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Nutrient Composition and Adequacy of two Locally Formulated Winged Termite (*Macrotermes Bellicosus*) Enriched Complementary Foods

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Abstract

The period from birth to two years of age constitute critical window of opportunity for promoting optimal growth and development of a child. Inadequate food intake and poor feeding practices are causes of malnutrition among Nigerian children, as many locally formulated complementary foods are deficient in protein and micronutrients. Roasted *Macrotermes bellicosus* (MB) is nutritious and relished as snack by people living the traditional lifestyle. This study was carried out to investigate possible use of MB in formulating nutrient-dense complementary foods from maize and sorghum. *Macrotermes bellicosus* was collected in Ibadan, Nigeria during their swarming, roasted, de-winged, powdered and added to fermented corn (CF) and sorghum (SF) flour in the ratio 100%flour, 90%flour+10%MB, 85%flour+15%MB, and 80%flour+20%MB to give eight complementary foods, which were analysed for proximate, mineral, vitamin and antinutrient composition using AOAC methods.

Hundred grammes of CF and SF contained 11.7g, 10.6g moisture, 8.9g, 9.7g crude protein, 3.1g, 2.8g fat, 74.3g, 74.8g total carbohydrates, 6.67mg, 26.60mg calcium, 295.50mg, 325.43mg phosphorus, 2.61mg, 7.61mg iron, 3.19mg, 2.41mg zinc, and yielded 353.9kcal, 358.6kcal energy respectively. Significant reduction occurred in moisture and carbohydrate content of MB-incorporated complementary foods while their crude protein, ash, fat, calcium, iron, zinc, vitamins B_3, B_6 B_{12} and β-carotene content increased significantly as the level of inclusion of MB increased ($p<0.05$). Level of atinutritional factors were insignificantly low in the blends, and cannot pose any health risk. *Macrotermes bellicosus* can be used in enriching cereal-based complementary foods as means of reducing infant and young child malnutrition in Nigeria.

Keywords: complementary foods, fermented corn flour, fermented sorghum flour, nutrient adequacy, winged termites

1. Introduction

Undernutrition is a serious medical condition marked by deficiency of energy, essential proteins, fats, vitamins, or minerals in a diet, and it is especially burdensome and dangerous for young, growing children. Malnutrition contributes to one third of the eight million deaths of children under five years of age every year among invisible children, hence, urgent action is required (Black et al., 2010; Rajaratnam, 2010). Most of the damage caused by malnutrition occurs in children before they reach their second birthday. This is the critical window of opportunity when the quality of a child's diet has a profound, sustained impact on his or her health and physical and mental development.

Diets that are lacking in high-quality protein, essential fats, carbohydrates, vitamins, and minerals can impair growth and development, increase the risk of death from common childhood illness, or result in life-long health consequences (Black et al., 2008). Complementary feeding period is the time when malnutrition starts in many infants (Daelmans & Saadeh, 2003), and poor feeding practices coupled with shortfall in food intake are the most important direct factors responsible for under-five malnutrition and illness among children in Nigeria (Solomon, 2005). Traditional complementary foods in the developing countries are of low nutritive value and are characterized by low protein, low energy density and high bulk, because they are usually cereal–based (Shiriki et al., 2015).

Insects link biodiversity conservation and human nutrition in a way that many other food sources do not. They often contain more protein, fat, and carbohydrates than equal amounts of beef or fish, and a higher energy value than soybeans, maize, beef, fish, lentils, or other beans (FAO, 2013). Edible insects consumption has been recently reported in Nigeria (Agbidye et al., 2009; Adeyeye, 2011) among which the termite, (*Macrotermes natalensis*) had the highest mean frequency (Agbidye et al., 2009). Dried *Marcrotermes bellicosus* has been reported to be a good source of dietary protein, fat and micronutrients (Banjo et al., 2006; Ekpo et al., 2009; Adeyeye, 2011; Adepoju & Omotayo, 2014). Adepoju and Omotayo (2014) reported the insect to be low in antinutrients and suggested its possible inclusion in formulating adequate, nutrient-dense complementary foods. This study was therefore carried out to determine the nutrient composition and suitability of *Marcrotermes bellicosus* as source of essential macro and micronutrients in formulating two adequate, nutrient-dense cereal-based complementary foods.

