

Nutritional composition, fatty acids and amino acids profiles and heavy metal assessment of *Rhynchophorus phoenicis* from three Southern States in Nigeria

Odemwingie Samuel, Abajue Maduamaka Cyriacus*

Department of Animal & Environmental Biology, Faculty of Science, University of Port Harcourt, Nigeria

Corresponding Author: Maduamaka Cyriacus

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Abstract

Rhynchophorus phoenicis (palm grub) is an indigenous edible insect widely consumed across the oil-producing states of the Niger Delta region of Nigeria and is increasingly recognized as a sustainable, protein-rich food resource. This study evaluated the proximate composition, mineral element content, fatty and amino acid profiles, and selected heavy metal levels (lead, mercury, cadmium, and arsenic) of palm grubs sourced from Bayelsa, Delta, and Rivers States. Proximate analysis showed that the grubs are rich in fat (21.6–33.5%) and protein (18.2–27.2%), with moisture content ranging from 22.06 to 25.95%, while carbohydrate was ranged from (12.607% - 16.124%). Mineral analysis revealed appreciable levels of phosphorus, sodium, potassium, and magnesium, with the phosphorus concentration highest in the Delta State samples (0.967 mg/g). Twelve fatty acids were identified, dominated by oleic, palmitic and linoleic acids, while thirteen amino acids were detected, with histidine occurring at the highest relative concentration (22.3–25.7%) across all three states. Heavy metal analysis showed trace levels of lead, cadmium and arsenic in Bayelsa State samples only, while mercury was not detected in any sample; concentrations in Delta and Rivers States were below detection limits for all four metals. These findings confirm that *Rhynchophorus phoenicis* is a nutrient-dense food source with generally low heavy metal contamination, supporting its continued and expanded use as an alternative protein source, while highlighting the need for continued monitoring in areas with a history of petroleum-related activity.

Keywords: *Rhynchophorus phoenicis*, palm grub edible insects, proximate composition, amino acids, fatty acids, heavy metals, Niger Delta

Introduction

Eating of insects by humans as food has attracted growing scientific and policy interest as one of the sustainable strategies for addressing global protein deficits, food insecurity and the environmental burden of conventional livestock production. Edible insects require substantially less land, water and feed per unit of protein produced than cattle, poultry or fish, and selected species convert organic substrates into high-quality protein, fat, and micronutrients with minimal ecological cost [1, 2, 3, 4]. The larva of African palm weevil, *Rhynchophorus phoenicis* (Coleoptera: Curculionidae), commonly referred to as the palm grub, is one of the most harvested and culturally accepted delicacies among the insects consumed in the Niger Delta of Southern Nigeria.

In the Niger Delta region of Nigeria, comprising Bayelsa, Delta and Rivers States among others, palm grubs are traditionally harvested from decaying raffia and oil palm trunks and are consumed roasted, fried or added to soups [5]. Before now, the palm grubs are valued by the indigenous people of the southern Nigeria, especially in the Niger Delta for their taste and delicacy, but today studies have highlighted their nutritional and medicinal properties [6], and represent them as accessible, low-cost source of animal protein for rural and peri-urban households. Previous investigations into insect-based foods have generally reported high crude protein and fat content, a favourable amino acids profile rich, essential amino acids, and appreciable concentrations of macro-micro-minerals, positioning such insects as a viable complement or alternative to conventional meat and fish protein [7, 8, 9].

A concern specific to the Niger Delta, however, is the region's history of crude oil exploration, gas flaring and petroleum-related industrial activity, which have been associated with contamination of soil, water and vegetation by heavy metals [10, 11] such as lead, cadmium, mercury and arsenic. Because *Rhynchophorus phoenicis* grubs develop within decaying palm trunks and feed on plant tissue that may bioaccumulate environmental contaminants, there is a legitimate food-safety concern that palm grubs harvested from this region could serve as a route of human exposure to toxic metals [12, 13, 14]. Robust data that simultaneously characterize both the nutritional value and the heavy metal burden of palm grubs across different states of the Niger Delta remain limited.

This study was therefore designed to determine the proximate composition, mineral element content, fatty acids and amino acid profiles of *Rhynchophorus phoenicis* grubs sourced from Bayelsa, Delta, and Rivers States. The study will further evaluate the concentrations of four priority heavy metals: lead (Pb), mercury (Hg), cadmium (Cd) and arsenic (As) in the palm grub samples. The findings are intended to provide an evidence base for assessing both the nutritional benefits and the food-safety implications of palm Grubs consumption in the Niger Delta.

