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Chemical Composition and Molar Ratio of Minerals in Orange-Fleshed Sweet Potato/Soybean Complementary Food Enriched with Crayfish

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ABSTRACT

This study evaluated the vitamin, mineral, anti-nutrient contents, and molar ratio of minerals of orange-fleshed sweet potato (OFSP)/Soybean complementary food enriched with crayfish. The diets had vitamin A and C contents (280.92 – 314.36 µg/g) and (12.91-15.25 mg/100 g) lower than the recommended levels so also the mineral contents calcium (25.39-81.50 mg/100 g), iron (0.88-0.98 mg/100 g) and zinc (0.26-0.28 mg/100 g). The levels of anti-nutrients 0.09-0.33 Tiu/g for trypsin inhibitor, 0.14 – 0.20 mg/100 g for tannin, 0.15-0.21 mg/100 g for alkaloids, and 0.11-0.17 mg/100 g for phytate in the diets were low. Plant foods are poor sources of minerals. Dehulling and peeling remove those ones in the peels and seed coats. Soaking, steaming, and blanching contributed to the low levels of anti-nutrients. The low phytate contents accounted for the very low molar ratios of the minerals: calcium (0.00011-0.00032), iron (0.0126 – 0.0143), and zinc (0.05-0.053). The very low anti-nutrient contents and molar ratios of the diets are an indication of the high bioavailability of the nutrients.

Keywords: *Orange-fleshed sweet potatoes, Complementary food, Micronutrient, Hidden hunger, Molar ratio, Antinutrient*

1.0 Introduction

Good nutrition during the first two years of life is vital for healthy growth and development. Starting good nutrition practices early can help children develop healthy dietary patterns. Early nutritional deficits are linked to long-term impairment in growth and health. Malnutrition during the first two years of life causes stunting leading to the adult being several centimeters shorter than his/her potential height. [1] reported that adults who were malnourished in early childhood have impaired intellectual performance and reduced capacity for physical work. Women who were malnourished as children have their reproductive capacity affected, low birth weight infants, and more complicated deliveries. Having many malnourished children in a population has national development implications. Thus, the overall functional consequences of malnutrition are immense [2].

Appropriate breastfeeding and complementary feed practices proclaimed by [3] are fundamental to infant nutrition and health. Persistent community health challenges in developing countries including Nigeria include childhood undernutrition. [4] also reported that a geographic and wellness survey conducted in twenty-one developing countries revealed that impoverished complementary feeding of 6-23 months infants added to unfavorable growth trends and [5] opined that poor infant feeding habits together with impoverished nutritional attributes of complementary foods as well as micro-nutrient deficiencies coexisting with persistent infections added to high mortality and morbidity rates among infants and young children in the sub-Saharan African countries.

Micronutrients (vitamins and minerals) are vital to healthy development, disease prevention, and well-being. Micronutrients apart from vitamin D are not synthesized in the body according to [6] therefore, must be derived from the diet. Though people only need small amounts of micronutrients, consumption of the recommended amount cannot be underestimated. Micronutrient deficiency, otherwise called hidden hunger, has devastating consequences, especially in infants and preschoolers. Half of under five children globally suffer from hidden hunger (UNICEF, 2019). [7] declared that the critical micronutrient in infant food needed for the prevention of long-term adverse effect of micronutrient deficiency are iron and zinc. Unfortunately, plant foods are poor sources of these nutrients. [8] also noted that approximately 15 % of infants in industrialized countries consume insufficient amount of dietary iron.

One of the major causes of hidden hunger in children in developing countries like Nigeria is the unavailability of affordable nutrient-dense complementary food. Complementary food defined by [9] is any food other than breast milk given to young children after six months of age and [10-11] defined complementary feeding as the transition from breastfeeding or infant formula [12] to family food for the period of 6 to 24 months of age. In Nigeria according to [13] complementary foods are made traditionally from local staples such as maize, sorghum, and millet which is difficult to prepare into a gruel of fluid consistency to suit the delicate mouth structure of infants because of its starchy nature.