2. Materials and Methods

2.1 Sample Collection and Preparation

Sample of *M. bellicosus* was collected around Alegongo Area, Akobo, Ibadan, Nigeria during their swarming flights. The sample was roasted for ten minutes over a gas cooker, dewinged by rubbing between the palms and then winnowed to remove the wings, labelled as "Roasted sample" and kept in a freezer at - 4ºC till when needed for analysis (Adepoju & Omotayo, 2014). About 1.5 kg each of white maize (*Zea mays*) and sorghum (*Sorghum bicolor*) were purchased from Bodija market in Ibadan, Oyo State, Nigeria. The maize and sorghum grains were cleaned and washed thoroughly to remove adhering dirt and dust. The maize and sorghum samples were separately soaked in distilled water for 72 hours, drained and wet-milled. The milled samples were sieved and allowed to settle for 3 hours and then drained. The drained samples were oven-dried for 12 hours at 60^0C in plastic trays, packed in cellophane nylon and kept till when needed (Inyang & Idoko, 2006). Various samples of complementary foods were prepared as follows:

Sample A	=	100 g Maize flour
Sample A_1	=	90 g Maize flour + 10 g *M. bellicosus*
Sample A_2	=	85 g Maize flour + 15 g *M. bellicosus*
Sample A_3	=	80 g Maize flour + 20 g *M. bellicosus*

Sample B	=	100 g Sorghum flour
Sample B_1	=	90 g Sorghum flour + 10 g *M. bellicosus*
Sample B_2	=	85 g Sorghum flour + 15 g *M. bellicosus*
Sample B_3	=	80 g Sorghum flour + 20 g *M. bellicosus*

2.2 Proximate Composition Analysis

Moisture content of the samples was determined by air oven at 105^0C (Plus 11 Sanyo Gallenkamp PLC UK) for 4 hours. The crude protein of the samples was determined using micro-Kjeldahl method (Method No 978.04, AOAC, 2005). Crude lipid was determined by Soxhlet extraction method (Method No 930.09, AOAC, 2005) and the crude lipid estimated as g/100g of sample. The ash content was determined by weighing 5g of sample in triplicate and heated in a muffle furnace (Gallenkamp, size 3) at 550^0C for 4 h (Method No 930.05, AOAC, 2005). The total carbohydrate content was obtained by difference. Gross energy of the samples was determined using ballistic bomb calorimeter (Manufacturer: Cal 2k – Eco, TUV Rheinland Quality Services (Pty) Ltd, South Africa).

2.3 Mineral Analysis

Potassium and sodium content of the samples were determined by digesting the ash of the samples with perchloric acid and nitric acid, and then taking the readings on Jenway digital flame photometer/spectronic20 (AOAC, 2005: (975.11)). Phosphorus was determined by vanado-molybdate colorimetric method (AOAC, 2005: (975.16)). Calcium, magnesium, iron, zinc, manganese, and copper were determined spectrophotometrically by using Buck 200 atomic absorption spectrophotometer (Buck Scientific, Norwalk) and compared with absorption of standards of these minerals (AOAC, 2005: (975.23)).

2.4 Vitamin Analysis

2.4.1 Vitamin A Determination

Vitamin A was determined through ultraviolet absorption measurement at 328 nm after extraction with chloroform. Calibration curve of vitamin A acetate was made and sample vitamin A concentration estimated as microgram (µg) of vitamin A acetate.

2.4.2 Thiamine (Vitamin B_1) Determination

Thiamine content of the sample was determined by weighing 1g of it into 100ml volumetric flask and adding 50ml of 0.1M H_2SO_4 and boiled in a boiling water bath with frequent shaking for 30 minutes. 5ml of 2.5M sodium acetate solution was added and flask set in cold water to cool contents below 50^0C. The flask was stoppered and kept at 45-50^0C for 2 hours and thereafter made up to 100ml mark. The mixture was filtered through a No. 42 Whatman filter paper, discarding the first 10ml. 10ml was pipetted from remaining filterate into a 50ml volumetric flask and 5ml of acid potassium chloride solution was added with thorough shaking. Standard thiamine solutions were prepared and treated same way. The absorbance of the sample as well as that of the standards was read on a fluorescent UV Spectrophotometer (Cecil A20 Model) at a wavelength of 285nm.

2.4.3 Riboflavin (Vitamin B_2) Determination

1g of each sample was weighed into a 250ml volumetric flask, 5ml of 1M HCl was added, followed by the addition of 5ml of dichloroethene. The mixture was shaken and 90ml of de-ionized water was added. The whole mixture was thoroughly shaken and was heated on a steam bath for 30 minutes to extract all the riboflavin. The mixture was then cooled and made up to volume with de-ionized water. It was then filtered, discarding the first 20ml of the aliquot. 2ml of the filterate obtained was pipetted into another 250ml volumetric flask and made up to mark with de-ionized water. Sample was read on the fluorescent spectrophotometer at a wavelength of 460nm. Standard solutions of riboflavin were prepared and readings taken at 460nm, and the sample riboflavin obtained through calculation.

