Plant Foods for Human Nutrition **57:** 257–274, 2002.

Fatty acid, amino acid, and trace mineral analyses of five weaning foods from Jos, Nigeria *

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Abstract. Five plant-based weaning foods (WF) (Dietrend, Jot-M, Soy, Ang, and Vic-T) locally prepared in Jos, Nigeria were analyzed by gas-liquid chromatography, reverse-phase high performance liquid chromatography, and atomic emission spectrometry with inductively coupled plasma to determine their fatty acid (FA), amino acid, and trace mineral contents, respectively. Results of these direct analyses were compared to expected values derived from food composition tables prepared by the United States Department of Agriculture (USDA). Additionally, results were compared against recommended nutrient values, using breast milk as the standard for FA content and recommended dietary allowances (RDA) for amino acid and mineral contents. The overall nutritional value of the five WF varied considerably and the quantities of particular nutrients determined by direct analysis differed markedly from those estimated using USDA food tables. Comparison of WF fatty acid composition relative to the RDA recommendations and a human milk standard revealed a much higher proportion of both linoleic (35–55 wt%) and α-linolenic acids (1%–7 wt%) relative to human milk lipids (11%–12% and 0.8%–0.9% wt, respectively); however, the WF were devoid of arachidonic acid and docosahexaenoic acid. Soy contained the highest amounts of linoleic acid (59.7 mg/g) and α-linolenic acid (7.46 mg/g) compared to the other four WF (10.2–41.0 and 0.35–3.18 mg/g, respectively). The linoleic acid/α-linolenic acid ratio was within the recommended range (5:1 to 10:1) in only Jot-M (10:1) and Soy (8:1). Dietrend, Vic-T and Ang, contained linoleic/α-linolenic ratios of 12:1, 29:1, and 82:1, respectively. The Soy weaning food would provide the most protein (24.3 g/day), based on an estimated daily intake of 65 g of weaning food by a normal six-month-old infant, compared to Jot-M (11.9 g/day), Dietrend (11.7 g/day), Ang (8.07 g/day), and Vic-T (7.26 g/day). The protein RDA for children up to 1 year of age is 13–14 g/day. Comparison of the mineral contents of the WF to the RDAs for various minerals indicated that all five would provide suboptimal amounts of calcium (16 to 250 mg/day) and zinc (1.42 to 3.56 mg/day) compared to respective RDAs of 400 mg/day and 5 mg/day. These data show that the Soy weaning food is an excellent source of linoleic acid and α-linolenic acid, as well as being a good source of high quality protein. Jot-M and Dietrend provide useful amounts of the essential FA; however, it is advisable to reevaluate the composition of Ang and Vic-T to find ways to improve the linoleic/α-linolenic ratio of each and increase their total protein content. These results document the shortcomings of using published food composition tables based on foods in America when devising weaning foods based on ingredients in another part of the world.

Key words: α-linolenic acid, Amino acids, Essential Fatty Acids (EFA), Infant nutrition, Jos, Linoleic acid, Nigeria, Trace minerals, Weaning food

Introduction

Weaning foods are semisolid or solid foods which are introduced to the diet of a breast- or formula-fed infant during the transition to an adult diet. They play a vital role in infant nutrition worldwide, especially in Nigeria and other developing countries, where inadequate weaning food supplementation is a major cause of malnutrition.

In Nigeria, as in most other sub-Saharan countries, nearly all women in both rural and urban areas practice breast-feeding. Although complementary feeding usually begins at four to six months, it is not uncommon for children to be breast-fed past two years [1]. The introduction of weaning foods usually involves use of a home-made semiliquid porridge prepared from staple cereals or tubers [2, 3]. The use of supplemental foods is vital to the infant, not only as a stepping stone to an adult diet, but also as a source of additional nutrients required for optimal growth and development. However, traditional weaning foods often do not fulfill the nutritional needs of the infant. The low energy and nutrient densities, stiff consistency and high volume of homemade porridge combine to offer a low cost filling meal that often lacks adequate nutritive value.

Concomitantly, in some developing countries, the nutrient quality of human milk may be suboptimal. For example, researchers found the milk of Yoruba women in southwestern Nigeria [4] and that of Fulani women in the northern part of the country [5] to be moderately deficient in linoleic acid (18:2n-6), an essential n-6 fatty acid. A low level of linoleic acid in human milk is indicative of an inadequate maternal diet which underscores, not only the importance of improving maternal nutrition, but also of using weaning foods that provide adequate amounts of linoleic acid.