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Diluting the gruel increases the bulk and makes consumption of large quantities by the infant at a sitting impossible because of their small stomach capacity and at the same time, limits the amount of nutrients derived. On the contrary, increasing the gruel nutrient content by making it thick makes it viscous and can choke the child. Moreover, the biological value (BV) of cereal protein is low because of some essential amino acids (lysine, the growth amino acid, and tryptophan) that are limiting. Cereal protein also has lower digestibility than animal protein, and some antinutritional factors such as trypsin inhibitors, phytate, haemagglutinins, and cyanogenic glucosides. All these make unmodified cereal food unsuitable for infant feeding. Nutritional adequacy of complementary food is essential to prevent malnutrition and/or infant mortality and morbidity. Complementary foods are designed specifically to meet the nutritional or physiological needs of infants and must be given at the right time, in adequate amounts, and safe manner.

Thus, this study is aimed at evaluating the micro-nutrient (vitamins and minerals), anti-nutrients and the molar ratio of the minerals of a complementary food prepared from orange-fleshed sweet potato and soybean enriched with crayfish with a view of ascertaining its possibility of ameliorating hidden hunger.

2.0 Materials and Methods

2.1 Procurement of Raw Materials

Orange fleshed sweet potato tubers (*Ipomoea batatas*) were obtained from the National Root Crops Research Institute, Umudike, Abia State, soybeans (Glycine max) and crayfish were purchased from Umuahia main market (Ubani market), Abia State and the chemicals used were bought from a certified laboratory chemical dealer in Umuahia town, Abia State, Nigeria.

2.2 Raw Material Preparation

Ten kilograms (10 kg) of orange-fleshed sweet potatoes (OFSP) were washed with potable water peeled manually with a stainless-steel knife, washed again, cut longitudinally into two, and immersed into water to prevent enzymic browning of the surfaces. The peeled OFSP were grated, wrapped with aluminum foil, steamed at 100°C for 30 mins, and then oven dried at 60°C for 12 h.

Orange fleshed sweet potato tubers
↓
Cleaning (washed with potable water to remove dirt)
↓
Peeling(manually)
↓
Washing
↓
Cutting (into two longitudinally)
↓
Immersion (in water to prevent enzymic browning of surfaces)
↓
Grating
↓
Steaming
↓
Oven drying (60°c for 12h)
↓
Dried grated steamed orange fleshed sweet potatoes
↓
Packaging (in airtight container)
↓
Storage (in a dry place)

Fig 1. Production of dried grated steamed orange fleshed sweet potatoes.

One kilogram (1kg) of soyabeans were sorted, washed, soaked in potable water (29±2°C) for 24 h, boiled at 100°C for 1 h, dehulled (manually) and toasted for 40 min in an open pan.

Soybean
↓
Cleaning (sorted manually)
↓
Washing
↓
Soaking (at 29± 2°C for 24 h)
↓
Boiling (100°C for 1h)
↓
Dehulling (by rubbing with hands)
↓
Cotyledons
↓
Toasting (open pan for 40 min)
↓
Packaging (in airtight container)
↓
Storage (in a dry place)

Fig 2. Production of toasted soy cotyledons.

Five hundred grams (500 g) of crayfish was cleaned and dried in the oven of 60°C for 10 mins.

Crayfish
↓
Cleaning (sorting and aspiration)
↓
Over drying (60°C for 10min)

Packaging (in air tight container)

↓

Storage (in a dry place)

Fig 3: Production of dried crayfish

2.3 Sample Formulation

The method of [14] was used with little modifications. The first, second and third samples were formulated in the ratios of 70:20:10, 60:30:10 and 65:25:10 (steamed grated orange fleshed sweet potato: toasted soy cotyledons: dried crayfish and were designated as SAC, SBC and SCC respectively and the fourth sample was formulated with only steamed grated orange fleshed sweet potato (100:0:0) and designated SDC. The respective blends were mixed, milled and sieved to obtain the complementary foods.

2.4 Chemical analysis

2.4.1 Determination of vitamins

2.4.1.1 Determination of vitamin A

The method of the association of vitamin chemists (Kirk and Sawyer,1988) as described by [15] was used to determine the contents of vitamin A in the experimental diets.

2.4.1.2 Determination of vitamin C

The method of [16] as described by [17] was used to determine the vitamin C contents of the samples.

2.4.2 Determination of minerals

2.4.2.1 Determination of iron, zinc and calcium

Iron, zinc and calcium contents of the formulated diets were determined using atomic absorption spectrophotometric (AAS) method as described by AOAC (2010).

2.4.3 Determination of antinutrients

2.4.3.1 Determination of phytate

The spectrophotometric method of AOAC (2010) was used to determine the phytate contents of the formulations.