2.4.4 Niacin (Vitamin B_3) Determination

5g of sample was extracted with 100ml of distilled water and 5ml of this solution was drawn into 100ml volumetric flask and make up to mark with distilled water. Standard solutions of niacin were prepared and absorbance of sample and standard solutions were measured at a wavelength of 385nm on a spectrophotometer and niacin concentration of the sample estimated.

Pyridoxine (Vitamin B_6) determination

The vitamin B_6 content of the sample was determined by extracting 1g of sample with 0.5g of ammonium chloride, 45 ml of chloroform and 5 ml of absolute ethanol. The mixture was thoroughly mixed in a separating funnel by shaking for 30mins, and 5ml of distilled water added. The chloroform layer containing the pyridoxine was filtered into a 100ml volumetric flask and made up to mark with chloroform. 0-10ppm of vitamin B_6 standard solutions were prepared and treated in a similar way as sample, and their absorbance measured on Cecil 505E spectrophotometer at 415mn. The amount of vitamin B6 in the sample was then calculated.

Cyanocobalamin (Vitamin B_{12}) determination

Cyanocobalamin content of the sample was determined by extracting 1g of sample with distilled water with shaking for 45min followed by filtering the mixture. The first 20 ml of the filterate was rejected, and another 20mls filtrate collected. To the collected filtrate, 5mls of 1% Sodium Dithionite solution was added. Standard cyanocobalamin solutions (0-10µg/ml) were prepared and absorbance of sample as well as standard was read on spectronic21D spectrophotometer at 445nm. The amount of sample cyanocobalamin was then estimated through calculation.

2.4.5 Ascorbic acid Determination

Ascorbic acid in the sample was determined by titrating its aqueous extract with solution of 2, 6-dichlorophenol-indophenol dye to a faint pink end point.

2.5 Antinutrient Analysis

Oxalate was determined by extraction of the samples with water for about three hours and standard solutions of oxalic acid prepared and read on spectrophotometer (Spectronic20) at 420 nm. The absorbance of the samples was also read and amount of oxalate estimated. Phytate was determined by titration with ferric chloride solution (Sudarmadji & Markakis, 1977); while trypsin inhibitory activity was determined on casein and comparing the absorbance with that of trypsin standard solutions read at 280 nm (Makkar & Becker, 1996). The tannin content was determined by extracting the samples with a mixture of acetone and acetic acid for five hours, measuring their absorbance and comparing the absorbance of the sample extracts with the absorbance of standard solutions of tannic acid at 500 nm on spectronic20 (Griffiths & Jones, 1977). Saponin was also determined by comparing the absorbance of the sample extracts with that of the standard at 380 nm (Makkar & Becker, 1996). All determinations were carried out in triplicate.

2.6 Statistical Analysis

The data obtained were subjected to analysis of variance (ANOVA), Fisher's Least Significance Difference (LSD) and Duncan multiple range tests at $p<0.05$.

3. Results

3.1 Proximate Composition of Roasted M. bellicosus, Cereal Flour and Complementary Foods

The result of proximate composition of roasted *M. bellicosus* and fermented maize and sorghum flour is as shown in Table 1(A). Roasted *M. bellicosus* moisture content was very low while the crude protein, fat, carbohydrate and gross energy content were very high. The moisture and crude fat content of the two cereal flour were low, the crude protein value was moderately high while the ash and total carbohydrates content were very high. The moisture and crude fat values of the maize flour were not significantly different from that of sorghum ($p>0.05$), while sorghum was significantly higher in crude protein ($p<0.05$) but insignificantly higher in ash, total carbohydrates and gross energy ($p>0.05$).

There was a significant reduction in moisture content of the formulated complementary foods, the level of reduction increasing with increasing level of inclusion of MB ($p<0.05$), Table 1(B). Significant differences also existed between the enriched complementary foods, the level of reduction in moisture content increasing with increase in inclusion level ($p<0.05$). There were significant increase in values of crude protein and fat, ash, total carbohydrates and gross energy of the enriched maize and sorghum complementary foods ($p<0.05$), the values increasing with increasing level of inclusion of *M. bellicosus*.