In a study conducted in northern Nigeria, Okolo and colleagues [6] found that although the milk of Hausa women contained adequate amounts of α-linolenic acid (18:3n-3), their exclusively breast-fed infants appeared to be deficient in this essential fatty acid. In contrast, four of eight children, in the

* This study was supported by a Minority International Research Training (MIRT) grant from the Fogarty International Center of the National Institutes of Health.

same study, who had been receiving supplemental weaning food, were not deficient in α-linolenic acid. These observations underscore the important role weaning foods play in providing adequate child nutrition in this community.

In the Jos Plateau of Nigeria, at least five locally prepared weaning foods are available and within economic reach of the general population. The goal of this research was to ascertain the nutrient content of these weaning foods. In particular, researchers were interested in the qualitative and quantitative aspects of their fatty acid, amino acid and mineral compositions. The weaning foods were prepared in Jos, Nigeria from locally available food sources that included rice, groundnuts (peanuts), soybeans, millet, maize and crayfish.

There are at least two ways to assess the specific nutrient content of weaning foods, assuming the nutrient compositions of the ingredient foods are known: 1) calculation of the content of weaning foods using published food tables, or 2) direct analysis of the content of the nutrients of interest. In the present study, direct chemical analysis of selected nutrients (fatty acids, amino acids and trace minerals) of five locally prepared weaning foods were done in Jos. The resulting data were compared with the corresponding values determined using published food tables. The daily total nutrient intake of the weaning foods was ascertained and the findings were compared to recommended daily values (RDV). Due to the variability between foods grown in Nigeria and those used to construct published food tables, it was anticipated that the nutrient content estimated by the two approaches might yield discrepant results. Also, the soybean-based weaning food was expected to provide more nutrients, particularly protein, than the other four weaning foods. Owolabi and colleagues [7] recommended adding soybeans to weaning foods to increase their protein content and prevent malnutrition. The analyses performed should provide insight regarding the use of published food tables, the composition of weaning foods in northern Nigeria, and ways in which to improve them.

Materials and methods

Weaning foods

The weaning foods were developed in 1991 at the Jos University Teaching Hospital (JUTH) in Jos, Nigeria. The weaning foods were processed and packaged at JUTH using cereals and other components purchased in local markets. Prior to analyses, all weaning foods were dried to a constant weight under a vacuum (Alcatel, USA) at 25 °C.

The five weaning foods analyzed for this study were Dietrend, Jot-M-Mix (Jot-M), Detoxified Soy-Powder (Soy), Angelic Baby Dinner (Ang) and Vic-

T-Mix (Vic-T). They were purchased at JUTH and are used widely in northern Nigeria, in the Jos Plateau in particular. Dietrend, Jot-M and Soy are normally prepared for consumption by adding 100 mL of boiling water per 10 g of weaning food, resulting in a 9% (w/w) mixture. Sugar is added to taste. The Angelic Baby Dinner is usually prepared with fried onions and tomatoes, palm oil, salt and optional vegetables; however, for the purpose of this study, the weaning foods were analyzed without additives.

Preparation of the weaning foods with boiling water discourages microbial growth and parasitic infestation. In addition to consuming human milk, it is estimated that healthy six- to seven-month-old-infants in Jos usually consume approximately 65 g (dry weight) of weaning food per day.

Chemical analysis of weaning foods

Fatty acid analysis. The dried powdered specimens were extracted with chloroform:methanol (2:1, v/v) as described elsewhere [8]; the solid, non-lipid material was removed by filtration. The total extracted lipid material was recovered after solvent removal in a stream of nitrogen. The samples were then redissolved in anhydrous chloroform and clarified by centrifugation (International Equipment Company, USA). Transmethylation was performed using 14% (w/v) BF_3 in methanol [9]. Fifty nanograms of heptadecanoic acid (internal standard) and a 1 ml aliquot of each sample were transferred to a 15 ml teflon-lined screw-cap tube. After removal of solvent by nitrogen gassing, the sample was mixed with 2 ml of BF_3 reagent, placed in a waterbath (Thermolyne, USA) at 100 °C for 30 min and cooled. After the addition of 2 ml of saline solution, the transmethylated fatty acids were extracted into hexane.

Aliquots of the hexane phase were analyzed by gas chromatography. Fatty acids were separated and quantified using a Hewlett-Packard gas chromatograph (5890 Series II) equipped with a flame-ionization detector. One to two microliter aliquots of the hexane phase were injected in split-mode onto a fused-silica capillary column (Omegawax; 30 m $\times$ 0.32 mm I.D., Supelco, Bellefonte, PA). The injector temperature was set at 200 °C, detector at 230 °C, oven at 120 °C initially, then 120–205 °C at 4 °C per min, 205 °C for 18 min. The carrier gas was helium and the flow rate was approximate 50 cm/sec. Electronic pressure control in the constant flow mode was used. The internal standard (heptadecanoic acid, 17:0) and calibration standards (Nu-chek, Elysian, MN) were used for quantitation of fatty acids in the various lipid extracts. Solvents were purchased from EM Science, Gibbstown, NJ. The data reported represent the average of three determinations from 1–2 samples of each weaning food.

