African Journal of Food Science. Vol (2) pp. 136-142, December, 2008
Available online http://www.academicjournals.org/ajfs
ISSN 1996-0794 ©2008 Academic Journal

Full Length Research Paper

Nutritional evaluation of four optimized cassava-based complementary foods

O. O. Onabanjo[1, 2]*, C. R. B. Oguntona[1], Bussie Maziya-Dixon[2], I. O. Olayiwola[1], E. B. Oguntona[3] and A. G. O. Dixon[2]

[1]Department of Nutrition and Dietetics, University of Agriculture, Abeokuta, Ogun State, Nigeria,
[2]International Institute of Tropical Agriculture, Ibadan, Oyo State, Nigeria,
[3]Department of Animal Nutrition, University of Agriculture, Abeokuta, Ogun State, Nigeria.

Accepted 02 December, 2008

Complementary foods were formulated and their nutritional composition analyzed from three yellow and one white cassava varieties. The composites were analyzed for proximate, mineral, fatty acids and amino acids. The mean values for the proximate composition of the diets are moisture (41.4 g kg^{-1}) wet weight, ash (47.4 g kg^{-1}), crude protein (145.8 g kg^{-1}), crude fat (106.7 g kg^{-1}), crude fiber (21.1 g kg^{-1}), total carbohydrate (633.5 g kg^{-1}), and energy (409.2 kcal). The diets supplied adequate amounts of most minerals, except iron (about 65% of the standard). The composites contained all the essential amino acids with adequate chemical score for most amino acids. The complementary diets contained moderate to high proportions of α-linolenic acids (18:3n3) and a high proportion of linoleic acid (18:2n6), which resulted in a high total n-6/total n-3 ratio and a high linoleic/ α-linolenic acids ratio. Micronutrient improved cassava varieties can be effectively used to formulate complementary food as acceptable micronutrients supplement.

Key words: micronutrient-improved, cassava, complementary foods, children.

INTRODUCTION

Childhood malnutrition is widely prevalent in many parts of the world, particularly in the developing countries like Nigeria (UNICEF, 2006). Protein, energy and micronutrient malnutrition are the commonest form. The period from birth to 2 years of age is a critical period for the promotion of optimal growth, health, and behavioral development. Studies in Nigeria have indicated a high prevalence of malnutrition among under-five children of which inappropriate breastfeeding and complementary feeding practices coupled with high rates of infectious diseases are the principal proximate causes of malnutrition during the first two years of life (NFCNS, 2003; NDHS, 2003).

Breast milk is the perfect food for the infant during the first 6 months of life (UNICEF, 2006), because it contains all the nutrients and immunological factors an infant requires to maintain optimal health and growth. However, at about 6 months, the supply of energy and some nutrients from breast milk is no longer adequate to meet an infant's needs, hence, need for complementary food (WHO/UNICEF, 1998; Dewey, 2003; Dewey and Brown, 2003). The amount of nutrients required from complementary foods depends on the quantity provided by human milk and varies markedly by nutrient, ranging from nearly 100% for iron to 0% for vitamin C. The calculation of the nutrients required from complementary foods is based on the recommended intake for each nutrient minus the amount of the nutrient consumed daily from human milk (WHO/UNICEF, 1998; Dewey and Brown, 2003). The adequacy of complementary diet to meet nutrient requirements depends on the nutrient content of foodstuff used in the formulation. The food-based dietary guideline for Nigeria has recommended the use of available foodstuff in various communities and home levels to prepare nutritious diets for infants and children.

Cassava, soybean, groundnut and carrot are readily available foods in Nigeria. They have promising nutritional attributes. Cassava is one of such staples with potential to meet this requirement, especially in the sub-Saharan Africa. The importance of cassava to the livelihoods of many millions of poor people has made the

*Corresponding author. E-mail: oonabanjo@cgiar.org.

commodity a target for interventions. New Partnership for Africa Development (NEPAD) has adopted the slogan "Cassava: A Powerful Poverty Fighter in Africa" for its Pan-African Cassava Initiative. The normal white tubers contain only small amounts of β-carotene (Bradbury and Holloway, 1998), but yellow cassava contains up to about 100 times as much (McDowell and Oduro, 1993). In addition, cassava leaves are good sources of β-carotene and are consumed as vegetables in many parts of the Third World, especially in the Democratic Republic of Congo, and Senegal. Cassava could be a vehicle for delivering micronutrient-rich food to alleviate deficiencies. Use of multimix might help to ensure nutrition security in infants and young children. The nutrient potentials of the food (cassava, soybean, groundnut and carrot) make it imperative that scientific studies be made on their composite for possible use as complementary food. The purpose of the study was to formulate and analyze the nutritional composition of complementary foods micronutrients improved (3 yellow and one fleshed) cassava varieties.