Table 1(A). Proximate composition of roasted *M. bellicosus* and cereal flour (g/100g)

Sample	*M. bellicosus*	Maize (A)		Sorghum (B)	
		(Wet)	(Dry)	(Wet)	(Dry)
Moisture	4.0±0.04	65.0±0.12	11.7±0.03	64.1±0.50	10.6±0.05
Crude Protein	31.8±0.10	3.3±0.03	8.9±0.09	3.9±0.04	9.7±0.07
Crude Fat	16.4±0.03	1.2±0.01	3.1±0.03	1.1±0.01	2.8±0.02
Ash	3.8±0.03	0.8±0.00	2.0±0.02	0.8±0.00	2.1±0.01
Total Carbohydrates	43.0±0.10	29.7±0.05	74.3±0.11	30.1±0.05	74.8±1.84
Gross Energy (kcal/)	450.7±0.00	-	353.9±0.28	-	358.6±6.81

Table 1(B). Proximate composition of enriched complementary foods (g/100)

Sample	Moisture	C. Protein	C. Fat	Ash	T. Carbohydrates	Gross
A	$11.7±0.03^{a}$	$8.9±0.09^{a}$	$3.1±0.03^{a}$	$2.0±0.02^{a}$	$74.3±0.11^{a}$	$353.91±0.28^{a}$
A_1	$11.4±0.03^{b}$	$17.8±0.10^{b}$	$5.1±0.02^{b}$	$2.9±0.01^{b}$	$61.7±0.11^{b}$	$362.36±0.64^{b}$
A_2	$11.1±0.04^{c}$	$18.6±0.09^{c}$	$5.6±0.03^{c}$	$3.2±0.02^{c}$	$61.6±0.11^{b}$	$364.85±0.09^{c}$
A_3	$10.7±0.04^{d}$	$19.7±0.10^{d}$	$5.8±0.04^{d}$	$3.5±0.02^{b}$	$60.5±0.16^{c}$	$367.12±0.12^{d}$
B	$10.6±0.05^{e}$	$9.7±0.07^{e}$	$2.8±0.02^{e}$	$2.1±0.01^{e}$	$73.8±1.84^{d}$	$358.64±6.81^{e}$
B_1	$10.3±0.04^{f}$	$18.3±0.07^{f}$	$4.3±0.03^{f}$	$3.8±0.02^{f}$	$61.5±0.12^{e}$	$357.40±0.22^{f}$
B_2	$10.1±0.05^{g}$	$19.7±0.11^{g}$	$4.7±0.12^{g}$	$4.1±0.01^{g}$	$60.8±1.84^{f}$	$364.25±0.31^{g}$
B_3	$9.8±0.04^{h}$	$21.2±0.12^{h}$	$5.3±0.04^{h}$	$4.4±0.03^{h}$	$56.1±0.02^{g}$	$363.08±0.18^{h}$
*RV	<5	>15	10-25	<3	64	400-425

Values are means ± standard deviations of triplicate determinations.

Means with different superscripts in a column are significantly different (p<0.05).

*RV = Recommended values (g/100g) *(CODEX CAC/GL 08. 1991): Codex alimentarius:

Guidelines on formulated supplementary foods for older infants and young children.

Sample A = 100g Maize flour; Sample A_1 = 90g Maize flour + 10g *M. bellicosus*

Sample A_2 = 85g Maize flour+15g *M. bellicosus;* Sample A_3 = 80g Maize flour+20g *M. bellicosus*

Sample B = 100g Sorghum flour; Sample B_1 = 90g Sorghum flour+10g *M. bellicosus;* Sample B_2 = 85g Sorghum flour+15g *M. bellicosus;* Sample B_3 = 80g Sorghum flour+20g *M. bellicosus*.

3.2 Mineral Composition of Roasted M. bellicosus, Cereal Flour and Complementary Foods

Marcrotermes bellicosus is rich in potassium, calcium, phosphorus, zinc, and copper, moderate in sodium, iron and manganese, but low in magnesium (Table 2(A)). Maize and sorghum flour are high in potassium, phosphorus, and zinc, low in sodium, and very low in calcium, magnesium, and manganese content. Maize flour was significantly higher in potassium, sodium, zinc and copper than sorghum flour (p<0.05), while sorghum flour was significantly higher in calcium, magnesium, phosphorus, iron and manganese than maize flour (p<0.05).

Addition of *M. bellicosus* to maize and sorghum flour (Tables (2B) and (2C)) resulted in significant increase in values of the minerals (p<0.05) in all the formulated complementary diets, the values increasing with increase in inclusion level of *M. bellicosus*. However, the mineral content of the formulated complementary foods were lower than the recommended values by FAO/WHO. The values of the minerals of enriched complementary foods were significantly different (p<0.05) from one another for both maize and sorghum, the 10% *M. bellicosus* incorporated flours having the lowest values while 20% *M. bellicosus* incorporated flours had the highest values.

