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NUTRIENT CONTENT OF *RHYNCHOPHORUS PHOENICIS* AND ITS APPLICATION IN COMPLEMENTARY FOOD FORMULATION

*Sunday UKWO[1], Mfoniso UDO[2], Ekefre EKONG[1]

[1]*Department of Food Science and Technology, University of Uyo, Uyo, Nigeria*
[2]*Department of Home Economics, Nutrition and Dietetics, University of Uyo, Uyo, Nigeria*
[*] sonipeter75@gmail.com
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Abstract: *Palm weevil (Rhynchophorus phoenicis) is an edible insect that is highly exploited as food. This study investigated variability in nutritional content during three developmental stages: early larva (ESL), late larva (LSL) and adult stage (ADS) and application of early larva stage in the formulation of complementary foods from the blend of broken rice and soybean flour at different proportions: A (100:0), B (94.5:5.5), C (89.5:10:5), (85.3:14.7), E (75.5:24.5) and F (70:30). Samples were assessed for proximate and mineral content while anti-nutritional factors and sensory analysis were conducted on the complementary food samples. Standard methods of analysis were used in all determinations. Results of proximate analysis indicated protein and lipid content were significantly different (p<0.05) among the developmental stages. Higher lipid content were noted in early larva (49.59%) and late larva stage (47.06%). The early larva stage was superior in ash and energy content while adult weevil had the highest percentage of protein (36.19%), carbohydrate (9.46%), fibre (9.43%) as well as micro mineral of Zn and Fe. Proximate composition of complementary foods indicated a significant (p<0.05) increase in the values for moisture, protein, lipid, ash and fibre content as the percentage of palm weevil flour increases in the formulated food samples. The recommended dietary levels for Zn and Fe in complementary foods were met with addition of 24.5% and 30% palm weevil flour without any further fortification. Anti-nutritional factors present in all complementary food samples were within safe levels. Sensory results showed that sample E with 24.5% and sample F with 30% palm weevil flour were more acceptable in all the sensory attributes determined.*

Key words: *Insect, Broken rice, Soybean, Developmental stage, Palm weevil*

1. Introduction

Feeding a growing world population require an increase in food production. This will inevitably place more pressure on already limited resources especially those associated with raising livestock. Livestock and fish are important sources of protein in most countries of the world and their production accounts for 70% of all agricultural land use [1]. With their global demand expected to more than double between 2000-2050 (229milion tons to 465million tons), meeting this demand will require innovative solutions [2]. The potential of using insect to help meet rising demand for meat products and to replace fish meal and oil is enormous. In order to guarantee food security and preserved the natural habitats, several studies with focus

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on diversification of food sources has been carried out and systematically investigated widely, with the utilization of insects for nutrition being suggested as a possible solution [3, 2]. Hence, more interests are currently being channeled toward entomophagy. This novel potential strategy can radically solve the problem of malnutrition and other nutritional deficiencies as well as improve the overall food and nutrition security, particularly in the developing regions like sub-Saharan African that are the worst hit. This is because different studies have shown that entomophagy contributes effectively to nutrition and health, the environment, and livelihoods of those involved in the edible insects value chain [2].

As reported by Food and Agricultural Organization, over 2 billion people globally consume insects as an integral part of their diets [2] and from study carried out by Jongema [4] about 2000 species of edible insects have so far been documented and it expected to increase as research on insect as food progresses and when this is compare to traditional livestock, edible insect production has the potential to positively contribute to environmental sustainability due to lower resource requirements, feed-conversion rates, and greenhouse gas emissions[5, 6]. With respect to locally-sourced food ingredients in low and middle income countries (LMICs), where the challenges of malnutrition is highest, edible insects can provide the much needed essential nutrients necessary to supplement dietary quality and provide diversity among individuals who naturally consume cereal-based foods [7]. Nonetheless, studies on nutritional quality of edible insect shows substantial differences in content within the same species and between species [8] and this variability is attributed to the diverse nature of insect species. The nutritional quality of insect also depends on the antinutritional content such phytate, thiaminase as well as vary according to transitional stages of development, origin of the insect and their feeding pattern [9]. Also, the nutritional value changes according to the processing methods applied before consumption. According to Payne et al. [7], insect nutritional composition showed high diversity between species. For instant, the nutrient value score of crickets, palm weevil larvae and mealworm was significantly healthier than that of beef and chicken and none of the tested insects were statistically less healthy than meat.

Studies on the development and production of complementary foods with animal products as major ingredients have not been widely reported. Existing studies are based on the use of fish and other seafood products [10, 11] with very little or no study reported on the use of edible insects. Presently there is a growing international interest in promoting diets composed of traditional and local food sources during complementary feeding regime [12, 13]. This is with the hope of combating malnutrition in young children through the use of local food ingredients such as insects processed using improved indigenous technologies specially in developing countries [14]. Also, complementary foods in developing countries have mainly been cereal based [14]. It is until recently that in Africa, supplementation of cereals with protein rich plant sources, soya bean, groundnut [15, 16], cowpeas [17, 18, 19], pigeon peas [20], common bean [18] and bambara nuts [17] have been tested. As a result, the World Food Programme (WFP) have continue to promote and encourage fortified flour blends containing soy bean in management of mild condition of malnutrition especially in children [21]. Also, corn-soy-blend plus (CSB+) is an example of a fortified flour blend commonly used for supplementary feeding programme in management of mild malnutrition among children under five years old.

Edible palm weevil (*Rhynchophorus phoenicis*) is a major pests of Raffia palms, Oil palms and Coconut palms. Although they are seen to be destructive, their nutritional potential have made them very valuable to man. They highly valued and exploited in many cultures including southern Nigeria. *Rhynchophorus* spps are found in a wide range of geographical regions of the world such as Asia, Africa and Southern America and presently, they are available in the wild and cultured in warehouses and laboratories [22]. Because of their nutritional quality, accessibility, simple rearing technique and rapid growth rates, insects offer a cheap and efficient means of checking protein deficiency among the low and middle income families by providing emergency food and

improving the quality of traditional diets among vulnerable people. The objective of this study is to examine the influence of transitional stages of development on the nutritional potential of edible palm weevil *Rhynchophorus phoenicis*. This study also aimed at developing and evaluating complementary foods based on edible palm weevil to combat malnutrition in Nigeria.