2.4.3.2 Determination of tannin

The Folin Denis spectrophotometric method of AOAC (2010) was employed for the determination of tannin in the samples.

2.4.3.3 Determination of alkaloid

The alkaloid content of the experimental diets was determined using the gravimetric method (AOAC, 2006).

2.4.3.4 Determination of trypsin inhibitor

The AOAC (2000) spectrophotometric method was employed in the determination of trypsin inhibitor contents of the formulated diets.

2.4.4 Estimation of molar ratio

2.4.4.1 Estimation of molar ratios of the minerals

The molar ratios of the formulations were estimated using Gibbs (2010) equation as described by [19].

2.4.5 Statistical analysis

Data collected was subjected to one way analysis of variance using SPSS version 220 software package for social sciences (SPSS Inc., USA). Means were separated using Duncan's new multiple range test and significance was accepted at 5 % probability level ($p<0.5$).

2.4.6 Experimental design

The experimental design used in this study was a randomized block design using three samples and one level of treatment. Samples were in the ratios of 70:20, 60:30, 65:25 (steamed orange flesh sweet potato: toasted soybean dhal) and the level of treatment is 10:10:10 (crayfish). The sample with the ratio 100:0:0 (steamed orange flesh sweet potato: crayfish) served as the control.

3.0 Results and Discussion

3.1 Vitamin content of the samples

Table 1 shows the vitamin, mineral, anti-nutrient contents, and mineral molar ratios of the samples. The vitamin A levels of the diets ranged from 280.92 µg/100 g in the sample that contained 30 % soybean (SBC) to 314.36 µg/100g in the sample that contained 100 % orange-fleshed sweet potato (OFSP) (SDC). The high level of vitamin A observed in the samples may be attributed to OFSP used in the formulation because OFSP is known to be high in beta carotene (pro-vitamin A). There were significant differences ($p<0.05$) among the values of vitamin A observed for the samples. The 100 % OFSP used in sample SDC accounted for the very high amount of vitamin A relative to the other samples. The amount of vitamin A recorded for the samples was lower than the values (1134 – 2560 µg/100g) obtained by [20] for solid-state fermented fonio, soybean, and OFSP blends complementary foods and recommended dietary allowance (FAO/WHO, 2007) value (375 µg/100g). The incorporation of soybean in the diets may have caused the decrease noticed in the vitamin A content of samples SAC, SBC, and SCC. Sample SBC which contained the lowest amount (60 %) of OFSP and the highest amount (30 %) of soybean had the least value (280.92 µg/100g) of vitamin A. This implies that soybean is not a source of vitamin A and that incorporation of a high amount of soybean may have an adverse effect on the vitamin A content of the food. Vitamin C in the samples occurred within the range of 12.91-15.25 mg/100g lower than the FAO/WHO (2002) recommended dietary allowance (30-35 mg/100g and the values (18.32-35.01 mg/100g) reported by [21] for fermented fonio, soybean, and OFSP blends. The obtained values were higher than the values (7.37-9.47 mg/100g) reported by [22] for fonio/ricebean-based complementary foods. Samples SAC (sample containing 20 % of soybean) and SCC (sample that contained 25 % of soybean) showed similar vitamin C values (13.49 mg/100g). The high vitamin C value (15.25 mg/100g) exhibited by sample SBC may probably be due to the lower amount of OFSP (60 %) and higher amount of soybean (30 %) used in the formulation since the sample with the highest amount of OFSP (100 %) and no soybean showed the least vitamin C value (12.9 mg/100g). [23] attributed the high vitamin C content of the samples to the vitamin in soybeans since vitamin C is present in leguminous plants. The vitamins in the samples can be said to be adequate since the diet is consumed more than once a day.