3.3 Vitamin Composition of Complementary Foods

Addition of *M. bellicosus* to maize and sorghum flour (Table 3(A) and 3(B)) resulted in significant increase in β-carotene, niacin, vitamin B6, and B12 content, with significant reduction in thiamine, riboflavin and ascorbic acid content of enriched complementary foods (p<0.05). For the vitamins with increased content, significant increase was observed as the level of inclusion increased, while there was also significant decrease with increasing level of inclusion for vitamins with decrease in values. Vitamin B_6 content of the formulated diets were higher in value compared with their FAO/WHO recommended value. However, there were significant reduction in thiamine, riboflavin and vitamin C content of the formulated diets (p<0.05). The levels of thiamine, riboflavin and vitamin C content were lower than the value recommended by FAO/WHO.

Table 2(A). Mineral composition of roasted *M. bellicosus* and cereal flour (mg/100)

Parameter	*M. bellicosus*	Maize (A)	Sorghum (B)
Potassium	361.13±0.31	211.83±0.17	205.33±0.25
Sodium	98.40±0.20	52.83±0.25	48.50±0.20
Calcium	227.50±0.20	6.67±0.26	26.60±0.30
Magnesium	24.33±0.15	14.00±0.36	14.73±0.15
Phosphorus	361.30±0.20	295.50±0.30	325.43±0.25
Iron	2.07±0.25	2.61±0.30	7.61±0.03
Zinc	15.03±0.31	3.19±0.04	2.41±0.03
Manganese	2.35±0.25	0.52±0.04	0.62±0.05
Copper	5.07±0.54	1.57±0.25	0.83±0.25

Table 2(B). Mineral composition of formulated maize complementary Foods (mg/100g)

	A	A_1	A_2	A_3	*RV
Potassium	211.83±0.17^a	216.47±0.25^b	219.50±0.30^c	223.57±0.35^d	516
Sodium	52.83±0.25^a	55.60±0.30^b	57.70±0.17^c	59.47±0.25^d	296
Calcium	6.67±0.26^a	7.50±0.20^b	9.27±0.35^c	10.60±0.17^d	500
Magnesium	14.00±0.36^a	15.17±0.25^b	16.73±0.15^c	18.20±0.36^d	76
Phosphorus	295.50±0.30^a	297.30±0.15^b	299.30±0.15^c	301.43±0.15^d	456
Iron	2.61±0.30^a	2.81±0.20^b	3.08±0.03^c	4.13±0.03^d	16
Zinc	3.19±0.04^a	3.49±0.04^b	3.82±0.04^c	4.12±0.03^d	3.2
Manganese	0.52±0.04^a	0.57±0.02^b	0.67±0.02^c	0.82±0.03^d	0.60**
Copper	1.57±0.25^a	2.17±0.35^b	2.40±0.30^c	3.13±0.25^d	0.34**

Values are mean ± standard deviation of triplicate determinations. Mean value with different superscripts in a row are significantly different (p0.05).

*RV = Recommended values (mg/100g) *(CODEX CAC/GL 08. 1991) / **RDA (Sareen, Jack & James, 2009).

Table 2 (C). Mineral composition of formulated sorghum complementary Foods (mg/100g)

	B	B_1	B_2	B_3	*RV
Potassium	205.33±0.25^e	209.50±0.25^f	211.77±0.15^g	214.50±0.20^h	516
Sodium	48.50±0.20^e	49.40±0.30^f	51.43±0.2^g	54.06±0.25^h	296
Calcium	26.60±0.30^e	27.60±0.30^f	29.07±0.35^g	31.50±0.03^h	500
Magnesium	14.73±0.15^e	15.50±0.20^f	16.50±0.17^g	18.63±0.15^h	76
Phosphorus	325.43±0.25^e	327.70±0.17^f	331.37±0.21^g	334.43±0.11^h	456
Iron	7.61±0.03^e	7.91±0.02^f	8.09±0.02^g	9.22±0.02^h	11
Zinc	2.41±0.03^e	2.63±0.05^f	3.31±0.03^g	3.92±0.04^h	3.2
Manganese	0.62±0.05^e	0.66±0.03^f	0.81±0.03^g	0.92±0.03^h	32
Copper	0.83±0.25^e	1.20±0.30^f	1.90±0.25^g	2.53±0.25^h	160

Values are means ± standard deviations of triplicate determinations.

