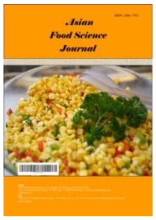

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# Cockroach (*Periplaneta americana*): Nutritional Value as Food and Feed For Man and Livestock

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Author URB designed the study, wrote the protocol and the first draft of the manuscript. Author BDS managed the literature searches. Both authors read and approved the final manuscript.*

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## ABSTRACT

**Aim:** To ascertain scientifically by proximate analysis, the nutrient composition and mineral contents of the American cockroach *Periplaneta americana.*
**Study Design:** Completely randomized sample design (CRD) was engaged in the study with 15 parameters replicated five (5) times, totaling seventy five experimental samples. The whole experiments were repeated in three trials.
**Place and Duration of Study:** Postgraduate laboratory, Faculty of Science, Niger Delta University Wilberforce Island, Bayelsa State, Nigeria between September 2019 and February 2020.
**Methodology:** The nutrient composition and mineral profile of the cockroaches were ascertained using randomly selected cockroach sample while adopting standard procedures of AOAC, (1990, 2005).Statistical analysis and significant difference tested at alpha level p≤ 0.05 was done using Turkey HSD test for difference between mean while results were presented in tables. The software used was SPSS version 20.
**Results:** The results for proximate analysis of nutrients found in *P. americana* are given as follows: moisture content: 12.42±1.6%, Crude ash: 3.52±0.8%, crude protein: 8.72±1.3%, crude fat: 17.64±1.9%, fibre: 21.28±2.1%, Carbohydrate (dry method): 87.56±4.2% and Carbohydrate (free nitrogen extract): 48.76±3.1%. Furthermore, *P. americana* was proven rich in both micro and

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macro minerals in very high to low concentrations such as:calcium (468.00±9.7mg/100g), magnesium (362.00±8.5mg/100g), iron (274.60±7.4mg/100g), potassium (242.5±7.0 mg/100g), phosphorus (128.76±5.1mg/100g), sodium (110.68±4.7mg/100g), manganese (12.63±1.6mg/100g), copper (7.54±1.2mg/100g) and zinc (4.74±1.0mg/100g). All results were calculated as mean percentages of five experimental evaluations.

**Conclusion:** Cockroaches are omnivores and feed on rotten vegetables, waste products from industries such as brewer's yeast, leftover bread, brewer's spent grains and several other food materials, hence they are very well efficient at turning plant based feed into animal protein. This makes them efficient projectors for addressing the problem of shortage of animal proteins thereby fulfilling the food security goal of sustainable development.

*Keywords: Cockroach; proximate analysis; nutrient; minerals; protein; carbohydrate; calcium.*

## 1. INTRODUCTION

Insects are highly suitable as feed due to their high nutritional values and since they are naturally a part of some livestock diet [1]. Insects are used for multiple purposes such as human food (entomophagy) [2,3], animal feeds [4] and as well as alternative sources such as medicinal (entomotherapy) [5,6]. Cockroach specie *Periplaneta americana* commonly known as the American cockroach is considered the edible amongst most cockroach species especially in countries like China where they are bred in captivity, sold and supplied to farmers who use them as feed for livestock and to the general public who eat them as food or for medicinal purposes or simply as tonic [4,7-9]. In pharmaceutical industries the insects are used for the production of drug formulations in curing a number of ailments such as gastroenteritis, duodenal ulcers and pulmonary tuberculosis, cancer, AIDS and potent anti-carcinogenic properties especially in traditional Chinese medicine where they are believed to work faster than other medicines [7,8]. Cockroaches are reported to have detoxifying properties and can act as diuretics. They are also effective for relieving sore throat, tonsillitis, liver cirrhosis and fluid build-up [9]. Cosmetic industries in Korea value the rich quality of cellulose contained in cockroach wings and cockroach powder are used in the production of facial mask and cream used for the treatment of burns [8]. According to [10,11], crystal-like milk derived from cockroach is considered a potential super food been awaited by the world.