2. Materials and Methods

Material Procurement

Samples of edible palm weevil at various stages of development (adult weevil, larva and late larva stages) were harvested from raffia palm tree (*Raffia hookeri*) at Ikpe Anang in Essien Udim Local Government Area. They were collected alive while the late larva stage was in the cocoon. Broken rice grains were obtained from at a local rice mill that processes rice planted and harvested by the local farmers in Ini Local Government Area while soybean were bought from Akpan Andem market in Uyo, Akwa Ibom State, Nigeria

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Sample Preparation

The adult palm weevils were de-winged while the cocoon were opened to remove the later stages larva. They were killed by asphyxiation in a freezer and dried at 50 °C for 48 h [23]. Part of the palm weevil samples were oven dry to a constant weight and then grounded to a flour for complementary food formulation. The broken rice grains (5 kg) and (3 kg) soybean seeds were properly cleaned and sorted to remove stones, dirt, chaff and other extraneous matters before they were used for further processing. The broken grains of rice obtained were washed with portable water and allowed to dry gradually in an oven for 6 hours at 60^0C. The dried grains were milled into fine flour and packaged in an airtight container. The soybean seeds were also washed with portable water and oven dried for 40 minutes at 60^0C. The dried soybean seeds were then roasted at 120^0C for 2 hrs then decorticated and winnowed, then milled and sieved to obtained soy bean flour. The flours were then stored at room temperature (27± 2^0 C) till used.

Food Formulations

Composite flour was formulated by mixing 70g rice and 30g of soybean flours. Five (5) formulations of complementary foods were generated by replacing 5.5, 10.5, 14.7, 24.5, 30.0g of the composite flour with palm weevil larva flour while sample without palm weevil larva component serves as a control (Table 1).

The complementary foods were formulated with the intention of meeting the specifications for complementary food protein-energy composition as outlined by Lutter and Dewey [24]. Broken rice flour served as the main source of carbohydrates; Soybean flour as a source of protein, sugars; Palm weevil grub as a source of protein, lipids, minerals like, iron, zinc, vitamins E and B- vitamins; soybean oil to supplement the source of fat and improved organoleptic properties of the final product; while sugar was to enhance taste and energy content of the product [25].

Table 1

Complementary food formulation

Sample code	Composite flour (g)	Palm grub flour (g)	Sugar (g)	Soybean oil (mL)
A	100	0	10	2
B	94.5	5.5	10	2
C	89.5	10.5	10	2
D	85.3	14.7	10	2
E	75.5	24.5	10	2
F	70.0	30	10	2

Production Process

Food formulations were thoroughly mixed in a rotary mixer (Philips type HR 1500/A, Holland) to produce homogenous complementary food formulations. They were processed by extrusion cooking and ground into flour that could be reconstituted in to porridge as recommended by Codex [26]. Extrusion was carried out using a locally fabricated extruder. The foods were produced in six batches. Different batches were sampled, homogenised and laboratory samples taken.

Methods of Analysis

Proximate and caloric value and mineral analysis were carried out on the three developmental stages of edible palm weevil (adult weevil, early larva and late larva stages) and in the formulated food products. Anti-nutrient composition and sensory analysis were conducted on the finished products only.

Determination of Proximate Composition and Calorific Value

The flour samples were analysed for their moisture, crude protein, crude fat, ash and crude fibre contents according to the method described by AOAC [27]. Carbohydrate was determined by difference i.e. % carbohydrate = 100 – (% moisture + % crude protein + % crude fat + % ash + % crude fibre). The calorific value was calculated using Atwater factor: Energy value = (crude protein x 4) + (crude fat x 9) + (carbohydrate x 4).

Determination of Mineral content

Techniques of ultraviolet – visible spectrophotometry, atomic absorption spectrophotometry and flame photometry were used for analysis of selected mineral content of edible palm weevil samples and the formulated complementary food samples. Standard stock solutions of mineral element to be analysed were prepared, diluted to the corresponding working solution for recovery experiment according to the methods outlined by Onwuka [28]. The wet ashing method as outlined by the author was used to determine the concentration of metallic element in food samples. The method of preparation and digestion procedure for biological sample was also employed. Determination of sodium and potassium content was done through the use of Jenway flame photometer at the wavelength of 589nm and 767nm for potassium and sodium respectively, while analysis for other mineral elements were carried out using a Perkin – Elmer model 3030 Atomic Absorption spectrophotometer (AAS) using their respective lamp and wavelength. Analysis of phosphorus was done using UV – visible spectrophotometer [27].

Determination of Anti-Nutritional Factors

Anti-nutritional factors such as saponins, phytic acid, tannins, and oxalate were determined on the formulated complementary food samples only. Saponins were determined using the method described by AOAC [27]. Phytic acid concentration was determined using the method described by Wheeler, and Ferrel [29]. The method of Allen et al., [30] was used for the determination of tannins level in food samples while the concentration of oxalate in the samples was determined using the method of Onwuka [28].

Sensory Evaluation of Complementary Food

Sensory characteristics of the complementary food were evaluated for different sensory attributes by twenty (20) semi trained panelist. All the panelists were briefed before the commencement of the evaluation process. Sensory attributes considered included appearance, taste, flavour, mouthfeel, consistency, aftertaste and overall acceptability. The rating were on a nine- point hedonic scale ranging from 9 (like extremely) to 1(dislike extremely) according to Ihekoronye and Ngoddy [31]. All panelists were provided with water at room temperature to rinse their mouth between evaluations.