Amino acid analysis. Two to three mg of each weaning food were transferred into, weighed and analyzed in a tared glass ampoule. Norleucine was the internal standard used in all determinations. After 1.0 ml of 6 N HCl was added, the samples were flushed with nitrogen, evacuated, sealed and placed in an oven (Blue M Electric Co., USA) at 110 °C for 24 hrs. Following hydrolysis, a 10 μl aliquot was withdrawn and subjected to derivatization.

Samples to be used for the determination of cysteine were first oxidized with performic acid [formic acid: 30% hydrogen peroxide, 9:1, (v:v)] for 18 hrs at room temperature [10]. Performic acid was removed in an evaporative centrifuge (Speed-Vac, Savant) and the samples were hydrolyzed with HCl as described above.

The tryptophan content was determined separately. With regard to the tryptophan analysis, 450 μL of 4.67 M KOH containing 1% (w/v) thiodiglycol were added to each sample. Hydrolysis was performed in plastic tubes within an evacuated ampoule at 110 °C for 24 hrs. After allowing the hydrolysate to cool, 0.5 mL of 4.2 M perchloric acid (PCA) and 50 μL of acetic acid were added to neutralize the solution. The samples were mixed thoroughly using a Thermolyne Maxi mixer, chilled on ice, and centrifuged. Fifteen microliters of the supernatant were transferred to 6 $\times$ 50 mm glass tubes and dried in a Speed-Vac (Savant, USA) in preparation for derivatization. Duplicate lysozyme controls were analyzed for quality control purposes.

The samples were dried using 20 μL of ethanol:triethylamine:water (2:1:2, v/v) and derivatized with 20 μL of ethanol:triethylamine:water: phenylisothiocyanate (7:1:1:1 v/v). Excess reagent was removed in a Speed-Vac (Savant, USA). Derivatized and dried samples were dissolved in 100 μL of equilibration buffer.

Analysis of the amino acids was performed with a Waters C18 column (3.9 $\times$ 150 mm). The gradient solution was the same as that described by Bidlingmeyer, et al. [11]. The solvents utilized were the sodium acetate buffer and acetonitrile (300 ml ACN, 200 ml water, 0.2 ml CaEDTA). Twenty microliter aliquots were injected onto the column. Tryptophan analysis was performed according to Hariharan, et al. [12]. Elution of the amino acids was achieved by increasing the acetronitrile concentration in the eluent. They were detected at 254 nm. The data reported represent the average of two determinations from 1–2 samples of each weaning food.

Minerals

The samples were dried (Lab-Line Instruments, USA) overnight at 110 °C. They were then stirred and allowed to cool to room temperature. Three replicate aliquots containing approximately 0.1g of each sample were weighed into 125 mL Phillips beakers and then digested using 20 mL concentrated nitric

Table 1. Composition (%wt/wt) of five weaning foods* from Jos, Nigeria

Components	Weaning food				
	Dietrend	Jot-M	Soy	Ang	Vic-T
Corn	60				
Soybean	30	30	100		
Rice				80	46
Millet		60			
Crayfish					7
Peanut	10	10			31
Carrot					23
Sesame seed				13	

*The five weaning foods were: Dietrend, Jot-M-Mix (Jot-M), Detoxified Soy-Powder (Soy), Angelic Baby Dinner (Ang), and Vic-T-Mix (Vic-T). They were formulated at the Jos Univeristy Teaching Hospital.

acid and 1 mL concentrated perchloric acid. The samples were covered with watch glasses and set on a hot-plate at 120 °C for one hour. The hot-plate temperature was then increased to 150 °C and the samples were refluxed overnight. The watch glasses were removed and the samples taken to near dryness (approximately 1 mL) at the same temperature. At that point, the samples were taken off the hot-plate, treated with 2.5 mL of nitric-perchloric acid (4:1), and a minimal amount of deionized water to rinse down the side walls of the beakers. After cooling, the solutions were quantitatively transferred to graduated centrifuge tubes and diluted to a 50 mL final volume with deionized water. The samples were analyzed by ICP-AES (Spectro Analytical Instruments, USA) for trace mineral contents. This digestion technique makes no attempt to solubilize any silicate-based materials that may be in the samples. The data reported represent the average of three determinations from 1–2 samples of each weaning food.