MATERIALS AND METHODS

Characteristics of raw ingredients

Cassava roots and leaves (*Manihot esculenta)*, soybean *(Glycine max.*), groundnut *(Arachis hypogaea*), and carrot (*Daucus carota*) were used to formulate four composite diets. The cassava roots and leaves, and soybean were obtained from the experimental fields of the International Institute of Tropical Agriculture, (IITA) Ibadan, Nigeria. Groundnut and carrot were purchased from local markets in Ibadan.

Cassava roots were peeled manually with a stainless steel knife, washed thoroughly with potable water to remove all dirt and adhering sand particles. The roots were then grated into mash using a stainless steel grater driven by a petrol engine, packed into Hessian sacks, and dewatered immediately using a hydraulic press to express liquid from the mash as well as to prevent fermentation. The mash was then sieved manually with a stainless steel sieve to pulverize the pressed cake and separate fibrous materials. The resulting flour was dried in an oven dryer at 40^0C, and milled using a stainless steel milling machine before being packaged into polyethylene bags and stored at a cool dry room at -20^0C.

Soybean and groundnut were cleaned and roasted in a preheated stainless steel pot on an electric stove for 15 min. The roasted seeds were dehulled manually by rubbing gently with hand and winnowed to remove the hulls. The dehulled seeds were then ground into fine flour with a domestic grinding machine. Cassava leaf flour was obtained by washing fresh leaves and pressing them between the palms to remove excess water. The leaves were heat-treated in an empty dry pot, placed over a source of heat. The leaves were tossed constantly with a wooden spoon to ensure even distribution of heat for 5 min. The heat–treated leaves were pounded in a wooden mortar for 30 min. The pounded leaves were put in twice their weight of water, gradually brought to a boil, and cooked for 1 h 30 min. The processed leaves were dried at 60^0C for 48 h, milled, and stored in air-tight zip-lock bags until analysis (Bokanga, 1994). The carrot powder was obtained by washing the carrot roots with water and then slicing and drying them at 40^0C, and milling them into flour with a stainless steel milling machine. Lastly, the processed food commodities were analyzed for their chemical proximate and mineral composition, fatty and amino acids profile and diets formulated based on the WHO/FAO Codex standard (FAO/WHO, 1991).

Formulation of composite flours

The composite flours were formulated by blending all the ingredients in different proportions using the Owl Tech Wizard Software^{TM}, Version 3 to develop and optimize the different formulations. The composite flours of the four complementary foods were formulated based on the optimization given by the software as follows:

Diet 1: Cassava root (variety 01/1371), 67%: soybean, 14.7%: groundnut, 10.5%: cassava leaves, 5.3%: carrot, 2.5% (w/w).
Diet 2: Cassava root (variety 01/1235), 67.6%: soybean, 13.5%: groundnut, 10.5%: cassava leaves, 5.7%: carrot, 2.7% (w/w).
Diet 3: Cassava root (variety 94/0006), 67.7%: soybean, 14.1%: groundnut, 9.7%: cassava leaves, 5.7%: carrot, 1.8% (w/w).
Diet 4: Cassava root (variety TME 1), 68.9%: soybean, 13.8%: groundnut, 9.3%: cassava leaves, 5.7%: carrot, 2.3% (w/w).

Chemical analysis

The composite flours were analyzed for their proximate composition, minerals, amino acids, and fatty acids profile to ascertain their conformity with the standards.

Proximate composition

Standard procedures (AOAC, 2005) were used to determine the moisture content, crude fat, fibre and ash content, crude protein (N * 6.25) by (HACH, 1990), and total carbohydrate (Dubois et al., 1956) from total starch and sugar. Energy value was calculated using the Atwater's conversion factors, protein and carbohydrate (4 kcal/g) and fat (9 kcal/g).

Methods validation

The accuracy of the concentrations determined in this study was checked by measurements of the reference materials SRM no. 2383 Baby Food Composite from the National Institute of Standards and Technology of the Department of Commerce, United States of America.