Statistical Analysis

Statistical Package for Social Science (SPSS, version 23) was used for statistical analysis. The differences between samples in each parameter tested was done using One Way Analysis of Variance (ANOVA) and New Duncan's Multiple Range Test was used when the analysis of variance indicates a significant difference in their means. A significant level of $P<0.05$ was used throughout the study.

3. Results and Discussion

Proximate composition and calorific value of developmental stages of Edible palm weevil

The result the proximate composition and calorific value of the three developmental stages of edible palm weevil is presented in table 2. The result indicated a higher lipid content in the early stage (49.59%) and the late larva stage (47.06%) when compare to that of the adult weevil (40.20%). The early larva stage was also superior in ash and energy content. Also, calorific value, protein and lipid content indicated significant differences ($p<0.05$)

among the developmental stages of the edible palm weevil However the adult weevil had the highest percentage of protein (36.19%), carbohydrate (9.46%) and fiber content (9.43%). The trend of result obtained in this study was similar to values reported by Omotoso and Adedire, [32]. The lipid content is responsible for its high palatability of the larva stages of edible palm weevil when consumed. The present of lipid in food is necessary for the proper cellular activities and structural functions of the body. Values for lipid as reported in this study was higher than those reported by Singh [33] on insects such as caterpillar and termite. Also higher protein content that was noted in the adult weevil could be attributed the variable feeding pattern. The adult is exposed to other sources of diets apart from the palm. As noted by Teffo et al [34], edible insect have shown to have a higher protein content and quality on mass basis when compared to some animal and plant foods therefore the consumption of palm weevil provide the essential amino acid needed for building body tissue and metabolic functions.

Table 2
Proximate composition (% dry weight) and calorific value of developmental stages of Edible palm weevil

Parameters	Stages of development		
	ESL	**LSL**	**ADS**
Lipid	$49.58^{a}\pm0.15$	$47.06^{b}\pm1.12$	$40.20^{c}\pm1.02$
Protein	$34.63^{c}\pm1.05$	$36.06^{b}\pm0.05$	$36.19^{a}\pm0.02$
Carbohydrate	$5.41^{b}\pm0.02$	$7.18^{a}\pm0.03$	$8.56^{a}\pm0.15$
Ash	$5.80^{a}\pm0.11$	$3.82^{b}\pm0.01$	$5.62^{a}\pm1.00$
Fiber	$4.50^{b}\pm0.02$	$5.62^{b}\pm1.01$	$9.43^{a}\pm1.00$
Calorific value(kJ/100g)	$2515.14^{a}\pm1.53$	$2474.30^{b}\pm1.68$	$2248.15^{c}\pm1.23$

**Values are Means ± SD of triplicate determination Means in the same row with different superscript are significantly different at (P <0.05). ESL=Early stage larva, LSL= late stage larva, ADS= Adult stage*

Higher fibre noted in the adult weevil could be attributed to the presence of chitin that constitute fibrous materials. The adult weevil has wing with rigid body structure which provide the beetle covering and body protection. The presence of fibre in diet is significant in easing bowel movement because of its ability to bind water and thus soften stool [1].

Mineral content of Edible palm weevil

The mineral content of the developmental stages of edible palm weevil is shown in Table 3. The edible palm weevil had a significant amount of macro elements of sodium, calcium, magnesium, potassium and phosphorus. The highest values of Na (62.14 mg/100g), K (95.63 mg/100g), Mg (132.00 mg/100g) and P (105.12 mg/100g) were noted in early larva stage while least values of 42.62 mg/100g 89.71 mg/100g 103.30 mg/100g 85.21 mg/100g were recorded for Na, K, Mg, and P respectively. However, the highest concentration of Ca 62.13 mg/100g was noted in the adult palm weevil. Values obtained for the micro mineral of Zn and Fe in the three developmental stages did not indicate any significant differences ($p<0.05$). However, adult stage recorded highest values of 3.03 mg/100g and 6.05 mg/100g in Zn and Fe respectively. Edible palm weevil. The present of macro element in edible palm weevil have been reported different authors [34, 32, 35] and values obtained in this study was similar to values reported. The present of these mineral elements in the edible palm weevil makes it an important food ingredient toward the eradication of various nutritional deficiencies. Sodium and potassium are the major electrolytes needed for intercellular ion balance, osmo-regulation and transportation across cells and membranes. The present of higher concentration of potassium when compared to sodium makes edible palm weevil very useful to human body when consumed as food.

Table 3

Mineral content (mg/100g) of developmental stages of Edible palm weevil

Parameters	Stages of development		
	ESL	LSL	ADS
Sodium (Na)	$62.14^{a}\pm1.10$	$61.59^{a}\pm0.15$	$43.62^{b}\pm1.02$
Potassium (K)	$95.63^{a}\pm0.05$	$90.14^{b}\pm0.15$	$89.72^{b}\pm0.02$
Calcium (Ca)	$56.24^{b}\pm1.15$	$42.46^{c}\pm0.03$	$62.13^{a}\pm0.15$
Magnesium (Mg)	$123.12^{a}\pm2.16$	$106.27^{b}\pm5.05$	$103.30^{c}\pm2.00$
Phosphorus (P)	$105.00^{b}\pm5.02$	$102.0^{a}\pm10.01$	$85.21^{c}\pm5.02$
Zinc (Zn)	$3.02^{a}\pm0.10$	$2.96^{a}\pm0.05$	$3.03^{a}\pm0.02$
Iron (Fe)	$6.02^{a}\pm0.05$	$5.95^{a}\pm0.01$	$6.05^{a}\pm1.00$

**Values are Means ± SD of triplicate determination Means in the same row with different superscript are significantly different at (P <0.05). ESL=Early stage larva, LSL= late stage larva, ADS= Adult stage*