Insect provide much of the protein animals need at a much lower environmental cost as they can feed on just about anything ranging from manure, or other type of organic waste including leftover foods, fruits, vegetables, offals, grains discarded by breweries [12,13] hence are been reared and sold in their millions incurring huge profits for the farmers [14]. Furthermore, [15,16] reported that insects of the order Blattodea to which *P. americana* belongs, are usually robust, grow under extreme conditions of low oxygen, poor lighting, high stocking density as well as have high nutritive value. Cockroaches can be reared as healthy food for humans [9] and as suitable feed for livestock which they make sustainable [4] or for the purpose of getting rid of food waste [9]. According to Behre et al. [1], insect feed is a sustainable addition to conventional feed, as insects are reared on waste streams and can generate diversified livelihood incomes. They are cheap to procure and process and are readily available in and outside the farms and households. They are reportedly cheap source of proteins and proposed as alternative to the meat industry [7,12]. In order to enhance the marketability of edible insects as food industrialization materials through diverse development, it is critical to understand traits of edible insects, particularly their nutritional content especially since insects are used in addition to foods rather than as a stand-alone food [17]. Thus, as possible requirement for the efficient utilization of the American cockroach, be it as food for man or feed for livestock, adequate information on its nutrient composition cannot be overemphasized. Several authors have studied the nutritional attributes of cockroaches without specifically narrowing it down to the specie *Periplaneta americana* hence reference is drawn always from the German specie *Blatta orientalis* which has been reported to have high protein content. Therefore, the aim of the research was to evaluate the proximate composition of nutrients and mineral profile of the single species of cockroach, the American cockroach (*P. americana*). The result of this study will be of utmost priority especially in the achievement of one of the agendum of the sustainable development goal of food security.

**Plate 1. The American cockroach (*P. americana*)**
*Source: Author*

## 2. MATERIALS AND METHODS

### 2.1 Collection of Test Insect

A total of four hundred adult cockroaches identified as American cockroaches were collected from various areas of residential buildings of Bayelsa State, Nigeria. The cockroaches were taken to the Postgraduate laboratory of the Niger Delta University, Wilberforce Island, Bayelsa State for proper identification and laboratory analysis.

### 2.2 Experimentation

Using the procedure of Soon-Kyung et al. [17], the cockroaches were washed in water to remove dirt and soil particles and later oven dried at 40°C for 8 hours. The dried cockroaches were ground into powder and stored at 4°C for later use in the bioassay. Proximate analyses and mineral content of the cockroaches were determined using standard procedures by Association of Official Analytical Chemists [18,19]. For proximate analyses, the nutrient content of the followings were determined: moisture, ash, crude protein, crude fat and crude fiber. Also mineral profile of the cockroaches such as calcium, magnesium, sodium, potassium, iron, manganese, copper, zinc and phosphorus were evaluated.

#### 2.2.1 Moisture content

A clean porcelain crucible was dried in an oven to obtain a constant weight (a). Five grams (5 g) of the sample was introduced into the crucible, the lid replaced and weighed to obtain the weight (b). The crucibles with contents were placed in the oven and the temperature set at 60°C for 24 hours. This was allowed to cool in a constant weight (c) [18].

$$\% \text{ Moisture} = \frac{b-c}{b-a} \times \frac{100}{1}$$

#### 2.2.2 Ash content

Two grams (2 g) of oven-dried sample was weighed in a crucible of known weight. The Crucible and content were placed in a muffle furnace and ignited at 550°C for 15 hours and later cooled to room temperature in a desiccated desiccator. The ash and crucible were then weighed [18].

$$\% \text{ Ash} = \frac{\text{weight of Ash}}{\text{weight of dried sample}} \times \frac{100}{1}$$

#### 2.2.3 Crude protein content

0.5 g of the sample was weighed into a standard 500 ml Kjeldahl flask containing the Kjeldahl catalysts 1.5 g of copper sulphate ($CuSO_{4)}$ and 1.5 g of sodium sulphate ($NaSO_{4),}$ some anti bumbs chips and 5ml of Concentration hydrogen tetraoxosulphatevi acid ($H_2SO_{4).}$ The digestion flask was placed on the digestion rack and heated gently for one hour to prevent charring and frothing. The heating was then increased about 4-5 hours until a clear bluish digest was observed. The digest was cooled and quantitatively transferred into a 50 ml standard flask and made up to the mark with distilled water. 10 ml of this solution was transferred in a kjeldahl distillation flask, treated with 10 ml of 40% sodium hydroxide (NaOH) and heated. The gas ammonia is collected in a conical flask containing 10 ml of 5% boric acid into which 2 drops of the mixed indicator was added. The tip of the distillation condenser is positioned in a way that the tip is immersed into the conical flask and the distillation continued until about 3 times, the original volume was obtained. The boric acid, mixed indicator solution turned green as ammonia was distilled into it [18].