Amino acid analysis

Amino acids composition was quantified after hydrolysis with HPLC in reversed-phase column, after a derivatization with 9-fluorentylmethyl chloroformate and a fluorescence detector at the Irene Analytical Services, South Africa (AOAC, 2005). The concentration of the individual amino acid was calculated in relation to the protein content. Chemical score was calculated as follows using egg as the reference protein.

$$\text{Chemical score} = \frac{\text{mg amino acid in 1g of test protein} \times 100}{\text{mg amino acid in 1g of reference protein}}$$

Fatty acid analysis

Fatty acids were separated and quantified using a Hewlett-Packard gas chromatograph equipped with HP Chemstation software (6890 Series II) after extraction with chloroform: methanol (2:1, v/v) as described by (Christopherson and Glass, 1969).

Table 1. Proximate composition of the composite diets g kg^{-1} dry weight*

Nutrients	Diet 1	Diet 2	Diet 3	Diet 4
	Yellow			White
Moisture	41.7± 0.14	40.5± 0.07	42.1± 0.02	41.1± 0.13
Ash	50.2± 0.07	49.4± 0.22	44.4± 0.08	45.4± 0.06
Crude protein	147.7± 0.22	145.6± 0.38	145.0± 1.02	145.0± 0.86
Crude fat	108.9± 0.57	107.0± 0.21	106.7± 0.08	104.1± 0.33
Fiber	21.0± 0.08	21.7± 0.11	20.1± 1.01	21.7± 0.88
Sugars	62.2± 0.54	58.9± 0.22	61.0± 1.09	46.5± 0.76
Starch	581.3± 1.31	600.1± 0.21	558.7± 0.97	577.9± 0.54
Total Carbohydrate	643.5± 1.80	658.9± 2.17	619.7± 1.17	624.4± 1.11
Energy (kJ)	414500±12.33	418900± 11.10	401900± 9.44	401500± 14.11

*Values are means ± SD for three determinations Complementary foods, Diet 1 (cassava variety 01/1371), 2 (variety 01/1235), 3 (variety 94/0006), 4 (variety TME 1)

Table 2. Mineral contents (mg kg^{-1})) of the diets.

Mineral (mg kg^{-1})	Diet 1	Diet 2	Diet 3	Diet 4
	Yellow			White
Iron	75.4	73.8	74.2	73.9
Zinc	63.0	62.6	62.2	62.0
Manganese	29.0	28.0	27.0	27.0
Copper	89.0	87.0	87.0	90.0
Calcium	2700.0	2480.0	2380.0	2510.0
Boron	13.0	13.0	14.0	13.0
Molybdenum	0.8	0.9	0.9	1.0
Cobalt	0.2	0.2	0.2	0.2
Nickel	1.9	1.7	1.7	2.0
Magnesium	1490.0	1490.0	1440.0	1470.0
Sodium	210.0	230.0	168.0	210.0
Potassium	9100.0	9000.0	8600.0	8600.0
Phosphorus	2400.0	2500.0	2600.0	2600.0
Silicon	1480.0	1480.0	1490.0	1460.0
Aluminium	10.0	1.4	9.0	1.1
Titanium	0.6	0.7	0.6	0.6
Chromium	0.0	0.0	0.0	0.0
Cadmium	0.1	0.1	0.1	0.1
Lead	1.0	1.0	1.0	1.0
Selenium	4.0	4.0	4.0	4.0

Analysis of minerals

The minerals were determined at Waite Analytical Services. School of Agriculture and Wine, University of Adelaide, Australia using an Inductively Coupled Plasma Atomic Emission Spectrometry (AOAC, 2005) (ICPAES) made in Switzerland by ARL model 3580 B. Replicates of three samples were analyzed to check on the accuracy and reproducibility of the method.

RESULTS

The proximate compositions of the diets are presented in Table 1. The mean compositions are moisture (41.4 g kg^{-1}), ash (47.4 g kg^{-1}), crude protein (145.8 g kg^{-1}), crude fat (106.7 g kg^{-1}), crude fibre (21.1 g kg^{-1}), total carbohydrate (633.5 g kg^{-1}), and energy (409.2 kcal). The mineral compositions of the four diets are presented in Table 2. The iron, zinc and calcium contents of the flours ranged from 73.8 - 75.4 mg, 62.0 - 63.0 mg and 2380 – 2700 mg per kg dry flours respectively. The flours supplied adequate amounts of most minerals except for iron and zinc contents, which supplied about 65 and 67% of the Codex standard (FAO/WHO, 1991) respectively. Again, a dry weight of 65 g of the composite flours were calculated and compared to recommended dietary allowances (RDA) for the same age groups (Dewey, 2001). The comparison result is presented in Table 3. All the four complementary foods were found to provide more than adequate intake levels of Selenium (4 mg/kg/day) and magnesium (957.1 mg/kg/day), and relatively low amounts of Calcium (1636 mg/kg/day), Iron (48.31 mg/kg/day), and Zinc (40.59 mg/kg/day).