Results

Fatty acid content of Nigerian weaning foods

Comparison of the ‘determined’ vs ‘calculated’ fatty acid contents of the five weaning foods (WF) is summarized in Table 2. Direct analysis revealed that Soy contained the largest amounts of linoleic acid and α-linolenic acid. Ang

Table 2. Comparison of the determined (Det.) vs calculated (Calc.) (mg/g dry weight) fatty acid contents of five weaning foods prepared in Jos, Nigeria

Fatty acid	Weaning food									
	Diet		Jot-M		Soy		Ang		Vic-T	
	Det.	Calc.	Det.	Calc.	Det.*	Calc.	Det.*	Calc.	Det.*	Calc.
Saturated										
14:0	0.06	0.09	0.07	0.09	0.13	0.21	0.04	0.21	0.04	0.08
16:0	9	14.9	10	14.5	13.3	21.8	8.23	7.73	4.17	13.55
18:0	2.32	3.95	2.35	4.32	3.42	8.05	3.83	3.12	1.32	2.69
Total	11.7	19.7	12.0	19.6	16.9	30.0	12.1	11.56	5.53	18.00
Monounsaturated										
16:1n-7	0.19	0.16	0.13	0.20	0.16	0.43	0.14	0.32	0.04	0.06
18:1n-9	23.5	45.6	21.6	42.5	20.9	48.2	29.5	27.39	11.2	57.54
20:1n-11	ND	0/81	ND	0.91	ND	0.43	ND	0.14	0.02	1.58
Total	23.6	46.6	21.7	43.6	21.1	49.1	29.6	28.07	11.3	59.18
n-6 Fatty acids										
18:2n-6	34.9	59.8	33.2	58.4	59.7	108	41	30.63	10.2	40.50
20:4n-6	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.19	ND	ND
Total	34.9	59.8	33.2	58.4	59.7	108	41.0	30.82	10.2	40.50
n-3 Fatty acids										
18:3n-3	2.84	4.68	3.18	4.91	7.46	14.4	0.5	0.86	0.35	1.88
20:5n-3	ND	ND	ND	ND	ND	ND	0.05	0.40	0.01	ND
22:6n-3	ND	ND	ND	ND	ND	ND	0.04	0.16	ND	ND
Total	2.84	4.68	3.18	4.91	7.46	14.4	0.59	1.42	0.36	1.88
Total fatty acids	73.0	131	70.1	127	105	201	83.3	71.9	27.4	120

* Data are an average of the results of the analysis of two samples.
ND = not detected.

was the only weaning food that contained detectable amounts of docosahexaenoic acid (DHA 22:6n-3), a finding which was likely due to the use of crayfish as an ingredient. The quantities of the two essential fatty acids (EFA) in Dietrend, Jot-M and Soy were only 50% to 60% of the amounts calculated from food tables. Having shown that the EFA contents of the weaning foods were considerably lower than the content calculated from published food tables, the fatty acid composition of the WF was compared to recommendations from the World Health Organization (WHO) [13].

Table 3 contains a comparison of the fatty acid composition (%wt/wt) of the five WF versus the WHO/FAO recommendations. The WHO recommends that the nutrient content of WF should mimic human milk as closely as possible. Therefore, data from a study by Koletzko and coworkers [14]

Table 3. Comparison of the fatty acid composition (%wt/wt) of five weaning foods to WHO recommendations

	Food source					
	Dietrend	Jot-M	Soy*	Ang*	Vic-T*	Recommended**
Total saturated	17.2	18.4	16.4	15.0	23.6	45.2–53.5
18:1n-9	30.9	29.5	19.3	34.8	38.1	NR
Linoleic acid (18:2n-6)	46.0	45.4	55.1	48.2	34.8	11.0–12.0
Arachidonic acid (20:4n-6)	0.01	0.01	0.01	0.02	ND	0.5–0.6
Linolenic acid (18:3n-3)	3.74	4.36	6.89	0.59	1.21	0.9–0.8
Docosahexaenoic acid (22:6n-3)	ND	ND	ND	0.05	ND	0.3–0.3
Total unsaturated	82.8	81.5	83.7	85.0	76.1	52.4–44.8
Unsaturated/ saturated ratio	5:1	4:1	5:1	6:1	3:1	1.16–0.84
18:2n-6/18:3n-3	12:1	10:1	8:1	82:1	29:1	5:1 to 10:1
Total n-6/ Total n-3	12:1	10:1	8:1	69:1	27:1	2.7–2.4

* Data are averaged from the results of the analysis of two samples.
** Recommended data from Koletzko [14]. Medians calculated from average fatty acid values reported in human milk in Europe and Africa. Ratio of 18:2 to 18:3 as suggested by World Health Organization/Food and Agriculture Organization [13].
NR = not reported.