3.2 Mineral Content of the Samples

The predominant mineral in the experimental diets was calcium ranging from 25.39-80.50 mg/100g. Significant differences ($p<0.05$) existed among the calcium contents of the samples. The sample without soybean and crayfish (SDC) exhibited the lowest value (25.39 mg/100g) of calcium due to the absence of enrichment (no addition of soybean and crayfish) which are sources of calcium. The calcium content of the formulations increased significantly with increased soybean inclusion. The value of calcium recorded in the work was very much lower than the FAO/WHO recommended dietary allowance (RDA) value (500 mg/100g) for infant foods, 96.23-327.17 mg/100g reported by Okoronkwo et al. (2023) for fermented fonio, soybean and OFSP blends and 296.48-413.8 mg/100g reported by [24] for fonio/ricebean based complementary foods respectively. Soybeans is rich in minerals hence their suitability in infant food enrichment. [25] reported that the calcium content of soybean is 220 mg/100g and that of sweet potato is 16.60 mg/100g. Calcium is required for normal bone development, bone and teeth maintenance, blood clotting, normal minute activity and irritability, enzyme activation, and heart action. Calcium deficiency leads to poor bone and teeth formation, rickets in children, osteoporosis in adults, slow blood clotting time and tetany [26]. The iron and zinc contents of the samples were very low. Iron level ranged from 0.88-0.98 mg/100g while zinc level ranged from 0.26-0.28 mg/100g. Diet containing only orange-fleshed sweet potato had the lowest value (0.88 mg/100g) of iron and zinc (0.26 mg100mg) among the formulated diets. The values obtained in this study were far much lower than the values reported by [27] for the recommended dietary allowance for iron (6-10 mg/100g) and zinc (3.2 mg/100g). The recorded values were also lower than the values (6.77-8.30 mg/100g) for iron and 4.23-4.8 mg/100g for zinc, 6.57-8.4l mg/100g for iron and 2.43-5.52 mg/100g, 3.0-4.25 mg100g for iron and 2.89.3.83 mg/100g for zinc and 17.71-47.66 mg/100g for iron obtained by [28] for fonio/rice bean based, [29] for fermented popcorn, African locust bean and Bambara groundnut blends and [30] malted guinea corn, soybean and roasted or boiled groundnut blends of complementary foods respectively. The values of iron observed for a sample containing 20 % soybean (SAC) (0.93 mg/100g) and that containing 25 % of soybean (SCC) (0.94 mg/100mg) were comparable (*p>0.05*) while the zinc values (0.28 mg/100g) for samples SBC (sample containing 30 % soybean) and SCC did not differ *(p>0.05*). The low values of iron and zinc obtained for the samples are not out of place because the raw materials for the formulations are plant foods and [31] noted that plant foods are poor sources of these minerals (iron and zinc). According to [32] dependence on complementary food with low iron concentration (as in the case of this study) will aggravate the already prevalent iron deficiency anemia in the poor resource settings and developing countries but with more than one serving per day can meet the daily demand. Of course, the developed countries are not spared. Iron is essential for the formation of hemoglobin of the red blood cells. Its deficiency leads to anemia characterized by weakness, loss of weight and pallor. Iron deficiency reported [33] and [34] is prevalent in children deprived of exclusive breastfeeding, weaned early and/or fed with high bulk/low nutrient dense complementary foods produced mainly with cereal which contains high levels of phytate that chelate the minerals especially calcium, iron and zinc thereby reducing their bioavailability. Zinc is a component of insulin and enzyme required by children for normal growth thus decreasing stunting prevalence Anigo et al. (2010) reported that zinc supply has relationship with linear growth. Zinc also boosts body immunity. The levels of iron and zinc recorded for these samples were lower *(p<0.05)* than the levels (140 g for iron and 8.3 mg for zinc per 100g) recommended for fortified complementary food (Lutter and Deway,2003).

Table 1: Vitamin, Mineral, Anti-nutrient contents and Molar ratio of the Mineral of the samples per 100 g