A 50ml burette was then filled with 0.1MHcl solution and the distillated was titrated.

$$\% \text{ Nitrogen} = \text{ml Hcl (sample)} - \text{ml HCl (blank)} \times M \times \frac{14}{1000} \times \frac{50}{10} \times \frac{100}{0.5}$$

% Protein = % NX 6.25

#### 2.2.4 Crude lipid of extract

0.5 g of the oven-dried sample was accurately weighed into a thimble. 200 ml of petroleum ether was poured into a previously weighed round bottom flask containing weighed anti bumping granules. A blank deformation was also done without the 0.5 g sample. The soxhlet extractor and the thimble with its contents were filled into the flask and the set up was placed on a heating mantle. The flask was heated slowly on the heating mantle until the solvent in the extraction was complete. The thimble was removed and air-dried. The extracted lipid in the flask was concentrated using rotary evaporator which was further dried in a desiccator and then weighed. The amount of lipid extracted was obtained from the difference between the weight of the flask before and after extraction [18].

$$\% \text{ Lipid} = \frac{\text{Weight Extract}}{\text{weight of sample}} \text{ x } \frac{100}{1}$$

#### 2.2.5 Crude fibre

The procedure involved acid digestion, filtration and base digestion. Two grams (2 g) of fat free sample was weighed and quantitatively transferred into a 400 ml beaker which has a mark at the 200 ml line. 50ml of 1.25% $H_2SO_4$ was added and the mixture made up to 200 ml mark with distilled water.

The beaker was then boiled for 30 minutes. The contents of the beaker were filtered through a funnel with the end of a suction pump. The residue was washed severally with hot water until it was acid free.

The residue was then transferred into the 400 ml beaker and 50 ml of 1.25% sodium hydroxide (NaOH) solution was added and made up to the 200ml level, with distilled water. The mixture was brought to boiling for 30mm with stirring. The contents were filtered through a funnel and washed severally with hot water until it was free from NaOH. Finally the residue was washed with 95% ethanol twice and transferred into a porcelain crucible and dried at 100°C [18].

$$\% \text{ Fibre} = \frac{\text{Weight of dried fibre}}{\text{Weight of fat free sample}} \text{ x } \frac{100}{1}$$

Mineral contents such as calcium, magnesium, sodium, potassium, iron, manganese, copper, zinc and phosphorus were also evaluated using standard atomic absorption method of Association of Official Analytical Chemists [19]. Two grams (2 g) of each sample was ash at 550°C for 15 hours in a muffle furnace. The resulting ash was then acid digested in 15 ml of concentrated Nitric acid ($HNO_3$). 20 ml of distilled water was added to the acid digest to dilute the solution. The solutions were filtered into 100 ml volumetric flask and made up to the mark with the distilled water. The samples were then aspirated on the Atomic Absorption Spectrophotometers for the variation of elements.

### 2.3 Data Analysis

Proximate composition of the samples was done using five experimental evaluations. Statistical analysis and significant difference tested at alpha level p≤0.05 was done using Turkey HSD test for difference between mean while results were presented in tables as mean and standard deviation of five replicates. Mean differences in mineral composition of the American cockroach was determined by one way ANOVA (two-factor with replication). The software used was SPSS version 20.

## 3. RESULTS AND DISCUSSION

Table 1 below gives the result for proximate analysis of the nutrient contents of the American cockroach which was proven to be high in carbohydrate, analyzed in two ways: nitrogen free extract (NFE) (48.73±3.1%) and dry method (DM) (87.56±4.2%), crude fibre (21.28±2.1%), crude fat (17.64±1.9%), moisture content (12.42±1.6%), crude protein (8.72±1.3%)and crude ash content of (3.52±0.8%).