The composites contained all the essential amino acids (Table 4). The comparison of the essential amino acids to the FAO reference values (WHO/FAO, 1985), and percentage chemical score are presented in Table 5. The complementary foods contained higher chemical scores of most essential amino acids. The chemical score ranged from 37.7% in formula 4 for methionine to 310% in formula 1 for leucine. Six (6) of the essential amino acids, Leucine, Lysine, Phenylalanine, Threonine, Tyrosine and Valine, met the FAO/WHO reference values in all the diets. The fatty acids compositions of the diets are presented in Table 6. The four diets contained all the fatty acids between Tetradecanoic acid Tetracosanoic acid (C-14 to C-24) with the exception of Hexanoic acid (C-6) through Tridecanoic acid (C-13), Pentadecanoic acid (C-15), and Nicodecanoic acid (C-21). Odd-chain fatty acids, such as Heptadecanoic acid (C-17:0) and 10-heptadecenoic acid (C-17:1), were present in very small concentrations, varying from 0.4 g kg^{-1} of total fatty acids to 1.1 g kg^{-1}. Compared with the WHO recommendation

Table 3. Daily consumption of the four complementary diets compared to the recommended daily allowance.

Mineral (mg kg^{-1}/day)	Diet 1	Diet 2 Yellow	Diet 3	Diet 4 White	Mean	RDA† (6-11 months)
Iron	49.01	47.97	48.23	48.035	48.31	90.0*
Zinc	40.95	40.69	40.43	40.30	40.59	41.0*†
Manganese	18.85	18.20	17.55	17.55	18.04	
Copper	57.85	56.55	56.55	58.50	57.36	
Calcium	1755.00	1612.00	1547.00	1631.50	1636.00	4000.0
Boron	8.45	8.45	9.10	8.45	8.61	
Molybdenum	0.52	0.59	0.59	0.65	0.59	
Cobalt	0.13	0.13	0.13	0.13	0.13	
Nickel	1.24	1.11	1.11	1.30	1.19	
Magnesium	968.50	968.50	936.00	955.50	957.10	530.0
Sodium	136.50	149.50	109.20	136.50	132.90	
Potassium	5915.00	5850.00	5590.00	5590.00	5736.00	
Phosphorus	1560.00	1625.00	1690.00	1690.00	1641.00	
Silicon	962.00	962.00	968.50	949.00	960.40	
Aluminium	6.50	9.10	5.85	0.72	5.54	
Titanium	0.39	0.46	0.39	0.39	0.41	
Chromium	0.00	0.00	0.00	0.00	0.00	
Cadmium	0.07	0.07	0.07	0.07	0.07	
Lead	0.65	0.65	0.65	0.65	0.65	
Selenium	2.60	2.60	2.60	2.60	2.60	1.00

† FAO/WHO (2002). *RDA, assuming a moderate bioavailability of 10% iron absorption.
*†RDA, assuming a moderate bioavailability.

Table 4. Amino acid composition of the diets (g kg^{-1} protein).

Amino acids	FAO/WHO reference.protein*	Diet 1	Diet 2	Diet 3	Diet 4
		Yellow			White
Isoleucine	42	40.0	38.4	39.5	41.4
Leucine	42	130.2	72.9	71.9	72.7
Lysine	42	65.4	61.4	64.1	62.6
Methionine	22	10.6	11.5	10.2	8.3
Phenylalanine	28	50.1	50.5	50.3	50.8
Threonine	28	35.3	35.8	35.9	36.1
Valine	42	46.5	46.1	47.3	48.5
Tryptophan	14	8.8	12.8	12.0	13.6
Alanine		45.9	44.8	45.5	47.3
Arginine		106.0	108.1	108.4	109.9
Aspatatic acid		111.9	113.2	11.08	114.1
Cysteine	20	11.2	9.0	9.0	08.9
Glutamic acid		177.3	181.7	179.1	178.5
Glycine		47.7	48.6	46.7	48.5
Histidine		37.1	27.5	33.0	26.0
Proline		48.3	48.6	48.5	47.9
Serine		44.8	47.3	45.5	44.9
Tyrosine	28	41.8	41.6	41.9	40.2

* (FAO/WHO, 1985)

Table 5. Percentage chemical scores of the essential amino acids in the diets.