regarding the average fatty acid content of human milk in Europe and Africa were used to arrive at WHO recommendations. The ideal 18:2n-6/18:3n-3 ratio (5:1 to 10:1) was taken from the WHO/FAO joint consultation. The lipid fractions of the Nigerian WF all exhibited linoleic and α-linolenic acid percentages that exceeded WHO standards. Accordingly, the proportion of the total unsaturated fatty acids was high and the proportion of the saturated fatty acid low in the Nigerian WF. The 18:2n-6/18:3n-3 ratio was found to be within the recommended range of values for both Soy (8:1) and Jot-M (10:1). The 18:2/18:3 ratio was 12:1 for Dietrend. However, for Ang and Vic-T, the ratios diverged markedly from the WHO recommendation (82:1 and 29:1, respectively). Since the WF were formulated from plant sources that lack C20-C22 polyunsaturated fatty acids, it was not surprising to find that

Table 4. Daily intake of five weaning foods (g/65 g) compared to RDV** (g/day)

Fatty acid	RDV**	Dietrend	Jot-M	Soy*	Ang*	Vic-T*
18:2n-6	0.50	2.27	2.16	3.88	2.67	0.66
18:3n-3	0.05–0.1	0.18	0.21	0.49	0.03	0.02
Total fatty acids	28.9	4.93	4.75	7.03	5.52	1.91

* Data are averaged from two samples.
** Recommended daily values for 18:2n-6 (0.5) and 18:3n-3 (0.1 to 0.5) from Pipes [27].

the percentages of arachidonic acid (20:4n-6) and DHA (22:6n-3) in the five WF were below the WHO recommendations.

Although, the presentation of fatty acid content of a particular food by percentage of total fatty acid is a useful way to compare WF to breast milk, it does not adequately convey the actual amounts (in grams) of essential fatty acids provided. The fatty acid contents (mg/g) of the five WF were multiplied by 65 g (the dry weight estimate of the daily intake of WF by a six-month-old infant in Jos, Nigeria). This calculation allowed comparison of the amount of EFA consumed (g/day) by a six-month-old infant to the Recommended Daily Values (RDV).

650kcal × 50t4

Table 4 data show the amounts of essential fatty acid and total fatty acids provided by a daily intake of 65 g of each of the five WF compared to the RDV. The daily consumption of each of the five WF provided more linoleic acid than recommended by WHO. However, with regard to α-linolenic acid content, both Ang (0.03 g/65 g) and Vic-T (0.02 g/65 g) were below the RDV (0.05–0.1 g/65 g). Also, all five WF provided much less total fatty acid (1.91–7.03 g/day) than the RDV (28.9 g/day). Thus, when compared to the human milk (WHO) standard, the WF proved more than adequate. However when compared to the RDV, two of the WF were low in α-linolenic acid and none of the WF provided the recommended quantity of total fatty acids.

Amino acid content of Nigerian weaning foods

The determined versus calculated amino acid contents of the five weaning foods are compared in Table 5. The Soy weaning food contained the most protein (0.355 g/g). Furthermore, the measured and estimated amino acid values for Dietrend, Jot-M and Soy were in good agreement. For all five WF, the results determined by direct analysis of tryptophan (5.32–19.1 mg/g) were consistently higher than the calculated amounts (2.02–4.85 mg/g).

Table 5. Comparison of the determined (Det.) vs calculated (Calc.) (mg/g dry weight) amino acid contents of five weaning foods produced in Jos, Nigeria

Fatty acid	Weaning food									
	Diet		Jot-M		Soy		Ang		Vic-T	
	Det.	Calc.	Det.	Calc.	Det.*	Calc.	Det.*	Calc.	Det.*	Calc.
Ala	7.51	9.47	7.67	12.6	13.0	16.7	6.27	8.0	4.41	7.92
Arg	13.1	13.5	14.0	13.7	25.4	27.6	9.44	13.6	7.93	14.85
Asp	17.6	22.4	18.7	24.0	36.2	54.1	7.99	13.8	10.5	18.2
Cys	2.80	2.59	2.81	3.15	4.37	4.79	2.48	2.38	1.66	1.91
Glu	33.9	31.8	34.1	39.0	63.5	60.0	22.5	26.9	18.5	31.2
Gly	7.57	7.96	8.13	7.98	12.9	15.3	4.71	7.8	4.12	8.11
His	5.26	5.21	5.05	5.37	9.44	10.6	2.69	3.30	2.79	3.96
Ile	8.13	7.83	8.80	9.27	16.9	17.7	4.61	6.42	4.71	6.25
Leu	15.0	15.9	14.3	19.5	26.4	28.6	9.22	11.4	8.10	10.36
Lys	10.0	9.05	10.2	9.15	21.6	22.9	3.24	7.9	5.09	6.36
Met	2.69	2.53	3.07	3.03	5.18	4.21	4.55	3.83	2.06	3.11
Phe	10.1	9.40	10.4	11.0	20.7	19.5	6.18	6.91	6.10	7.78
Pro	11.0	11.3	10.5	13.1	18.1	20.6	6.85	5.84	4.90	6.21
Ser	9.96	9.36	10.3	11.5	18.8	19.9	6.10	6.74	5.48	7.93
Thr	7.00	7.18	7.54	7.80	13.0	15.3	4.95	5.46	3.73	5.43
Trp	9.40	2.02	7.55	2.49	19.1	4.85	5.42	2.04	5.32	1.78
Tyr	6.85	7.25	6.92	7.62	12.4	14.6	4.49	4.95	4.50	6.29
Val	9.26	9.04	10.2	10.5	17.8	18.9	5.97	7.7	5.67	7.94
Total	187	184	190	211	355	376	118	145	105	155