Parameter	SAC	SBC	SCC	SDC	RDA
Vitamin					
Vitamin A (µg)	$281.44^{c}\pm 0.18$	$280.92^{d}\pm 0.34$	$282.26^{b}\pm 0.35$	$314.36^{a}\pm 0.18$	375
Vitamin C (mg)	$13.49^{b}\pm 0.02$	$15.25^{a}\pm 1.02$	$13.49^{b}\pm 1.02$	$12.91^{a}\pm 1.02$	30-35
Mineral (mg)					
Calcium	$61.46^{c}\pm 2.32$	$81.50^{a}\pm 2.02$	$73.48^{b}\pm 2.30$	$25.39^{d}\pm 2.22$	500
Iron	$0.93^{b}\pm 0.01$	$0.98^{a}\pm 0.01$	$0.94^{b}\pm 0.01$	$0.88^{c}\pm 0.01$	6-10
Zinc	$0.27^{b}\pm 0.00$	$0.28^{a}\pm 0.01$	$0.28^{a}\pm 0.00$	$0.26^{c}\pm 0.01$	3.2
Anti-nutrient (mg)					
Trypsin inhibitor (tui/g)	$0.31^{c}\pm 0.70$	$0.33^{a}\pm 0.54$	$0.32^{b}\pm 0.61$	$0.09^{d}\pm 0.00$	--
Tannin	$0.16^{c}\pm 0.01$	$0.20^{a}\pm 0.01$	$0.18^{b}\pm 0.01$	$0.14^{d}\pm 0.05$	--
Alkaloids	$0.15^{-c}\pm 0.01$	$0.16^{c}\pm 0.00$	$0.19^{b}\pm 0.01$	$0.21^{a}\pm 0.03$	--
Phytate	$0.14^{b}\pm 0.00$	$0.17^{a}\pm 0.01$	$0.16^{a}\pm 0.01$	$0.11^{c}\pm 0.01$	
Molar ratio of minerals					**SDL^{+}**
Calcium	$0.00014^{b}\pm 0.001$	$0.00011^{c}\pm 0.000$	$0.00013^{b}\pm 0.000$	$0.00032^{a}\pm 0.001$	>1
Iron	$0.0126^{a}\pm 0.011$	$0.0131^{c}\pm 0.0001$	$0.0143^{b}\pm 0.00$	$0.0127^{a}\pm 0.001$	>18
Zinc	$0.05^{b}\pm 0.02$	$0.053^{a}\pm 0.00$	$0.053^{a}\pm 0.01$	$0.05^{b}\pm 0.00$	>0.17

values are means of triplicate determinations ± standard deviation (SD). Means with different superscripts are significantly different (p< 0.05).
SAC = 70:20:10 (steamed OFSP: soyabean: crayfish), SBC = 60:30:10 (steamed OFSP: soyabean: crayfish), SCC = 65:25:10 (steamed OFSP: soyabean: crayfish) and SDC = 100:0:0 (steamed OFSP: soyabean: crayfish)
RDA = Recommended Dietary Allowance (FAO/ WHO, 2002)
SDL^{+} = Suggested desirable level phytate: calcium= less than, phytate: Iron = less than 18 and phytate: Zinc = less than 0.17.

3.3 Antinutrient content of the samples

The experimental samples showed very low residual antinutrients. Trypsin inhibitor in the diets ranged from 0.09 Tiu/g in the diet without soybean and crayfish (SDC) to 0.33Tiu/g in the sample containing 30 % soybean (SBC). There were slight variations in the values of residual trypsin inhibitor among the samples. Trypsin inhibitor residue increased with increased soyabean incorporation showing that legumes contain trypsin inhibitor. The residual trypsin inhibitor observed in the study were lower *($p<0.05$)* than (1.16-1.78Tiu/g) obtained by [6] for fonio/ricebean-based complementary foods. Trypsin inhibitor is known to bind trypsin and chymotrypsin with more specificity on trypsin thereby interfering with the digestion and absorption of protein. The binding reported by [34] leads to the formation of an irreversible condition known as enzyme-trypsin inhibitor complex that causes a drop in the concentration of trypsin in the intestine thus a decrease in diet protein digestibility. The condition is worse with legume protein because of its inherent deficiency in sulfur containing amino acids which hinders the sulfur-containing amino acids from synthesizing more trypsin and chymotrypsin. Trypsin inhibitors together with other antinutrients such as phytate, haemagglutinin, tannin, saponins, oxalate and some cyanogenic glucosides interfere with the bioavailability of nutrients [35] especially proteins and minerals. The low values of trypsin inhibitor recorded for the samples may be attributed to steaming and toasting of the raw materials because according to [36] , cooking destroys trypsin inhibitors. The observed low values of trypsin inhibitor in the formulation are an indication that protein in the formulations will not be interfered with. Similar to trypsin inhibitors, the tannin content recorded for the samples increased with increased soybean addition. The tannin content of the developed infant foods ranged from 0.14-0.20 mg/100g. [5] stated that the safe level of tannin is 150-200 mg/100g. The amount of tannin found in the formulations were very low and positively very far from the safe level but higher than (0.048-0.067 mg100g), (0.014-0.026 mg/100g) and (0.09-0.13 mg/100g) reported by [4] for fonio/ricebean based, [4] fermented popcorn, African locust beans and Bambara groundnut and [23] for solid-state fermented fonio, soybean and orange-fleshed sweet potato (OFSP) blends complementary foods respectively. The low tannin content of the experimental diets obtained indicated zero tannin toxicity. The increase in tannin content with increased soybean inclusion noticed among the samples was expected because legumes are high in tannin. Soaking dehulling and discarding of the cooking water as well as malting and roasting reduces the tannin content of beans. Tannins depress the absorption of iron, availability of amino acids and protein digestibility. Their reduction has important implications for the final nutritional properties of the developed products [5].