Mean value with different superscripts in a row are significantly different (p<0.05)

Table 3(A). Vitamin composition of maize flour and *M. bellicosus* enriched complementary foods (mg/100 g)

	A	A_1	A_2	A_3	*RV
β-carotene (μg/)	216.23±0.40^a	223.77±0.40^b	225.50±0.30^c	227.60±0.30^d	400
Thiamine	0.35±0.02^a	0.31±0.02^b	0.26±0.02^c	0.21±0.03^d	0.5
Riboflavin	0.12±0.01^a	0.06±0.01^b	0.04±0.01^c	0.02±0.01^d	0.5
Niacin	2.09±0.25^a	2.16±0.03^b	2.24±0.03^c	2.35±0.02^d	6
Vitamin B_6	0.72±0.04^a	0.78±0.01^b	0.83±0.02^c	0.91±0.03^d	0.5
Vitamin B_{12} (μg/)	0.18±0.03^a	0.19±0.02^b	0.27±0.03^c	0.31±0.02^d	0.9
Vitamin C	2.83±0.06^a	2.40±0.03^b	2.22±0.04^c	2.00±0.05^d	30

Values are means ± standard deviations of triplicate determinations.

Means with different superscripts in a row are significantly different (p<0.05).

Table 3(B). Vitamin composition of sorghum flour and *M. bellicosus* enriched complementary foods (mg/100 g)

	B	B1	B2	B3	*RV
β-carotene (μg/)	30.23 ± 0.50^{e}	34.80 ± 0.30^{f}	37.20 ± 0.46^{g}	39.10 ± 0.46^{h}	400
Thiamine	0.43 ± 0.02^{e}	0.37 ± 0.03^{f}	0.24 ± 0.01^{g}	0.18 ± 0.02^{h}	0.5
Riboflavin	0.14 ± 0.01^{e}	$0.08^{j} \pm 0.01^{f}$	0.05 ± 0.01^{g}	0.18 ± 0.02^{h}	0.5
Niacin	4.11 ± 0.03^{e}	3.63 ± 0.02^{f}	3.71 ± 0.04^{g}	3.76 ± 0.02^{h}	6
Vitamin B_6	0.49 ± 0.02^{e}	0.52 ± 0.01^{f}	0.56 ± 0.02^{g}	0.64 ± 0.02^{h}	0.5
Vitamin B_{12} (μg/)	0.27 ± 0.02^{e}	0.31 ± 0.02^{f}	0.35 ± 0.03^{g}	0.64 ± 0.02^{h}	0.9
Vitamin C	3.84 ± 0.03^{e}	3.01 ± 0.04^{f}	2.85 ± 0.04^{g}	2.67 ± 0.04^{h}	30

Values are means ± standard deviations of triplicate determinations. Means with different. superscripts in a row are significantly different (p≤0.05).

3.4 Antinutritional Factors of Maize, Sorghum and Enriched Complementary Foods

Maize and sorghum flour were very low in phytate, oxalate, tannin and saponin content, with no detectable level of trypsin inhibitors (Tables 4(A) and (B)). Significant reduction in values resulted on all antinutritional factors studied as the level of inclusion of *M. bellicosus* increased (p<0.05).

Table 4(A) Antinutritional factors in maize flour and *M. bellicosus* enriched complementary foods (mg/100 g)

Parameters	A	A_1	A_2	A_3
Phytate	0.063 ± 0.001^{c}	0.051 ± 0.000^{b}	0.041 ± 0.000^{z}	0.029 ± 0.002^{m}
Oxalate	0.030 ± 0.002^{w}	0.022 ± 0.001^{e}	0.017 ± 0.002^{r}	0.012 ± 0.001^{t}
Tannin	0.022 ± 0.000^{a}	0.013 ± 0.000^{h}	0.001 ± 0.000^{f}	0.007 ± 0.001^{g}
Saponin	0.076 ± 0.002^{c}	0.064 ± 0.002^{d}	0.051 ± 0.001^{e}	0.039 ± 0.003^{w}
T. I (TIU/mg)	ND	ND	ND	ND

Mean value with different superscripts in a row are significantly different (p<0.05).