Calcium and magnesium formed a significant part of human bones as well as prosthetic group in enzyme that hydrolyses and transfer phosphate groups, consequently, they are essential in energy requiring chemical reactions in human body. Phosphorus is usually found in equal amount in human system where they served as key structural element. The function of zinc in human body is that Zn forms an integral part of a number of metalloenzymes and as a catalyst in regulating the activity of specific zinc-dependent enzyme. Iron is present in cells of living organism and plays a vital role in several biochemical reactions. Most of iron is present in the haemoglobin and myoglobin, pigments, cytochromes and other proteins participating in transport, storage and utilization of oxygen [32, 7, 36]

Proximate composition and calorific value of complementary food

Table 4 shows the result of proximate composition of complementary food formulated from blends of broken rice, soybean and edible palm weevil larva flour. There was a significant ($p<0.05$) increase in the recorded values for moisture, protein, lipid, ash and fibre content as the percentage of palm weevil flour increases in the formulated food samples. Protein content ranged from 15.99% in sample A to 25.10% in sample F. The lipid content in the formulated food samples ranged from 4.36% in samples A to 11.07% in sample E. The ash content also varied from 4.84% in ample A to 6.30% in sample F. Fibre content of the formulated food ranged from sample A (1.20%) to sample F (2.40%). However, there was a significant reduction ($p<0.05$) in the moisture and carbohydrate contents. Moisture content decreases from 9.10% in sample A to 5.10% in sample F while carbohydrate content also decreases from 64.50% for sample A to 50.02% for sample F. The addition of palm weevil flour led to a significant increase on the calorific value which varied from 1530 kJ/100g for sample A to 1687 kJ/100g) for sample F.

Table 4

Proximate composition(%) and calorific value of complementary food

Parameters	**Complementary Foods**					
	A (100:0)	B (94.5:5.5)	C (89.5:10.5)	D (85.3:14.7)	E (75.5:24.5)	F (70:30)
Moisture	$9.10^{a}\pm0.01$	$7.52^{b}\pm0.02$	$7.13^{bc}\pm0.03$	$6.30^{c}\pm0.01$	$6.13^{cd}\pm0.01$	$5.10^{d}\pm0.02$
CHO	$64.50^{a}\pm1.00$	$60.62^{a}\pm0.05$	$58.05^{c}\pm0.01$	$55.70^{d}\pm0.03$	$51.05^{c}\pm0.02$	$50.02^{c}\pm0.01$
Protein	$15.99^{e}\pm0.11$	$18.46^{d}\pm0.02$	$20.36^{c}\pm0.01$	$22.00^{b}\pm0.05$	$24.32^{a}\pm0.05$	$25.10^{a}\pm0.02$
Lipid	$4.36^{d}\pm0.02$	$6.63^{cd}\pm0.11$	$7.25^{c}\pm0.12$	$8.26^{b}\pm0.12$	$10.15^{ab}\pm0.20$	$11.07^{a}\pm0.01$
Fiber	$4.84^{d}\pm0.05$	$5.07^{c}\pm0.02$	$5.38^{c}\pm0.01$	$5.58^{b}\pm0.11$	$6.14^{a}\pm.0.02$	$6.30^{a}\pm0.05$
Ash	$1.20^{d}\pm0.01$	$1.70^{c}\pm0.01$	$1.83^{c}\pm0.01$	$2.15^{b}\pm0.12$	$2.21^{b}\pm0.02$	$2.40^{a}\pm0.02$
Calorific value (kJ/100g)	$1530^{f}\pm0.05$	$1590^{e}\pm1.00$	$1601^{d}\pm0.05$	$1625^{c}\pm0.08$	$1657^{b}\pm0.05$	$1687^{a}\pm2.01$

**Values are Means ± SD of triplicate determination Means in the same row with different superscript are significantly different at (P <0.05). CHO: Carbohydrate*

The moisture content of any food product is an integral factor when considering food quality characteristics of that product. As reported by Folake and Bolanle [37], moisture content of a food affects its stability and overall quality. The moisture content of formulated complementary food samples were within the acceptable limit of not more than 10% [38]. The carbohydrate in the breakfast cereal is attributed to the high proportion of broken rice which serves as the principal ingredient in this formulations. Rice is a very rich carbohydrate source responsible for the bulk of daily calories for many humans and animals [39], and it is an important source of dietary energy. Carbohydrate content of this product fell within the recommended levels of carbohydrate in complementary foods as outlined by Lutter and Dewey [24] as well as values reported by Kinyuru et al [25] on insect fortified complementary foods in Kenya and higher when compared to values reported by Parker et al [40] from Ghana.

Variability of protein and lipid content of the complementary food samples resulted from the use of varying degrees of soy flour and palm weevil flour in different formulations. Soy flour is a rich source of protein while palm weevil flour contain moderate protein but higher in lipid content. Values for protein as obtained in this study was higher than the recommended levels in complementary food while lipid content was within the recommended levels as outlined by Lutter and Dewey [24]. As noted by Parker et al [40], palm weevil offers an essential amount of nutrients which can feasibly be added into various nutrition intervention programmes to address various health and nutrition deficiencies. Moreover, there is evidence of an improved nutrient content of the formulated complementary food samples.