The results of this study further reveals the mineral content of *P. americana* adult as follows: calcium (468.33±9.7 mg/100g), magnesium (362.00±8.5 mg/100g), iron (274.60±7.4 mg/100g), potassium (242.54±7.0mg/100g), phosphorus (128.76±5.1 mg/100g), sodium (110.68±4.7mg/100g), but showed low contents for manganese (12.65±1.6 mg/100g), copper (7.54 ±1.2 mg/100g) and zinc (4.74±1.0mg/ 100g) with the lowest content as presented on Table 2.

### 3.1 Discussion

As the practice of entomophagy is gradually gaining acceptance all over the world by which people can supplement the meager protein content of their high carbohydrate diets, cockroaches have been found to be highly nutritious amongst insects that possess high levels of proteins, fats, and minerals. Like nutrient composition of other edible insects, the nutritional values for cockroaches are highly variable, these variations have been attributed to the origin of species, insect food substrates as well as measuring methods employed [20,21].

The moisture content of the *P. americana* was relatively low (12.42±1.6%) dry weight. This result is in agreement with that of Abulude et al. [22]. This is indicative of the fact that the cockroach meal/feed possesses a longer shelf life and can be stored for a long period of time upon preparation without spoilage. According to Siulapwa et al. [23], low moisture content reduces microbial activities and deterioration of food/feed during storage. Feeds with high moisture content are liable to quick spoilage especially from fungal contamination. Toxins produced by the moulds make such feed unpalatable thus causing illness or even death to animals [24]. Dry feeds though unpalatable are usually stable.

Ash content is useful as it contains all the minerals in the feed. The crude ash value of *P. americana* was (3.52±0.8%) and is in comparison with the results obtained by various authors who worked independently [22,25-27] using different species of cockroach. The low ash content is indicative of the absence of contaminants and that *P. americana* feed and food preparations can retard the growth of microorganisms. This value also falls within the recommended ash content value for meat and dairy products.

Crude fibre is the estimation of the indigestible or slowly digestible fraction of the feed that provide the bulk necessary for proper peristaltic action in the intestinal tract. The American cockroach has the crude fibre content of (21.28±2.1%) which compares favorably with that of Chulu [25] as daily fibre requirement for human. Fibre regulate blood sugar level, bowel function and feed bowel health, hence their presence in any food/feed is of utmost importance [28].

**Table 1. Proximate analysis of the nutrient contents of *P. americana* adults**

| Nutrient | Percentage (%) composition of *Periplaneta americana* |
|---|---|
| Moisture content | $12.42±1.6^a$ |
| Crude ash | $3.52±0.8^b$ |
| Crude Protein | $8.72±1.3^c$ |
| Crude fat | $17.64±1.9^d$ |
| Crude fibre | $21.28±2.1^e$ |
| Carbohydrate (Dry Matter) | $87.56±4.2^f$ |
| Carbohydrate (NFE) | $48.73±3.1^g$ |

*Results are presented as mean percentages of five experimental evaluations. There was significant (p≤0.05) difference recorded among variables, but none (p>0.05) was recorded among replicates in row (p=0.93).*
*Source: Authors*

**Table 2. Mineral content of *Periplaneta americana* adults**

| Mineral | Mineral composition of *Periplaneta americana* (mg/100g) |
|---|---|
| Calcium | $468.00±9.7^a$ |
| Magnesium | $362.00±8.5^b$ |
| Sodium | $110.68±4.7^c$ |
| Potassium | $242.54±7.0^d$ |
| Iron | $274.60±7.4^e$ |
| Manganese | $12.63±1.6^f$ |
| Copper | $7.54±1.2^g$ |
| Zinc | $4.74±1.0^h$ |
| Phosphorus | $128.76±5.1^i$ |

*Results are presented as mean and standard deviation of five experimental evaluations. There was significant (p≤0.05) difference recorded among variable, but none (p>0.05) was recorded among replicates in row (p=0.16).*
*Source: Authors*

The crude fat of the cockroach *P. americana* was relatively high (17.64±1.9%).This is in conformity with previous results of several authors [22,26,27] who worked on different species of cockroach. This is also in line with the percentage (20-35%) of fat needed daily by the human body as stated by Ferrierra [28]. Fat is vital in the structural and biological functioning of cells. The implication of the insect fat content in the cockroach is that it decreases the chances of storage deterioration by lipid oxidation which is usually on the increase in insects with excessively high fat content [25]. According to NRC [31], fat availability in diets play important role in enhancing the palatability of foods, functioning of cells and in the transportation of vitamins.

