues and symptoms of kwashiorkor. In this study iron content is slightly higher in fermented cassava than in co-fermented ogi mixture might be due to utilization of iron by microbes in the fermenting medium. However, excess iron can lead to iron poisoning in children (Adeyeye and Falaye, 2004). Iron values in this study were however lower than average RDA of 17.8 mg/100 g (low breast milk intake) 9.13 mg/100 g (medium breast milk intake) and 5.8 mg/100 g (High breast milk intake) expected from complementary foods.

Retinol and/retinoic acid are required for the synthesis of the iron transport protein transferring (Devlin, 2006) according to Subharno *et al*. (1993), supplementation with iron and vitamin A can virtually eliminate nutritional anemia.

In this study the values of calcium and magnesium decreased in co-fermented mixture this is contrary to the finding of Oyewole and Odunfa (1990) that fermentation release bound calcium and magnesium.

Calcium is needed for bone and teeth formation and its deficiency can lead to rickets in infant and children. Calcium in this study is also higher in fermented cassava ogi than in co-fermented ogi mixture. However, the values of all samples will adequately meet the calcium needs 295 mg day^{-1} from complementary foods (WHO, 1998) for ages 9-11 months (Average need based on daily consumption of 250 mL day^{-1}) and in excess of the required calcium (average of 295) content needed for 11-23 months (based on daily consumption of 750 mL day^{-1}).

Magnesium is needed for more than 300 different enzymes systems in the body. Human body has a remarkable capacity to conserve magnesium. In this study, magnesium content is also higher in fermented cassava ogi than co-fermented mixture may be because some microbes in the fermenting medium have utilized magnesium to activate their enzymes. Magnesium and potassium values in both values were significantly ($p>0.05$) too low to meet the recommended daily allowance for 6-23 months; Both samples in this work have abundance of calcium (449-607 mg) higher than 525 mg required in complementary foods for 6-12 months and 350 mg day^{-1} for 12-23 months day^{-1}. Potassium values were comparable in both samples. But sodium is higher in fermented cassava than co-fermented ogi mixture. Sodium is the major cathion of fluids in the body cells. Sodium and potassium ratio of 0.60 is recommended. In this study, the ratio was 0.40. The sodium values of both samples in this study was 3-4 fold lower than recommended value of sodium needs from complementary food for ages 6-23 months. Copper is for blood formation. It is needed for the manufacture of haemoglobin and the red blood cells. According to Adeyeye and Falaye (2004) copper supplement improved food intake and weight gain of children recovering from severe malnutrition. The copper content were comparable in both samples and higher than average RDA from complementary foods. Copper deficiency is of little concern since it is widely distributed in plant foods.

It helps in skeletal development and proper functioning of the brain and spinal cord. Deficiency can lead to defective growth abnormalities. Manganese is a component of key some enzymes. The values of both samples were comparable to the recommended daily requirement (15.2 μg) for 11-23 months old (WHO, 1998). Ash content was low and comparable in both samples. Fermentation process especially sieving and dewatering stages might have reduced the ash content of both samples.

The carotenoid value of co-fermented mixture in this study was lower than RDA average value of 96.8 μg RE day^{-1} for 6-23 months based on 750 mL day^{-1} while that of fermented maize. Carotenoids have susceptibilities to degradation during the heat treatment or the release of organic acids during fermentation process due to isomerization from trans-carotenoids (normal configuration in nature) to *cis*- carotenoids occurs (Rodiquez, 2002).

The low values of carotenoids in cassava ogi might be due to carotenoids susceptibility to degradation during heat treatment or the release of organic acids e.g., during fermentation process because isomerization from trans-carotenoids (normal configuration in nature) to *cis*-carotenoids might have occurred.

According to Rodriguez-Amaya (2002), *cis*-isomers increased during heating of carrot juice. In home traditional sun-drying also causes considerable carotenoid destruction. Exclusion of oxygen, protection from sunlight, low-normal temperature (like in fermentation) diminish carotenoid decomposition during storage, also normal cutting, shredding, chopping, pulping of fruits and vegetables increase exposure to oxygen and sun-drying bringing about loss of carotenoids (Rodriguez-Amaya, 2002).The significantly (p0>0.5) higher value of β-carotenoid in co-fermented mixture must have been contributed from the carrot component this is contrary to the finding of sulaeman (2001); who reported that fermentation reduce carotenoid content of carrot.

Fermentation increases the swelling capacity of starch component and hot paste viscosity of the fermented product (Osungbaro, 1990). Difference in viscosity of different starches could be due to: Protein-starch interaction, amylose-lipid formation. The diameter and covalently bonded phosphate monoester groups of potato starch granule could give a higher paste viscosity. However, in this study fermented cassava had higher peak viscosity and final viscosity than co-fermented mixture this might be due the difference in starch granules, size and composition of the materials in the co-fermented mixture; this finding also agreed with Sokari (1992), who reported that co-fermentation of cassava and soybeans had significant effect on peak and final viscosities.

CONCLUSION

Co-fermentation of cassava/cowpea/carrots ogi appear to improve the nutritional quality of cassava ogi in terms of carotenoid (RE) and crude protein and in total amino acids (excluding tryptophan, cysteine and tyrosine) and reduced viscosity. While, fermented cassava ogi had higher values in all the essential minerals.

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