Mineral content of formulated complementary food

Table 5 shows the concentration of mineral elements in rice/ soybean complementary food fortified with palm weevil flour. Values obtained from the analysis of the complementary food samples for the macro elements (Na, K, Ca, Mg and P) indicated an increased in all the macro element concentrations as the percentage of palm weevil flour increases in the rice/soybean flour blends. Values obtained for macro elements indicated significant difference ($p< 0.05$) in all instances. Result showed that Na concentration increased from 8.12 mg/100g in sample A to 27.15 mg/100g in sample F, K increased from 2.54mg/100g in sample A to 12.34 mg/100g in sample F, Ca level increased from 10.25 mg/100g to 25.70 mg/100g in sample F. The concentration of Mg also increased from 5.62 mg/100g in sample A to 12.38 mg/100g in sample F while that of P increased from1.91 mg/100g in sample A to 5.50 mg/100g in sample F. The concentrations of the trace elements (Zn and Fe) analysed also indicated an increased as the percentage of palm weevil flour increases in the rice/soybean flour blends. The concentrations of Zn and Fe increased from 0.84 mg/100g and 1.52 mg/100g in sample A to 4.42 mg/100g and 6.62 mg/100g in sample F mg/100g respectively. Values as obtained for the trace elements Zn and Fe are within the recommended levels of 4.6 mg/100g and 9.3 mg/100g respectively stipulated by FAO/WHO [41]. However, values for the macro elements were similar to values obtained in an insect fortified complementary foods in Ghana [40] and still below the recommended daily allowance of these elements [42]. As suggested by Kinyuru et al [25], mineral premix is need to increase mineral bioavailability in formulated complementary foods. The result as obtained for Zn and Fe shows that it is possible to achieve the recommended dietary level of these important mineral elements using local ingredients without resorting to fortification. It is expected that the Fe and Zn bioavailability especially in the formulated complementary foods would have been higher if the soybean seed were germinated and the level of polishing of rice grain reduced

Table 5

Mineral content (mg/100g) of formulated complementary food

Parameters	Complementary Foods A (100:0)	B (94.5:5.5)	C (89.5:10.5)	D (85.3:14.7)	E (75.5:24.5)	F (70:30)
Na	$8.12^{f}\pm0.05$	$12.25^{e}\pm1.50$	$14.90^{d}\pm1.00$	$17.20^{c}\pm0.05$	$22.80^{b}\pm1.00$	$27.15^{a}\pm0.05$
K	$2.54^{d}\pm0.05$	$5.31^{cd}\pm0.01$	$6.41^{c}\pm0.02$	$9.23^{b}\pm0.01$	$12.26^{a}\pm0.01$	$12.34^{a}\pm0.02$
Ca	$10.25^{d}\pm0.01$	$12.18^{c}\pm0.05$	$14.41^{bc}\pm0.05$	$16.93^{b}\pm0.01$	$23.51^{ab}\pm0.01$	$25.70^{a}\pm0.05$
Mg	$5.62^{d}\pm0.05$	$8.29^{cd}\pm0.01$	$9.92^{c}\pm0.02$	$10.15^{b}\pm1.10$	$12.21^{a}\pm0.10$	$12.38^{a}\pm0.05$
P	$1.91^{d}\pm0.01$	$3.54^{c}\pm0.02$	$3.88^{b}\pm0.01$	$3.98^{b}\pm0.03$	$5.41^{a}\pm.0.01$	$5.50^{a}\pm0.01$
Zn	$0.84^{c}\pm0.01$	$3.91^{b}\pm0.05$	$3.98^{b}\pm0.02$	$4.12^{ab}\pm0.10$	$4.40^{a}\pm0.01$	$4.42^{a}\pm0.01$
Fe	$1.52^{d}\pm0.01$	$3.21^{c}\pm.02$	$3.38^{bc}\pm0.01$	$4.09^{b}\pm0.02$	$6.22^{a}\pm0.01$	$6.60^{a}\pm0.02$

**Values are Means ± SD of triplicate determination Means in the same row with different superscript are significantly different at ($P <0.05$)*

Anti-nutritional content of formulated complementary food

The anti-nutrient content of complementary foods formulated from rice/soybean four blends fortified with palm weevil flour is shown in Table 6. Significant differences ($p < 0.05$) exist between all samples in terms of their anti-nutritional components. The results indicated a decreased in the concentration of saponin, tannin and oxalate as the percentage of palm weevil flour increases in the complementary foods samples. However, the concentration of phytate increases as the percentage of palm weevil in the complementary food increased. Saponin concentration decreased from 3.61% in sample A to 2.51% in sample F. The concentration of tannin and oxalate also decreased from 5.24 mg/100g and 4.93 mg/100g in sample A to 3.82mg/100g and 2.01mg/100g in sample F respectively. In addition, phytate concentration increased from 11.05 mg/100g in sample A to 17.30 mg/100g in sample F. Saponins are present in food products containing soybean and other legumes. They are not regarded as true anti- nutrient because they known to help lower risk of high cholesterol and cancer thereby controlling blood sugar [43]. However, the present of saponins in food imparts bitter taste and astringency resulting from poor organoleptic properties of the food product. Saponins are also implicated in the inhibition of various enzymes thereby negatively impacting on protein digestion and assimilation. Literature has shown that phytic acid forms complexes with minerals such as calcium, iron, magnesium zinc and protein and influence their solubility and bioavailability. The phytate content of all samples were below the 25 mg/100g permissible level [44]. High phytate content of the complementary food samples could be attributed to the present of broken rice in the formulations. Tannins are anti-nutrient that form complex with protein resulting in insoluble precipitate of proteins in the gut thereby reducing digestibility of proteins in foods. Apart from saponins, tannins are known to cause an astringent reaction in the mouth and make food unpalatable. Tannins also interfere with digestibility and absorption of mineral nutrients such as iron and zinc.

Table 6

Anti-nutritional content of formulated complementary food

Parameters	Complementary Foods					
	A (100:0)	B (94.5:5.5)	C (89.5:10.5)	D (85.3:14.7)	E (75.5:24.5)	F (70:30)
Saponins(%)	3.61^{a}±0.01	3.58^{a}±0.02	3.27^{b}±0.01	3.07^{b}±0.01	2.58^{c}±0.02	2.51^{c}±0.03
Phytate(mg/100g)	11.05^{d}±1.20	11.65^{cd}±1.00	12.27^{c}±1.20	13.50^{b}±2.00	16.78^{a}±2.00	17.30^{a}±1.22
Tannins(mg/100g)	5.24^{a}±0.02	5.21^{a}±0.01	5.18^{a}±0.02	5.10^{a}±0.01	3.90^{b}±0.05	3.82^{b}±0.05
Oxalate(mg/100g)	4.93^{a}±1.00	4.85^{a}±0.05	3.71^{b}±1.00	3.60^{b}±0.03	2.18^{c}±0.01	2.01^{c}±0.02

*Values are Means ± SD of triplicate determination Means in the same row with different superscript are significantly different at ($P < 0.05$).