The mean percentage crude protein (8.72±1.3%) level of the cockroach specie aligns with that reported by Abulude et al. [22]. This also falls within the values of those of cow milk (3.8%), hen's egg (12.4%) and beef (18.0%) as stated by FAO [30], therefore can adequately supplement for the daily protein requirement of 23.56 % as stipulated by NRC [31]. This can be substantially augmented by incorporating processed cockroach meat powder into children, pregnant and lactating mother's diets or even adults who are malnourished. Also cockroach powder and processed meat can be adequately incorporated in the feeds of livestock especially poultry for faster growth rate. If an adult male of about 70 kg body weight requires 35 g of protein daily. Only about 113 g of the cockroach food would be required to provide an average adult man's minimum daily protein need [25]. Bigger sized insects form hardened cuticle covered with Nitrogen- Hydrogen bonded chitin layer which increases the Nitrogen content [32]. High protein content is suitable for feed production as reported by Mayer [33]. It is therefore reasonable and economical to supplement diets with edible cockroach or be eaten as dessert, delicacy or appetizer to meet up with the protein demand of the body.

The result of the study also showed that the cockroach had high content of carbohydrate whether by dry matter (87.56±4.2%) or Nitrogen free extraction (48.76±3.1%). This result also confirmed those reported by authors [22,34,28]. Carbohydrates are important nutritive elements in the human body. They are the main energy source, can reduce consumption of protein and help in detoxification.

Minerals are known to play important metabolic and physiological roles in living system. The levels of minerals present in the American cockroach were very high and indicated that the insect is proven as good source of both macro and micro minerals for humans (young, pregnant and lactating mothers) and animals (livestock). Calcium is a major mineral nutrient required in the diet of humans. The calcium content of the cockroach *P. americana* was (468.00±9.7 mg/100g) which quadruples the daily intake requirement of 100-120mg of human adult. The mineral calcium is essential for the building of bones and teeth, helps in muscle contraction and relaxation, nerve function, blood pressure regulation, immune system health and as a messenger in cell signaling. It is extremely important to avoid loss of bone [35].

Magnesium is also a macro nutrient required daily in high amount in human diet (400-420 for men and 310-320 for women). It was revealed by the study to be present in the cockroach dry weight as (362.00±8.5 mg/100g). This value can also supplement for the daily requirement value needed by humans especially women and expectant mothers, since magnesium is essential in making protein, muscle construction, nerve transmission, immune system health, metabolic processes and energy production synthesis of biomolecules [35]. It is also a structural component of cell membrane and chromosomes and is used in ion transport and cell migration.

Sodium as a macro nutrient is needed for proper fluid balance, nerve transmission and muscle contraction [17] with the recommended daily intake given as 1.5- 3.8 g of sodium chloride per day. The quantity found present in the dry weight of the cockroach (110.68±4.7mg/100g) also aligns with that of Abulude et al. [22] and far exceed the above recommended daily requirement by humans and thus can adequately supplement the sodium chloride daily intake.

Potassium is another major mineral required in large quantity by humans for proper fluid balance, nerve transmission and muscle contraction [35]. It also acts as electrolyte in the body and functions as a cofactor for a number of enzymes. Its deficiency leads to fatigue, muscle cramps and abdominal pains [17]. It was found to be high in the cockroach (242.54±7.0mg/100g) far exceeding the recommended daily requirement of 4.7 g as reported by [36].