The level of alkaloids found in the complementary foods formulated ranged from 0.15-0.21 mg/100g. The level (0.15 mg/100g) of alkaloid in the sample SAC (sample that contained 20 % soybean) and that (0.16 mg/100g) in sample SBC (sample that contained 30 % soybean) compared favorably *($p>0.05$)*. Sample SDC (sample without soybean and crayfish) showed the highest alkaloid value (0.21 mg/100g) in relation to the other samples. This agreed with the statement that potatoes is high in alkaloids/glycoalkaloids. According to [8] poor storage and exposure to sunlight increase the glycoalkaloid content of potato tubers.

The value of alkaloids recorded for the formulated infant diets were lower than the values (0.16-0.28 mg/100g) reported by [5] for fonio/ricebean-based complementary diets and WHO (2003) safe limit value (61 mg/100g). The value of alkaloid found in the samples were within the safe limit. Alkaloids may induce allergies in infants [4] The phytate content of the sample were very low ranging from 0.11 mg/100g in the sample that contained 100 % OFSP to 0.17 mg/100g in the sample that contained 20 % soybean (SAC) The formulations incorporated with 30 % and 25 % soybean had comparable *($p>0.05$)* phytate contents (0.17 and 0.16 mg/100g) respectively. The least value of phytate showed by sample SDC may be as a result of no inclusion of soybean in the diet. The value of phytate exhibited by the samples which contained soybean and crayfish varied slightly. The values increased with increased soybean incorporation. The observed values did not vary much with the values (0.12-0.17 mg/100g) reported by [7] for fonio/ricebean-based complementary food and 0.06-0.18 mg/100g except for the control (0.06 mg/100g) reported by [8] for solid-state fermented fonio, soybean and OFSP blends complementary foods. Sprouting (malting) reduces phytate and tannin in grains. Antinutrients are chemical substances contained in food that interfere with the bioavailability and utilization of profitable nutrients in the body. Trypsin inhibitor is known to interfere with protein utilization, tannin have a significant negative effect on the bioavailability of amino acids including lysine while phytate binds calcium and other minerals in pigmented [8]. The low levels of antinutrients (trypsin inhibitor, tannin, alkaloid and phytate) recorded for the samples indicated high bioavailability of the nutrients, especially calcium, lysine, protein, iron and zinc in the diets. Dehulling of the soybean, peeling of the OFSP and steaming of these materials may have accounted for the observed low values of antinutrients in the developed infant foods as these processes are known to reduce antinutrients in foods.

3.4. Molar ratios of minerals in the sample

The computed mineral phytate interrelationship in the experimental diets was very low. The molar ratio of calcium: phytate, zinc: phytate and iron: phytate were lower than the suggested desirable levels (SDL^{+}) for zinc (>0.17), iron (>18) and calcium (>1) respectively [12]. The level of competing dietary components especially phytate reported [13] is a major determinant of zinc absorption and phytate is the most important of these. Zinc bioavailability is reduced by phytate by the formation of insoluble mineral chelates. Each chelate formation depends on the relative level of zinc and phytate. The recommended boundaries between low, moderate and high zinc availability are phytate: zinc molar ratios below 5,10 and above 15. The low zinc molar ratio values observed for the formulations suggested maximum absorption and utilization of the zinc in the formulations implying no impairment of the zinc utilization in the body which in turn enhances phosphorus bioavailability. High dietary zinc availability promotes phosphorus availability [14]. The very low molar ratio values obtained for calcium, iron and zinc is suggestive of the high bioavailability of the minerals.

4.0 Conclusion

It was observed from the study that the experimental diets were low in vitamins A and C and minerals (calcium, iron and zinc) lower than the recommended values but with more than two servings a day, the vitamin recommendations may be met.

In the case of minerals, it is recommended that minerals premix should be added. Generally, it is recommended that more crayfish be incorporated in the formulations to boost their micronutrients. The study also showed very low anti-nutrients and molar ratios of the minerals suggesting high bioavailability of the nutrients in the diets.

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