The present of oxalates in large doses in human food causes gastrointestinal disorders. Oxalates form complexes with calcium, magnesium and iron leading to the formation of insoluble salts and resulting in the formation of oxalate stones [45]. It has also been known to negatively affect the absorption of potassium and sodium in human body. The anti-nutritional factors present in all the complementary food samples were at safe levels necessary to prevent all these effects from taking effect consequent upon the consumption of the products
.

Sensory properties of formulated complementary food

The mean scores obtained from sensory analysis of complementary foods produced from broken rice/ soybean flour blends fortified with palm weevil flour is presented in Table 7. The mean scores obtained from the assessment of the appearance of the complementary food samples indicated a decreased in appearance as the proportion of palm weevil flour increases in the blends. The mean scores for other attributes such as taste, after taste, flavour, mouthfeel, consistency and overall acceptability increased as the proportion of palm weevil flour the blends increases. Sample A(100:0) which had no palm weevil flour in the blend was the best in appearance. Sample E(75.5:24.5), recorded the best scores for after taste, mouthfeel consistency and overall acceptability while sample F(70:30) had the highest scores for taste and flavour. Sample E and F were more acceptable in all sensory attributes determined except in appearance only. This may be due to higher proportions of palm weevil flour in those food samples

Table 7:

Sensory properties of formulated complementary food

Parameters	Complementary Foods					
	A (100:0)	B (94.5:5.5)	C (89.5:10.5)	D (85.3:14.7)	E 75.5:24.5)	F (70:30)
Appearance	8.12^{a}±0.05	8.07^{a}±2.10	7.59^{b}±2.00	7.23^{c}±1.05	5.36^{c}±1.60	5.10^{cd}±1.21
Taste	6.58^{b}±1.00	6.30^{bc}±1.50	6.21^{c}±1.02	6.53^{b}±1.00	7.01^{a}±0.05	7.04^{a}±0.05
After taste	6.12^{b}±0.05	6.10^{b}±0.07	6.00^{bc}±0.25	5.86^{c}±1.01	7.10^{a}±0.01	7.05^{a}±1.23
Flavour	7.45^{c}±1.20	7.46^{c}±0.50	7.55^{bc}±1.00	7.62^{b}±0.05	7.89^{a}±1.50	7.96^{a}±1.61
Mouthfeel	6.63^{e}±0.05	6.71^{d}±1.00	6.85^{c}±1.30	6.88^{c}±1.00	7.21^{a}±.1.21	7.00^{b}±0.01
Consistency	6.84^{d}±0.06	6.91^{c}±0.05	6.98^{bc}±0.01	7.12^{b}±1.10	7.40^{a}±1.00	7.38^{a}±0.04
Overall acceptability	7.11^{b}±0.01	7.10^{b}±2.00	7.03^{c}±0.05	7.19^{ab}±1.21	7.24^{a}±0.42	7.21^{a}±1.00

**Values are Means ± SD of triplicate determination Means in the same row with different superscript are significantly different at (P <0.05).*

4. Conclusion

Edible palm weevil (*Rhynchophorus phoenicis*) is an edible insect that is highly valued and exploited by locales due to their nutritional potential. The present study established the variability in nutritional content of developmental stages of edible palm weevil and it application in the formulation of complementary foods from broken rice and soybean flour blends. The proximate composition and calorific value of the three developmental stages of edible palm weevil indicated a higher lipid content in the early stage and late larva stages of development when compare to that of the adult weevil. The early larva stage was also superior in ash and energy content. However the adult weevil had the highest percentage of protein, carbohydrate and fiber content .The edible palm weevil had a significant amount of macro elements of sodium, calcium, magnesium, potassium and phosphorus in the three developmental stages while values obtained for the micro mineral of Zinc and Iron indicated that adult stage recorded highest values. The present of these micro minerals in the edible palm weevil makes it an important food ingredient toward the eradication of various nutritional deficiencies. Results of proximate composition of complementary food formulated from blends of broken rice, soybean and edible palm weevil larva flour indicated that moisture, protein, lipid, ash and fibre content increased as the percentage of palm weevil flour increases in the formulated food samples. Protein and carbohydrate content of complementary foods samples as obtained in the study was higher than the recommended levels while lipid content was within the acceptable limits. Values obtained from the analysis of the complementary food samples for the macro elements (Na, K, Ca, Mg and P) indicated an increased in all the macro element concentrations as the percentage of palm weevil flour increases in the rice/soybean flour blends. However values were far below the recommended daily allowance (RDA). The result for Zn and Fe at 30% of palm weevil flour impute in the broken rice and soybean flour blends gave an acceptable levels of Zn and Fe which indicated that it is possible to achieve the recommended dietary level of these important mineral elements using local ingredients without resorting to fortification. The anti-nutritional factors present in all the complementary food samples were at safe levels necessary to prevent negative health effects consequent upon the consumption of the products. Sensory results showed that sample E with 24.5% and sample F with 30% palm weevil flour were more acceptable in all sensory attributes determined except in appearance only. This may be attributed to higher proportions of palm weevil flour in the blends.

5. References

[1]. FOOD AND AGRICULTURAL ORGANISATION (FAO). Promises and challenge of informal food sector in developing countries. Food and Agriculture Organisation. Rome (2007).

[2]. VAN HUIS, A.; VAN ITTERBEECK, J.; KLUNDER, H.; MERTENS, E.; HALLORAN, A.; MUIR, G.; VANTOMME, P. Edible insects: Future: Prospects for Food and Feed Security, 1st ed.; Food and agriculture organization of the United Nations: Rome, Italy, (2013).