Amino acid	Diet 1	Diet 2	Diet 3	Diet 4
	Yellow			White
Isoleucine	95.2	91.4	94.0	98.6
Leucine	310.0	173.6	171.2	173.1
Lysine	155.7	146.2	152.6	149.0
Methionine	48.2	52.3	46.4	37.7
Phenylalanine	178.9	180.4	179.6	181.4
Threonine	126.1	127.9	128.2	128.9
Valine	110.7	109.8	112.6	115.5
Tryptophan	62.9	91.4	85.7	97.1

Table 6. Fatty acids composition of complementary diets as g kg^{-1} total fatty acids.

Fatty acid		Diet 1	Diet 2	Diet 3	Diet 4
		Yellow			White
Saturated fatty acid					
Tetradecanoic acid	(14:0)	0.7	0.5	0.4	0.4
Hexadecanoic acid	(16:0)	97.3	97.2	97.7	98.1
Heptadecanoic acid	(17:0)	1.0	0.9	0.9	1.1
Octadecanoic acid	(18:0)	0.6	29.8	30.3	30.2
Eicosanoic acid	(20:0)	13.1	13.1	13.7	13.3
Docosanoic acid	(22:0)	0.6	20.5	20.8	21.0
Tetracosanoic acid	(24:0)	1.6	11.4	11.7	11.6
Monosaturated fatty acids					
9-tetradecenoic acid	(16:1)	0.7	0.6	0.6	0.7
10-heptadecenoic acid	(17:1)	0.4	0.4	0.5	0.4
9- octadecenoic acid	(18:1)	529.0	518.7	512.9	515.8
11-eicosenoic acid	(20:1)	10.0	9.8	9.9	9.7
13-docosenoic acid	(22:1)	0.6	0.6	0.6	0.6
Polyunsaturated fatty acids					
9,12-octadecadienoic acid	(18:2)	270.6	282.2	285.9	283.2
9,12,15-octadecatrienoic acid	(18:3)	12.5	13.3	13.2	13.0
9,12,15-eicodecatrienoic acid	(20:3)	0.6	0.7	0.6	0.6
9,12,15,18-eicodecatetranoic acid	(20:4)	0.4	0.5	0.6	0.4

diets contained moderate (12.5 - 13.3 g kg^{-1}) to high proportions of α-linolenic acids (18:3n3) and high proportion of linoleic acid (18:2n6), which resulted in a high total n-6/total n-3 ratio and a high linoleic/ α-linolenic acids ratio (20.10 - 22.10) (Table 7).

DISCUSSION

In assessing the overall nutritive intake of infants, the combined composition of the breast milk and complementary food needs to be taken into consideration. Some nutrients, such as fatty acids, are abundant in breast milk. However, low concentrations of other nutrients, such as iron, calcium, and zinc, may lead to clinically significant deficiencies if without supplementation (FAO/WHO, 1995). Also, the recommendation of the World Health Organization that children should be exclusively breastfed until 6 months, with introduction of complementary foods and continued breastfeeding thereafter (FAO/WHO/UNU, 1985), was considered in analyzing the nutritional value of the complementary foods.

The potential disadvantages of fiber in foods for infants and young children are an important nutritional issue (Jansen, 1980). Possible undesirable aspects of high fiber levels in weaning foods include increased bulk and lower caloric density, irritation of the gut mucosa, and

Table 7. Fatty acid composition (g kg^{-1} wt/wt) of the complementary diets compare to WHO recommendations.

Fatty acid	Diet 1 Yellow	Diet 2	Diet 3	Diet 4 White	Recommended†
Linoleic acid 18:2n-6	270.6	282.2	285.9	283.2	110-120
α- Linolenic acid 18:3n-3	12.5	13.3	13.2	13.0	8-9
Arachidonic acid 20:4n-6	0.4	00.5	0.6	0.4	5-6
Total unsaturated	824.8	826.8	824.8	824.4	448-524
Total saturated	174.9	173.4	175.5	175.7	452-535
Unsaturated/saturated ratio	5:10	5:10	5:10	5:10	0.84:1-1.16:1
18:2n-6/18:3n-3 ratio	20:10	21:10	22:10	22:10	5:1-10:1
Total n-6/total n-3 ratio	22:10	22:10	22:10	22:10	2.4:1-2.7:1

† Recommended data from Koletzko et al. (1992). Medians calculated from average FA values reported of human milk in Europe and Africa. Ratio of 18:0 to 18:3 as suggested by the FAO/WHO Joint Consultation, 1995.

adverse effects on the efficiency of absorption of various nutrients of significance in diets with marginal nutrient content.