* Data are averaged from the results of the analysis of two samples.

Table 6 contains the amino acid compositions (% of total) of all five WF, which compared favorably with the WHO ideal [15]. Dietrend, Jot-M and Ang were below the WHO standards only in their lysine content. All other WHO recommendations for the essential amino acids were satisfied by the five WF.

After ascertaining that all five WF contained adequate proportions of the essential amino acids, researchers looked to see if the WF contained enough total amino acids (in grams) to meet the protein needs of an infant. Therefore, researchers multiplied the amino acid contents (mg/g) of the five WF by 65 g in order to estimate the total amount of amino acid provided by each day to weaning six-month-old infants. These values were then compared to the recommended daily allowance (RDA). The protein RDA for a 6-month-old infant is 13 g per day [16]. Sixty-five grams of the Soy weaning food would

Table 6. Amino acid composition (% of total)* of five weaning foods (WF) compared to WHO ideal

Amino acid	WHO Ideal** % of total amino acids	Dietrend % AA/Ideal × 100	Jot-M % AA/Ideal × 100	Soy % AA/Ideal × 100	Ang % AA/Ideal × 100	Vic-T % AA/Ideal × 100
Ile	2.8	155	165	170	140	160
Leu	6.6	121	114	113	118	117
Lys	5.8	93	93	105	47	83
Met+Cys	2.5	117	124	108	238	142
Phe+Tyr	6.3	143	145	148	143	160
Thr	3.4	110	117	108	123	105
Trp	1.1	457	361	488	418	461
Val	3.5	141	154	143	145	154

* WF % of total amino derived from amino acid composition (mg/g) (Table 3).
** World Health Organization [15].

Table 7. Comparison of the determined (Det.) vs calculated (Calc.) mineral contents (mg/g) of five weaning foods produced in Jos, Nigeria

Mineral	Weaning food									
	Dietrend		Jot-M		Soy*		Ang*		Vic-T*	
	Det.	Calc.	Det.	Calc.	Det.	Calc.	Det.	Calc.	Det.	Calc.
Ca	0.89	0.85	1.04	0.87	2.69	2.50	3.85	1.61	0.25	0.91
Cu	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
Fe	0.04	0.02	0.08	0.02	0.10	0.01	0.20	0.03	0.11	0.03
K	6.18	7.98	6.73	7.16	11.6	17.3	3.17	2.38	4.26	6.85
Mg	1.36	1.68	1.48	1.98	2.26	2.93	1.63	0.92	0.82	1.34
Mn	0.01	0.02	0.02	0.02	0.03	0.03	0.01	0.01	0.01	0.02
P	4.03	4.17	3.89	4.44	5.69	6.59	3.52	2.38	1.89	3.04
Zn	0.03	0.03	0.04	0.04	0.05	0.06	0.04	0.03	0.02	0.04

* Data are averaged from the results of the analysis of two samples.
Cr, I, Mo, Na and Se were unavailable for comparison.

Table 8. Comparison of the Recommended Dietary Allowances (mg) for various minerals and the amount of these minerals in 65 g of the five weaning foods

Mineral	RDA to 6 months	Dietrend	Jot-M	Soy*	Ang*	Vic-T*
Ca	400	58.1	67.6	175	250	16.3
Cr	0.01–0.04	0.03	0.04	0.05	0.06	0.05
Cu	0.40–0.60	0.31	0.6	0.81	0.94	0.37
Fe	6.0	2.52	5.45	6.38	12.9	7.15
Mg	40.0	88.4	96.2	147	106	53.3
Mn	0.30–0.60	0.86	1.14	2.00	0.93	0.59
Mo	0.015–0.030	0.26	0.33	0.40	0.12	0.13
P	300	262	253	370	228	123
Zn	5.0	2.17	2.89	3.56	2.62	1.42

* Data are averaged from the results of the analysis of two samples.
I, Se, and F were either not reported or not detectable.

provide 24.3 g of protein. Both Dietrend and Jot-M came close to meeting the RDA, providing 11.7 and 11.9 g of protein, respectively. However, Ang and Vic-T failed to meet the RDA criteria. As a result, although the five WF met or approximated the WHO standards for amino acid percentages, two of them fell short of satisfying the RDA for total protein.