[3]. BELLUCO, S., C. LOSASSO, M. MAGGIOLETTI, C. C. ALONZI, M.G. PAOLETTI, AND A. RICCI.. Edible insects in a food safety and nutritional perspective: A critical review. Compr. Rev. Food Sci. Food Safety. 12:296–313, (2013) Available at https://doi.org/10.1111/1541-4337.12014

[4]. JONGEMA, Y. Worldwide list of recorded edible insects. Wageningen (NL): Wageningen University & Research; [cited 2017 Jun 04]. 100. Available from http://www.wur.nl/en/Expertise-Services/Chair-groups/Plant-Sciences Laboratory-of-Entomology/Edible insects/Worldwide-species-list.htm.

[5]. OONINCX D. G, VAN ITTERBEECK, J. HEETKAMP, M. J, VAN DEN BRAND H, VAN LOON J. J, VAN HUIS A. An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. *PLoS One*; 5(12):e14445.(2010).

[6]. VAN HUIS A, OONINCX D. G.. The environmental sustainability of insects as food and feed. *A review Agron Sustain Dev*.;37:43 (2017).

[7]. Payne C, Scarborough P, Rayner M, Nonaka K. 2016. Are edible insects more or less 'healthy' than commonly consumed meats? A comparison using two nutrient profiling models developed to combat over- and under nutrition. *Eur J Clin Nutr.* 70(3):285–91 (2016) Available at https://doi doi: 10.1038/ejcn.2015.149.

[8]. RUMPOLD B, SCHLÜTER O. Nutritional composition and safety aspects of edible insects. *Mol Nutr Food Res.* 57(5): 802–23.(2013).

[9]. FINKE M. D. Complete nutrient content of four species of feeder insects. Zoo Biol. ;32(1):27–36 (2013).

[10]. HAUG, A. CHRISTOPHERSEN, O. A., KINABO, J., KAUNDA, W. AND EIK, L. O.,. Use of dried kapenta (*Limnothrissa miodon* and *Stolothrissa tanganicae*) and other products based on whole fish for complementing maize-based diets. *African Journal of Food Agriculture, Nutrition and Development* 10: 2478-2500 (2010)

[11]. MOSHA, T. C. E. AND BENNINK, M. R., Protein digestibility-corrected amino acid scores, acceptability and storage stability of ready-to-eat supplementary foods for pre-school age children in Tanzania. *Journal of the Science of Food and Agriculture* 85: 1513-1522 (2005) Available at https://DOI: 10.1002/jsfa.2147

[12]. BRIEND, A. AND DARMON, N. Determining limiting nutrients by linear programming: a new approach to predict insufficient intakes from complementary foods. *Pediatrics* 5: 1288-1290. (2000)

[13]. ONIMAWO, L. A., AKUBOR, I. P. *Food chemistry*. Integrated approach with biochemical background, AMBIK press Ltd. 222-235 (2005).

[14]. MICHAELSEN, K. F., HOPPE, C., ROOS, N., KAESTEL, P., STOUGAARD, M., LAURITZEN, L., MOLGAARD, C., GIRMA, T. AND FRIIS, H., Choice of foods and ingredients for moderately malnourished children 6 months to 5 years of age. *Food and Nutrition Bulletin* 30: 343S-404S .(2009)

[15]. ANIGO, K. M., AMEH, D. A., IBRAHIM, S. AND DANBAUCHI, S. S.,. Nutrient composition of complementary food gruels formulated from malted cereals, soybeans and groundnut for use in North-western Nigeria. *African Journal of Food Science* 4: 65-72. (2010).

[16]. Martin, H., Laswai, H. and Kulwa, K.,. Nutrient content and acceptability of soybean based complementary food. *African Journal of Food Nutrition and Development* 10: 2040-2049. (2010).

[17]. INYANG, U. E. UMOH, H. I. AND UKWO, S. P.. Effect of Co-fermentation Duration on the Nutritional Composition and Anti-nutritional Contents of Sorghum-Cowpea Flours and Sensory Properties of Their Gruels. *IOSR Journal of Environmental Science, Toxicology and Food Technology* 13(2): 56-64. (2019) Available at https:// doi:10.9790/2402-1302015664www.iosrjournals.org.

[18] MUHIMBULA, H. S., ABDULSUDI, I. AND KINABO, J., . Formulation and sensory evaluation of complementary foods from local, cheap and readily available cereals and legumes in Iringa, Tanzania. *African Journal of Food Science* 5: 26-31. (2011).

[19]. ONYEIKE, E. N., AYALOGU, E. O., AND OKARAONYE, C. C. Nutritive value of the larvae of raphia palm beetle (Oryctes rhinoceros) and weevil (Rhyncophorus pheonicis). *Journal of the Science of Food and Agriculture,* 85, 1822–1828 (2005).

[20]. ASMA, M. A., BABIKER, F. E. AND TINAY, A. H., . Development of weaning food from sorghum supplemented with legumes and oil seeds. *Food and Nutrition Bulletin* 27(1): 26-34 (2006)

[21]. WORLD FOOD PROGRAMME. (WFP) handbook: fortified blended food – good manufacturing practice and HACCP principles (a handbook for processors in partnership with the UN World Food Programme). WFP, Rome, Italy (2010) . Available at: http://foodquality. wfp.org.

[22]. OKOLI, C. OLODI, W. B. OGBUEWU, P. ALADI, N. O. AND OKOLI, C. G. . Nutrient Composition of African Palm Grub (*Rhynchophorus phoenicis*) Larvae Harvested from Raphia Palm Trunk in the Niger-delta Swamps of Nigeria. *Asian Journal of Biological Sciences*. 12 (2):.284-290. (2019).Available at https://doi: 10.3923/ajbs.2019.284.290.