A maximum level of 5% of fiber for infants and young children is set by the FAO/WHO/UNU Codex standards (FAO/WHO, 1998). Children should have lower dietary fiber intakes than adults, with the recommended amount proportional to body weight (Hegazy et al., 1989).

The fat content of the complementary foods was within the FAO/WHO Codex standard (FAO/WHO, 1991). This could be attributed to the inclusion of soybean and groundnut in the blends, and tends to agree with the recommendations (FAO/WHO, 1998), that vegetable oils be added in foods meant for infants and children. This will not only increase the energy density but also be a transport vehicle for fat soluble vitamins. Brown et al. (1998) have concluded that infants aged 6 - 8 months who are consuming an average amount of breast milk/day (674 g/day) do not need the dietary supplementation of fatty acids to achieve 30% of the daily intake. If the breast milk has a low fat concentration, as may happen in developing countries, infants require an additional 10 - 24% of the energy from fat. By the time infants reach 9 months of age, their complementary food diet should provide 13% of the energy from fat (Dewey and Brown, 2003). The four complementary formulas supply appreciable quantities of fat to the blends. The fat can also provide essential fatty acids, such as n-3 and n-6 Polyunsaturated Fatty Acids (PUFA), needed to ensure proper neural development.

Fatty acids, especially the essential ones (EFA), α-linolenic acid and linoleic acid, are precursors to docosahexaenoic acid and arachidonic acid that are critical for growth and development, particularly of the nervous system in the first 6 months of life (Salem et al., 1996). Both are necessary components of myelin, synaptic cell membranes, and photoreceptor cells. The report of WHO on complementary feeding concludes that diets low in fat may be adequate, as long as the minimum requirements for EFA are met (Brown et al., 1998). Fernandez et al. (2002), and his colleagues also were of the same opinion, as the findings of their study on the fatty acid composition of Nigerian weaning foods revealed that the foods were devoid of arachidonic and decosahexanoic acids, but high in linoleic and linolenic acids. The linoleic acid to α-linolenic acid ratio observed in this study is higher than the recommendation. The concern is that the relatively high levels of linoleic acid might inhibit the synthesis of docosahexaenoic acid from α-linolenic acid (Ballabriga, 1994).

The energy values of the complementary foods are in accordance with the recommendations of FAO/WHO/UNU (1985), which specify 1000 kJ/g (1.0 kcal/g) as safe for small children aged 2 to 5 years. The Food and Agriculture Organization and the World Health Organization (FAO/WHO, 1998) have also recommended that foods fed to infants and children should be energy-dense. This, according to the recommendation, is necessary because low energy intake foods tend to limit total energy intake and the utilization of other nutrients. This suggests that infants may not have to consume larger quantities of the formulas to meet their energy needs.

The requirements for the maintenance of body protein equilibrium as well as the optimum pattern of individual essential amino acids change little between the ages of 6 and 24 months (Reeds and Garlick, 2003). According to the Codex standard, the amounts of protein that should be supplied by complementary foods are between 60 and 110 g kg^{-1}of dry food. The protein values in this study agrees with the recommended values of the Codex standard, meaning that all the formulas provide adequate levels of protein for a child who consumes an average amount of breast milk. These values are slightly below the recommendation of the FAO/WHO/UNU (1985), which recommends a minimum protein content of

150 g kg^{-1}dry weight. Both soybean and groundnut have been recommended for infant feeding (Badamosi et al., 1995; Temple et al., 1996; Gibson et al., 1998; Nnam , 2002) due to their positive contribution to protein nutrition levels.

The amino acid content of complementary foods is a particularly relevant issue in infant feeding, where Protein-Energy Malnutrition (PEM) has continued to pose challenges in developing countries. This, according to other researchers, is due to poor feeding practices and the low quality protein commonly associated with plant-based single diets (Badamosi et al., 1995; Temple et al., 1996). All the essential amino acids were present in the complementary foods, but quite a number did not meet the FAO/WHO reference values. A lower score for any of the essential amino acids designates the limiting characteristics of the amino acid and gives an indication of the protein quality.