Iron and zinc deficiency are wide spread in developing countries, especially in children and women of reproductive age. According to Shaffer [36], iron is a critical component of many metabolic proteins and enzymes. The iron content of the cockroach (274.60±7.4mg/100g) exceeds the recommended daily requirement of men: 8mg/100g, women: 18mg/100g and pregnant women: 27mg/100g in United States of America as reported by Shaffer [36]. Iron contains the molecules haemoglobin found in red blood cells and myoglobin which carry oxygen in the body of animals to the tissues and also function as cofactor of various enzymes [37,35,17]. Iron deficiency leads to anemia, reduced physical activity and increased maternal morbidity and mortality.

Zinc is the micro mineral functioning as essential component of many enzymes which catalyze activation, cell division and immune system health action [34,36]. Its presence is needed for making protein and genetic material. It also functions in taste perception, wound healing, normal fetal development, sperm production, growth, development and sexual maturation, reproduction and neurological function [35]. It functions in cellular metabolic processes as structural part of cell membrane and transcription factor [36]. Zinc deficiency causes impaired growth and contributes considerably to the high infectious disease burden. From the result, zinc content was (4.74±1.0mg/100g) which can be complementary to infant feeds that could receive a boost with the addition of processed cockroach foods to the diets given that the recommended daily intake is 11 and 8 mg/100g respectively for men and women [35]. This composition also agrees with that reported by Chulu [25] for zinc. Iron, zinc, copper and manganese strengthen the immune system as antioxidant enzyme cofactors. Likewise, magnesium and zinc prevent cardiomyopathy, muscle degeneration, growth retardation, impaired spermatogenesis, immunological dysfunction and bleeding disorders.

Copper is a cofactor of many enzymes involved in energy production, connective tissue formation and iron metabolism [36]. It is a component of oxidizing enzymes which contribute to oxidation-reduction reaction [35]. It was found in reasonable amounts in the cockroach under study (7.54±1.2 mg/100g).

The mineral manganese is present in appreciable amount in the cockroach (12.63±1.6 mg/100g) which is above the stipulated recommended value for men (2.3 mg/100g) and women (1.8mg/100g) as stated by Shaffer [36]. Manganese functions as part of many enzymes which contribute to activate antioxidant activity in the mitochondria and assist enzymes in metabolism, bone development and wound healing [38]. Its deficiency leads to osteoporosis, diabetes and epilepsy [17].

Phosphorus is a minor mineral also found in the cockroach (128.76±5.1 mg/100g) which is in agreement with that stated by Abulude et al. [22]. This is also in congruence of earlier reports by Chulu [25] which gave 84 mg/100g as the requirement for human. It is reportedly essential for healthy bones and teeth. It also maintains acid-base balance, used as cell membrane component and functions as part of the energy molecules Adenosine Triphosphate (ATP) and Adenosine Diphosphate (ADP) which contain phosphate [35,17].

Finally, just like the nutrient composition of other edible insects, the nutritional values for the American cockroach *P. americana* are highly variable which is attributed to the origin of species, different ecotypes and age of cockroach, insect food substrates as well as the measuring methods employed [39,40,27,20,21]. Observations by the following authors [41-44], revealed that species type, environmental condition, geographical location, feeding habits and developmental stages of the insects play important role in the variability of nutrient level of edible insects. According to Feng et al. [45], food safety evaluation of cockroach confirmed it as not poisonous to animals and humans. A cockroach farmer named 'Li Bingcaia' in Yibin, Southwestern Sichuan province of China in his statement, reported "cockroaches are gold, they have high protein content and are highly nutritional' [9].

## 4. CONCLUSION

This study revealed that the American cockroach (*P. americana*) has high nutritional qualities. Proximate nutrient composition indicated that cockroach has high shelf-life and can be preserved in good quality long after preparation. The result of this study confirmed the fact that cockroaches are indeed a good source of basically fat, protein and other micro- and macronutrients which were readily present and should therefore be recommended as both food and feed for humans and animals.

## 5. RECOMMENDATION

The consumption of cockroach following the proper preparation methods should be encouraged regarding its medicinal and nutrient properties both as food for man and feed for animals basically livestock. *Periplaneta americana* provide high quality proteins, fats and supplement (minerals) even when dried. Hence, should be farmed and cultivated with modern techniques in order to increase their commercial value and availability.

## CONSENT

It is not applicable.

## ETHICAL APPROVAL

It is not applicable.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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