[23]. WOMENI H. M, TIENCHEU B, LINDER M, CHOUATCHO NABAYO E, TENYANG N, TCHOUANGUEP MBIAPO F, VILLENEUVE P, FANNI J, PARMENTIER M. Nutritional value and effect of cooking, drying and storage process on some functional properties of *Rhynchophorus phoenicis*. *International Journal of Life Science and Pharma Research,* **2**: 203-21 (2012).

[24]. LUTTER, C. K. AND DEWEY, K. G.,. Proposed nutrient composition for fortified complementary foods. *Journal of Nutrition* 133: 3011S-3020S (2003).

[25]. KINYURU, **J. N.** KONYOLE, S. O. ONYANGO-OMOLO, S, A. KENJI, G. M. . ONYANGO, V.O. OWINO B.O. OWUOR, B.B. ESTAMBALE AND ROOS**,** N.. Nutrients, functional properties, storage stability and costing of complementary foods enriched with either termites and fish or commercial micronutrients. Journal of Insects as Food and Feed 1 (2): 149 - 158

(2015). Available at https://doi 10.3920/JIFF2014.0011.

[26]. Codex Alimentarius. Codex standard for food grade salt. CX STAN 150-1985, Amended. Codex Alimentarius (1991).

[27]. OFFICIAL METHODS OF ANALYSIS, (AOAC) 18th Edition Association of Official Analytical Chemists, Washington D.C, USA. 56-68 (2010).

[28]. ONWUKA, G. I. *Food Analysis and Instrumentation*. Theory and Practices. Napthali Prints, Lagos, Nigeria 140-176 (2018).

[29]. WHEELER, E. L., FERREL, R. E., . A method for phytic acid determination in wheat fractions. *Journal of Cereal Chemistry*, 45:312-316 (1971).

[30]. ALLEN, S. E., GRIMSHAW, H. M., PARKINSON, J. A., QUARMBY, C.. *Chemical analysis of ecological materials*. Ed. S. E. Allen. Blackwell Sci. Pub., Oxford, London, Edinburgh, Melbourne, 565 (1984)

[31]. IHEKORONYE, A. I., NGODDY, P, O.. Integrated Food Science and Technology for the tropics. 1st ed. MacMillan publishers. 261, 265, 291 (1985).

[32]. OMOTOSO O.T. Nutritional quality, functional properties and anti-nutrient compositions of the larva of *Cirina forda* (Westwood) (Lepidoptera: Saturniidae). *Journal of Zhejiang University science B* 7: 51-55 (2007).

[33]. SINGH, P. *The rearing of beneficial insects*. New Zealand Entomologist, 7, 304–310 (2004).

[34]. TEFFO, L. S. TON, R. B. AND ELOFF, J. N. Preliminary Data on the Nutritional Composition of Edible Sting-bug consumed in Lipopo Province South Africa. *S. Afr. J of Sci*, 103: 434-436 (2007).

[35]. OKARAONYE C. C, IKEWUCHI J. C.. *Rhynchophorus phoenicis* (F) larva meal nutritional value and health implications. *J Biol Sci.* 8(7):1221–1225 (2008).

[36]. ELEMO, B. O., ELEMO, G. N., MAKINDE, M. A. ERUKAINURE, O. L. Chemical Evaluation of African Palm Weevil, *Rhynchophorus phoenicis* larva as a food source".*Journal of Insect Science* (11): 146, 1536-2442 (2011). Available at . https:// doi:10.1673/031.011.14601.

[37]. FOLAKE, O. S. AND BOLANLE, O. O.. Chemical Analysis and Sensory Evaluation of Ogi Enriched with Soybeans and Crayfish. *Nutr. Food Sci*. 36(4): 214-217 (2006).

[38]. ALAWODE, E. K., IDOWU, M. A., ADEOLA, A. A., Some quality attributes of complementary food produced from flour blends of orange flesh sweet potato, sorghum, and soybean. *Croatian Journal of Food Science and Technology,* 9(2): 122-129 (2017). https://doi.org/10.17508/CJFST.2017.9.2.06

[39]. RYAN, E. P. Bioactive Food Components and Health Properties of Rice Bran. J. Amer. Veter. Med. Assoc. 238:593- 600 (2011). https://doi.org/10.2460/javma.238.5.593.

[40]. PARKER ,M. E. ZOBRIST, S. LUTTERODT, H. E. ASIEDU,C. R. DONAHUE, C. EDICK, C. MANSEN, K. PELTO, G. MILANI, P. SOOR, S. LAAR, A. AND ENGMANN, C. M.. Evaluating the nutritional content of an insect-fortified food for the child complementary diet in Ghana. BMC Nutrition 6(7): 1-11 (2020) Available at https://doi.org/10.1186/s40795-020-0331-6

[41]. FOOD AND AGRICULTURE ORGANISATION/WORLD HEALTH ORGANISATION (FAO/ WHO). Human energy requirements. Joint FAO/WHO Expert Consultation. FAO, Rome, Italy (2004).

[42]. FOOD AND AGRICULTURE ORGANISATION/WORLD HEALTH ORGANISATION. (FAO/ WHO) Vitamin and mineral requirements in human nutrition. Joint FAO/WHO Expert Consultation. WHO, Geneva, Switzerland (2002).

[43]. IWE, M. O. *The Science and Technology of Soybean*. 1st Edition. Rejoint Communication Services Limited. Enugu Nigeria. 97 (2003).

[44]. NAGEL, R., Living with phytic acid. The Weston A. price foundation wincosin ave., Washington D.C. (2010). http://www.weston aprice.org/food-features/living-with –phytic-acid

[45]. OWINO, V.O., SINKALA, M., AMADI, B., TOMKINS, A.M. AND FILTEAU, S.M.,. Acceptability, storage stability and costing of α-amylase-treated maize-beans-groundnuts-bambaranuts complementary blend. *Journal of the Science of Food and Agriculture* 87: 1021-1029 (2007). Available at https://doi:10.1002/jsfa.2799