Complementary foods are important sources of micronutrients for developing infants. Iron, Zinc, Phosphorus, Magnesium, and Calcium have been identified as problem nutrients from six months of age and must be supplemented by the addition of complementary food (Brown et al., 1998). According to Brown and co-workers (WHO, 1998), breast milk can adequately supply the nutrients need of infants 9 to 11 months old for vitamin C, folate and B_{12}. In contrast, complementary foods should provide approximately 12% of the vitamin A, 25% to 50% of the Cu, riboflavin, 50% to 75% of thiamin, Mn, and 75% to 100% of niacin, Zn and Fe, assuming an average composition and intake of breast milk, meaning that the composition of these micronutrient is low in human breast milk. The Calcium, Zinc, Copper, Magnesium, and Phosphorus contents of the four complementary foods are adequate to meet the needs of children aged 6 to 23 months. This supported the findings (Bond et al., 2005). However, the Iron standards were not met, although about 65% of the FAO/WHO Codex standards were supplied (FAO/WHO, 1991). These local complementary foods would have to be further fortified with iron to adequately complement breast milk.

The absorption and utilization of the iron and zinc in complementary foods which contain plant materials are significantly lower than in those from animal sources. The bioavailability of non-heme iron found in plant sources is 2 - 8%, compared to 25% bioavailability of heme iron found in animal products (Brown et al., 1998). Phytic acid is a potential inhibitor of both iron and zinc in plant food materials. It affects the bioavailability of minerals by forming an insoluble complex with the metals of Iron, Zinc, and Calcium, inhibiting their absorption (Gibson et al., 1998). The inhibitory effect of phytic acid on Zinc absorption is notably dose-dependent (Sandstrom and Lonnerdal, 1989). Hence, any strategies that reduce the phytic acid content of these complementary foods might markedly enhance Zinc bioavailability and simultaneously increase absorption of non-heme Iron and calcium to some extent.

The bioavailability of non-heme Iron or Zinc can also be improved by enriching the complementary foods with sources of absorption enhancers such as ascorbic acid (for non-heme Iron), other organic acids and cellular animal protein (for non-heme Iron and Zinc), and fat (for retinol and provitamin A carotenoids). These enhancers can be added in the form of fresh fruits (citrus fruits), vegetables (tomatoes, green leaves), legumes (groundnut flour) or small amounts of meat, poultry, or fish (perhaps as dried flours) and their inclusion in complementary foods should be encouraged (Gibson et al., 1998).

From this study, it would be concluded that utilization of micronutrients improved cassava varieties particularly to formulate complementary food in various cassava agro-ecologies in the region will contribute to an increase in the intake of micronutrients and hence help in combating deficiencies, primarily of Iron, Calcium, and Zinc.

ACKNOWLEDGEMENTS

We thank the International Institute of Tropical Agriculture, Ibadan, Nigeria, for support to this research.

REFERENCES

AOAC (2005) Official Methods of Analysis Association of Official Analytical Chemists, Washington D.C, USA.
Badamosi EJ, Ibrahim LM, Temple VJ (1995) Nutritional evaluation of a locally formulated weaning food, JUTH-PAP. West Afr. J. Biol. Sci. 3: 85-93.
Ballabriga A (1994) Essential fatty acids and human tissue composition. An overview. *Acta Paediatrica Scandinavica*. 402: 63-68.
Bokanga M (1994). Processing of cassava leaves for human consumption. International workshop on cassava safety. Acta Horticulturae 375: 203- 207.
Bond B, Fernandez Diane R, VanderJagt Dorothy J, Williams Margaret, Huang Yung-Sheng, Chuang Lu-te, Millson Mark, Andrews Ronee, Glew Robert H (2005). Fatty acid, amino acid and trace mineral analysis of three complementary foods from Jos, Nigeria. J.Food Comp. Anal. 18: 675-690.
Bradbury JH, Holloway WD, (1988). Chemistry of Tropical root crops; Significance for nutrition and agriculture in the pacific. ACIAR monograph series. Ramsay ware printing, Melbourne. p.890
Brown KH, Dewey KG, Allen LH (1998). Complementary feeding of young children in developing countries: a review of current scientific knowledge. WHO/NUT/98. World Health Organization, Geneva, Switzerland.
Christopherson SW, Glass L (1969). Preparation of milk Fat Methyl Esters by Alcoholysis in an essential nonalcoholic solution. J. Dairy Sci. 52: 1289-1290.
Dewey KG, Brown KH (2003). Update on Technical Issues Concerning Complementary Feeding of Young Children in Developing Countries and Implications for Intervention Programs. Food Nutr. Bull. 24: 5-28.
Dewey KG (2003). Nutrient Composition of Fortified Complementary Foods: Should Age-Specific Micronutrient Content and Ration Sizes Be Recommended? J. Nutr. 133: 2950S-2952S.
Dewey KG (2001). Nutrition, growth and complementary feeding of the breastfed infant. Ped. Clin. N. Amer. 48: 87-104.
Dubois M, Gilles KA, Hamilton JK, Rebers PA, Smith F (1956). Colorimetric method for determination of sugars and related substances. Anul. Chem. 28: 350-356.