T. I = Trypsin Inhibitors; ND = Not detected at milligramme level

Table 4(B). Antinutritional factors in sorghum flour and *M. bellicosus* enriched complementary foods (mg/100 g)

Parameters	B	B_1	B_2	B_3
Phytate	0.23 ± 0.00^{a}	0.22 ± 0.00^{b}	0.20 ± 0.00^{c}	0.19 ± 0.00^{d}
Oxalate	0.13 ± 0.00^{a}	0.12 ± 0.00^{b}	0.11 ± 0.00^{c}	0.11 ± 0.00^{c}
Tannin	0.09 ± 0.00^{a}	0.08 ± 0.00^{b}	0.07 ± 0.00^{c}	0.05 ± 0.00^{d}
Saponin	0.10 ± 0.00^{a}	0.09 ± 0.00^{b}	0.08 ± 0.00^{c}	0.07 ± 0.00^{d}
T. I (TIU/mg)	ND	ND	ND	ND

4. Discussion

4.1 Proximate Composition

The low moisture content of roasted *M. bellicosus* underscores it high value of dry matter content, and hence high value of macronutrients. The value obtained for the macronutrients of the insect was very similar to those reported for roasted *M. bellicosus* in the literature (Adepoju (2016), and within the range stated for termite (*Trinervitermes germinates*, Afiukwa *et al*., 2013), while the value for moisture and crude protein content was similar to that of Adepoju & Omotayo (2014). Generally, the insect is rich in crude protein, crude lipid, ash, total carbohydrates and gross energy. The high values of the macronutrients of the insect can contribute significantly to macronutrients of infant complementary foods.

The values of moisture, crude protein, fat total carbohydrate and gross energy of fermented maize and sorghum flour were similar to the ones reported in the literature (Adepoju & Daboh, 2013). The fermented flour were low in moisture and fat content, which is an indication that they can be kept for a period of time before they go bad. They were moderate in protein content compared with that of other plant-based staples used for complementary foods such as yam and rice (Adepoju, 2012; Otegbayo et al., 2001). However, the two fermented flour were high in ash, total carbohydrates and gross energy content. The high values of total carbohydrates and gross energy content underscore the reason why they are used as basic staples for locally made complementary foods.

The reduction in moisture content of the *M. bellicosus* enriched complementary foods was similar to the trend reported by Adepoju and Daboh (2013) for *Cirina forda* powder enriched maize and sorghum complementary foods. The lower moisture content in the enriched complementary foods was an indication that the dried form of the enriched flour can keep long before use.

The increase in protein, fat, ash, total carbohydrate and gross energy content of enriched complementary foods is an indication that addition of *M. bellicosus* resulted in significant improvement in the nutrient content of the formulated foods. The same trend of increase in nutrient content of the enriched flour was observed by Adepoju and Daboh (2013) in *Cirina forda* powder enriched fermented maize and sorghum flour. Inclusion of *M. bellicosus* powder in enriching locally formulated cereal-based complementary foods seems to be a promising way of increasing the protein content of animal origin and gross energy content of the complementary foods.

Feeding infants and young children with the *M. bellicosus* enriched cereal-based complementary foods twice daily will likely provide the greater part of their recommended value of macronutrient needs on daily basis, especially at 20% level of inclusion.

4.2 Mineral Composition

The value obtained for mineral composition of the *M. bellicosus* was closely related to the values reported by Adepoju and Omotayo (2014). *M. bellicosus* is rich in potassium, calcium, phosphorus, zinc, manganese and copper, moderate in sodium and iron content compared with plant sources, and very low in magnesium. Its sodium: potassium ratio is highly desirable as the two are responsible for intra and extra cellular electrolyte balance (Insel et al., 2007; Rolfe et al., 2009)). Calcium is required for development of strong bones and teeth, and participates in muscle contraction, blood clotting and nervous impulses, while phosphorus is required for development of strong bones and teeth, important in genetic material, used in energy transfer and buffer system that maintain acid-base system (Rolfe et al., 2009). Zinc is required for growth, cell replication, fertility and reproduction, and hormonal activities among others (Rolfes et al., 2009; Insel et al., 2007; Roth & Townsend, 2003), while manganese and copper are co-factors in some enzyme activities (Sareen et al., 2009), hence, the inclusion of the insect in complementary foods will be advantageous.

The fermented maize and sorghum flour were high in potassium and phosphorus, moderate in iron but low in sodium, zinc, manganese and copper, and very low in calcium and magnesium in comparison with their daily requirements. The very low values of essential macro and micro minerals explains the inadequacy of these basal staples being used for complementary foods with little or no source(s) of calcium and complete protein, hence they are usually high in energy but low in other essential nutrients. Use of this type of complementary foods will result in undernutrion and growth failure in old infants and young children being fed with this kind of foods.