Comparisons of the determined vs calculated mineral contents of the five weaning foods are summarized in Table 7. In general, the estimated mineral values closely approximated the values determined by direct chemical analysis. However, the determined iron contents for all five WF were consistently higher than the calculated values and the measured mineral content of Ang was higher in calcium and magnesium relative to values estimated from food composition tables.

Table 8 contains summaries of the comparisons between the amount of various minerals in 65 g of each of the five WF and RDA values; for all five WF, the daily intake of both calcium and zinc would have fallen below the RDA. The phosphorous content was low in all WF, except Soy; Dietrend was low in iron as well. All five WF met the RDA values for chromium, copper, magnesium, and manganese.

Discussion

The results of the present study allowed the answering of two questions: Can the nutrient content of WF in Nigeria be adequately estimated using published food tables? and, Can those same WF meet recommendations from the World Health Organization (WHO) and the National Research Council?

From this study, it was learned that published food composition tables are unreliable for ascertaining the nutritional content of weaning foods prepared from local ingredients in Jos. Calculations resulted in a general overestimation of the amount of fatty acids the WF would provide to the developing child. In contrast, the analyzed amino acid and mineral contents were close to calculated values.

There are several explanations that could account for the discrepancies between the determined and calculated nutritional parameters of the weaning foods: differing soils, climates, agricultural practices, or the different varieties of plants used to prepare the weaning food in Jos, Nigeria and those plants used for the USDA database. Also, the analytical methods may have differed, depending on the laboratory that performed the analyses and the year in which they were performed.

When using food composition tables, it is important to keep in mind how the food was prepared and whether or not the data were corrected for loss of nutrients during processing. These considerations are pertinent, not only for estimating the nutritive value of available weaning foods, but also when developing new weaning foods.

Having shown that the food tables failed to predict the content of particular nutrients in the five Nigerian WF, researchers wanted to determine how well the determined nutrient contents compared to recommendations from WHO as well as to Recommended Dietary Allowances (RDA) established by the National Research Council. Overall, of the five Nigerian WF, Soy provided the most EFA and had a favorable 18:2/18:3 ratio. Soy also contained the most protein. Jot-M and Dietrend contained large amounts of essential fatty acids; however, the 18:2/18:3 ratio of its lipid fraction was 12:1. It would be beneficial to modify the composition of these two WF to decrease the proportion of 18:2 and/or increase the proportion of 18:3 in order to meet the WHO recommendation of a 5:1 to 10:1 18:2/18:3 ratio. Both Dietrend and Jot-M nearly met the recommended quantities of total daily protein and amino acid percentages. Ang and Vic-T contained more than the recommended amount of linoleic acid had contained inadequate amounts of α-linolenic acid, which resulted in a highly unfavorable 18:2/18:3 ratio in both WF. These two WF also contained the lowest amounts of protein.

As mentioned above, when the FA composition of the WF were compared with recommended values, the criteria utilized to assess the FA content was the joint consultation of WHO and the Food and Agriculture Organization (FAO). The WHO/FAO recommends that 'During weaning and at least until two years of age, the child's diet should contain 30–40% of energy from fat and provide similar levels of essential fatty acids as are found in breast milk.' According to these criteria, researchers concluded that Soy and Jot-M contained useful amounts of both linoleic and α-linolenic acids while exhibiting a favorable 18:2/18:3 ratio as well. Dietrend contained high levels of the two essential fatty acids, but had an 18:2/18:3 ratio of 12:1. Ang and Vic-T both had an 18:2/18:3 ratio that diverged widely from the WHO/FAO recommendation. An overabundance of 18:2n-6 relative to 18:3n-3 in an infant's diet could inhibit the conversion of α-linolenic acid into long chain polyunsaturated fatty acids (PUFA), such as docosahexaenoic acid (DHA) [17]. Holman and colleagues [18] reported that the α-linolenic acid deficiency in a patient receiving total parenteral nutrition was caused by the use of safflower oil that had a linoleic/α-linolenic acid ratio of 115:1. Since infants, in general, utilize both DHA and arachidonic acid extensively for central nervous system membrane development during the first year of life, the appropriate 18:2/18:3 ratio is, therefore, critical.