FAO/WHO (1991). Codex standard for processed cereal-based foods (including guidelines on formulated supplementary foods for older infants and young children). World Health Organization, Geneva, Switzerland.

FAO/WHO (2002). Human vitamin and mineral requirements. Report of a joint FAO/WHO expert consultation. Rome, Italy

FAO/WHO (1998). Preparation and use of Food-Based Dietary Guidelines. Report of a Joint FAO/WHO Consultation. Technical Report Series 880. WHO, Geneva, Switzerland.

FAO/WHO/UNU (1985). Energy and protein requirements. Reports of a joint FAO/WHO/UNU expert consultation. World Health Organization Technical Report Series 724. WHO. Geneva, Switzerland.

Fernandez DE, Vanderjagt DJ, Williams M, Huarg YS, Chuang Lut-te, Millson M, Andrew R, Pastuszyn A, RH Glew (2002). Fatty acids, amino acids, and trace mineral analyses of five weaning foods from Jos, Nigeria. Plant Foods for Human Nutrition. 57: 257-274

Gibson RS, Ferguson EL, Lehrfeld J (1998). Complementary foods for infants feeding in developing countries: their nutrient adequacy and improvement. Eur. J.Clin. Nutr. 52: 764-770.

HACH (1990). Systems for food, feed and beverage analysis procedures. HACH Company, Loveland, Colorado. 80539-0389, USA.

Hegazy SM, Hussien NM, Bressani R (1989). Nutritional quality of low-cost food supplements for infant feeding. Egypt J. Food Sci. 17:1-13.

Jansen GR (1980). A consideration of allowable fiber levels in weaning foods. Food Nutr. Bull. 2:38-47.

Koletzko B, Thiel I, Abiodun PO (1992). The fatty acid composition of human milk in Europe and Africa. J. Paed. 120: 62-70.

McDowell I, Oduro KA (1993). Investigation of the B- carotene content of yellow varieties of cassava (*Manihot esculenta* Crantz). J Plant Foods. 5: 169-171.

Nigeria Demographic and Health Survey (NDHS) (2003). In Nutrition of young children and Mothers in Nigeria, USA.

Nigeria Food Consumption and Nutrition Survey Summary. IITA, Ibadan, Nigeria (2003).

Nnam NM (2002). Evaluation of Complementary Foods based on Maize, Groundnut, Pawpaw and Mango flour Blends. Nig. J. Nutr. Sci. 22(23): 8 -18.

Reeds PJ, Garlick PJ (2003). Protein and amino acid requirements and the composition of complementary foods. J. Nutr. 133: 2953S-2961S.

Salem Norman JR, Wegher Brent, Mena Patricia, Uauy Ricardo (1996). Arachidonic and docosahexaenoic acids are biosynthesized from their 18-carbon precursors in human infants. Proc. Natl. Acad. Sci. USA

Sandstrom, B and Lonnerdal, B. (1989). Promoters and antagonists of zinc absorption, In Zinc in Human Biology ed. CF Mills 57-58. International Life Sciences Institute. *Human Nutrition Reviews,* Springer-Verlag. London, UK.

Temple VJ, Badamosi EJ, Ladeji O, Solomon M (1996). Proximate Chemical Composition of three locally formulated complementary foods. West Afr. J. Biol. Sci. 5: 134-143

UNICEF (2006). United Nations Children's Fund. State of the World Children, Brodock Press Limited.

WHO/FAO (1995). (World Health Organization/Food and Agriculture Organization). WHO and FAO consultation: fats and oils in human nutrition. Nutrition Rev. 53: 202-205.

WHO/UNICEF (1998). Complementary Feeding of Young Children in Developing Countries: A Review of Current Scientific Knowledge. WHO/NUT/98.1. World Health Organization, Geneva. pp. 1-228.