Addition of *M. bellicosus* powder at various levels of inclusion improved the values of all the minerals in fermented maize and sorghum flour significantly, showing that its inclusion will be beneficial to locally formulated cereal-based complementary foods, especially at 20% w/w level of inclusion. Formulations with 20% inclusion level (A3 and B3) of the insect gave the highest nutrient content for the formulated complementary foods, and hence are the best. A high intake of potassium has been reported to protect against increasing blood pressure and other cardiovascular risk (Insel et al., 2007). Feeding infants and young children the enriched maize and sorghum complementary foods will supply greater percentage of daily mineral needs, except calcium and magnesium. However, milk, which is a rich source of calcium is expected to be fed to the infant and young child on complementary feeding, hence the low value of calcium in this enriched foods should not be a barrier to its adoption.

The recommended daily allowance (RDA) of iron for children aged 1-3years old is 7 mg/day (Faber et al., 2008). According to (Codex Alimentarius, 1991), complementary food which satisfied two third of minerals and/or vitamins RDA is acceptable. The iron content of the formulated diets ranged between 2.81 and 4.13 mg per 100gm which fulfilled the minimum RDA for children aged 1-3yeear, but this may not meet the requirement for infants between ages 6 and 11 months old based on the recommended value. The amount of zinc in the enriched foods meets the requirement for infants at age 6-11 months and 1-3 years.

4.3 Vitamin Composition of Fermented Flour and Enriched Complementary Foods

The fermented maize flour was high in β-carotene content while that of sorghum flour was very low. The fermented flour were however low in all the water soluble vitamins except vitamin B_{12}. The low level of these vitamins is believed to be due to the extent of soaking of the fermented sample, as it has been reported that soaking food samples for a period of time leads to leaching of the water soluble micronutrients into the soaking water (Adepoju et al., 2010, Adepoju, 2012). Addition of *M. bellicosus* powder led to remarkable increase in the β-carotene content of the enriched foods, the increment being due to the vitamin A content of the insect, which has been previously reported to be a good source of vitamin A (330.42±0.12 μg/100g, Adepoju & Omotayo, 2014). Vitamin A is an antioxidant which prevent cells from damage by free radicals, essential for maintaining healthy eyes and skin, needed for normal growth and reproduction, promote healthy immune system and prevention of infections (Rolfe et al., 2009; Roth & Townsend, 2003). Enriched maize complementary foods will supply substantial amount of vitamin A to daily requirements of infants and young children, whereas, the enriched sorghum ones will require a rich source of vitamin A to be able to meet the nutritional needs of the children.

Significant reduction observed in most of the water soluble vitamins of the enriched complementary foods was due to lowering of the fermented maize vitamins by the very low levels of water soluble vitamins of the insect (Adepoju & Omotayo, 2014). Only vitamin B6 daily requirement can be met by the complementary foods, hence, other sources of meeting the other water soluble vitamins are needed to augment the one in the complementary foods.

4.4 Antinutrient Composition of Fermented Flour and Enriched Complementary Foods

The fermented flour were low in all the antinutrients studied. This is believed to be due in part to the fermentation of the grains, as processing has been found to reduce the level of antinutrients in foods (Adepoju & Adeniji, 2008; Adepoju et al., 2010). The flour did not contain trypsin inhibitors at the mg/100g level of detection. The reduction observed in the antinutrient content of formulated complementary foods as the level of inclusion of *M. bellicosus* powder increased was believed to be as a result of very low level of these antinutrients in the insect (Adepoju & Omotayo, 2014). Inclusion of *M. bellicosus* powder is therefore beneficial in reducing the level of antinutrients in complementary foods. The level of the antinutrients were very low and negligible, and hence, cannot constitute any hindrance to nutrient bioavailability in the enriched complementary foods.

5. Conclusion and Recommendation

Marcroterme Bellicosus is high in animal protein, fat, energy, potassium, zinc, iron and vitamin A which are essential for growth and development of infants and young children if bioavailable. Its very low level of antinutrients is suggestive of the bioavailability of these nutrients. Addition of *Marcroterme bellicosus* to maize and sorghum flour improved both macro and micronutrient composition of the resulting complementary foods. There were significant improvement in the crude protein, fat, energy, essential minerals and vitamin content of the enriched formulated diets compared with the unenriched flour.

The levels of antinutrients in the formulated diets were low and cannot interfere with the bioavailability of the nutrients. *Macrotermes bellicosus* can be used to improve the nutrient density of maize - and sorghum - based complementary foods for infants, especially in the rural communities of Nigeria where access to, and affordability of animal-based protein is difficult, thereby reducing the level of malnutrition in these infants. The use of *Marcroterme bellicosus* in enriching infant and young child complementary foods is recommended when the insect is in season.

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