Fatty acids contained in the lipid fraction of human milk or infant formulas are not only a source of energy but also function as integral components of cell membranes, including myelin [19–21]. The n-6 and n-3 long chain PUFA, arachidonic acid (AA 20:4n-6) and DHA (22:6n-3) in particular, are abundant in neural tissues, such as the brain and retina [20, 21]. During the rapid development of the infant brain in the late fetal period and first 12 months of post-natal life, both AA and DHA are utilized extensively in synaptic cell membrane composition and photoreceptor cells [22].

In humans, AA is synthesized from linoleic acid and DHA is synthesized from α-linolenic acid. While there is debate regarding the ability of the infant to complete these conversions in the first six months of life, there is general agreement that the enzyme systems that are available cannot independently meet the needs of the developing child [17, 21, 23]. Thus, an infant's diet in the first year of life must contain adequate quantities of not only the essential fatty acids (linoleic and α-linolenic acid) but also the n-3 and n-6 PUFAs needed to insure proper neural development. Usually these needs are met by the mother's milk, but not by the weaning foods that are commercially available in Nigeria and most other countries [20].

The proportion of oleic acid in Vic-T (38.1%), Ang (34.8%), Dietrend (30.9%) and Jot-M (29.5%) were all comparable to that of human milk, but the percentage of oleic acid in Soy was low at 19.3%. With comparable oleic acid proportions, it became apparent to researchers that the high percentage of unsaturated fatty acid in the WF was due to the high proportions of both linoleic and α-linolenic acid in the lipid fraction. This also accounted for the low proportion of saturated fatty acids in the WF. Therefore, the fatty acid composition of the WF appeared to compliment that of human milk.

The amino acid content of these five WF is a particularly relevant issue in Nigeria, where undernutrition is common. In fact, the five locally-prepared WF analyzed herein were developed in an attempt to decrease the incidence of protein-energy malnutrition in the country. All five weaning foods met most of the WHO standards for amino acid composition. However, Soy was the only WF that satisfied the RDA for total protein content on a daily intake basis. Both Dietrend and Jot-M, which contained peanuts as an ingredient, came close to meeting the RDA recommendations. These findings are explained by the high protein content of soybeans and peanuts, and underscore their importance as WF ingredients. Similarly, Owolabi and colleagues [7] found that communities producing and using soybeans had a relatively low incidence of severe malnutrition among children. Also, in 1998, Nkama and co-worker [24] found that supplementation of rice or millet flour breakfast food with cowpea and/or peanut flour improved the protein content of masa (a Nigerian cereal-based food). The low total protein content of Ang and Vic-T should be a cause for concern.

With regard to mineral content and relative to the RDAs, all five WF contained inadequate amounts of both calcium and zinc relative to the RDA. Also, Dietrend was low in iron while Soy was the only WF to contain adequate amounts of phosphorus. However, since these WF are used to supplement human milk, it is believed that a nursing child's calcium needs would probably be met by the mother's milk. However, Obizoba and colleague [25] found that baobab milk (made from the dry pulp of baobab fruits) contained more protein, iron and calcium than both human milk and cows milk. Therefore, supplementation of the Nigerian WF with baobab flour would not only provide the needed minerals, but increase their protein content as well.

Weaning foods are utilized not only as a transition to adult food, but also as a supplement to human milk. The essential fatty acid content of human milk in Nigeria may be suboptimal due to poor maternal diet [5]. The weaning foods that were analyzed in the present study are prepared for consumption by adding warm water, which results in a porridge-like meal. The percentage of dry weaning food content is generally 9% thus producing an easily ingested and filling meal for the infant but one which contains a low nutrient density.

When assessing the nutrition of the child, not only must the topic of nutrient density be addressed but also the ability of the child to absorb the nutrients that are provided in the diet. The bioavailability of nutrients in weaning foods is an especially pertinent topic in a country such as Nigeria where diarrheal diseases are common. Diarrhea and other bowel disorders may impair a child's ability to absorb fatty acids and other nutrients [2, 26]. Thus, for obvious reasons, one should not assume that the nutrient content of the weaning foods is an accurate predictor of the nutrients actually being utilized by the child.

In conclusion, it is believed that the quantitative and qualitative analyses of locally prepared weaning foods will provide practical information that can be used to improve infant nutrition in Nigeria. For example, these data could be used to assess the bioavailability of weaning foods or the effect of weaning foods on the fatty acid composition of lipids in human tissues. The discrepancies found between the estimated and calculated fatty acid composition of the weaning foods caused the researchers to wonder: if one were to predicate a weaning food from published food composition data, would the resulting product contain substantially less of the nutrients in question? It is anticipated that these nutrient analyses could be used to update food composition tables currently being created in African countries in order to develop improved weaning foods to meet the nutritional needs of children in Nigeria and elsewhere.

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