Materials and Methods

Sample Collection and Preparation

Live *Rhynchophorus phoenicis* grubs were purchased from local markets in Bayelsa, Delta, and Rivers States, Nigeria, representative of the primary areas of local harvest and consumption in each state. Samples were transported to the

laboratory in aerated containers, washed with distilled water to remove surface debris, oven-dried to constant weight, and milled into a fine powder using a laboratory blender. The powdered samples (2g) were stored in airtight, labelled containers at room temperature away from direct sunlight until analysis.

Proximate Analysis

Moisture, ash, crude fibre, and crude protein contents were determined according to standard Association of Official Analytical Chemists (AOAC) procedures. Moisture content was determined by oven-drying to constant weight at 105 °C; ash content by incineration in a muffle furnace at 550 °C; crude fibre by sequential acid and alkali digestion; and crude protein by the micro-Kjeldahl method (with a nitrogen-to-protein conversion factor of 6.25). Crude fat was extracted using the Soxhlet method with n-hexane as solvent, and total carbohydrate content was calculated by difference (100 minus the sum of moisture, ash, crude fibre, crude protein, and crude fat).

Mineral Element Analysis

Samples were digested using a wet-ashing procedure with a mixture of concentrated nitric, sulphuric and perchloric acids. Sodium and potassium were determined by flame photometry, while calcium, magnesium, manganese, zinc, copper, phosphorus and iron were determined using atomic absorption spectrophotometry (AAS), with phosphorus quantified colorimetrically by the vanadomolybdate method. Results are expressed in milligrams per gram (mg/g) of dry sample.

Fatty Acid Profile

Crude fat extracted from each sample was converted to fatty acid methyl esters (FAMES) by acid-catalysed transesterification. The FAME derivatives were analysed by gas chromatography with flame ionisation detection (GC-FID), and individual fatty acids were identified by comparison of retention times with authentic standards. Results are reported as concentration (µg/mL) and as a percentage of total fatty acids identified.

Amino Acid Profile

Amino acid composition was determined following acid hydrolysis of defatted samples with 6 M hydrochloric acid at 110 °C for 24 hours under nitrogen. The hydrolysates were analysed using an automated amino acid analyser, and individual amino acids were quantified by comparison with certified reference standards and expressed as a percentage concentration.

Heavy Metal Analysis

Lead, cadmium and arsenic concentrations were determined by atomic absorption spectrophotometry following wet-acid digestion of the dried samples, while mercury was determined by cold-vapour atomic absorption spectrophotometry (CV-AAS). All reagents used were of analytical grade, and instrument calibration was verified using certified reference standards before sample analysis.

Results are expressed in milligrams per gram (mg/g) of dry sample.

Summary of the Procedures for Nutritional Composition

Moisture Content

$$= \frac{W_1 - W_2}{W_3 \text{ weight of sample}} \times 100$$

Where W_1 = weight of petri-dish and sample before drying, W_2 = weight of petri-dish and sample after drying, W_3 = weight of sample.

Ash content

$$\% \text{ Ash content} = \frac{W_3 - W_1}{W_2 - W_1} \times \frac{100}{1}$$

Where W_1 = weight of empty platinum crucible, W_2 = weight of platinum crucible and sample before burning, W_3 = weight of platinum and ash.

Crude Fiber

$$\% \text{ crude fiber} = \frac{\text{Weight of fiber}}{\text{Weight of sample}} \times 100$$

Crude Proteins

Calculations

$$\% \text{ Nitrogen} = \text{Titer value} \times 0.01 \times 14 \times 4$$

$$\% \text{ Protein} = \% \text{ Nitrogen} \times 6.25$$

Carbohydrate Determination

(Differential method)

$$100 - (\% \text{ Protein} + \% \text{ Moisture} + \% \text{ Ash} + \% \text{ Fat} + \% \text{ Fiber})$$

Statistical Analysis

Data in this study are presented as raw values for each state. Comparisons across the three states were descriptive based on numerically obtained data, and transformed into bar charts to identify patterns of similarity and variation in nutrient profiles and heavy metal composition.

Results

Proximate Composition

The proximate composition of palm grubs from the three states is presented in Figure 1 with moisture content been the highest in sample from Bayelsa State (25.95%) and lowest in Delta State sample (22.06%). Crude protein content was markedly higher in the samples from Delta (27.2%) and Rivers (26.6%) State than in Bayelsa State sample (18.2%). In contrast, a reverse pattern was observed for fat and oil content, which was highest in in the sample from Bayelsa State (33.5%) than the ones from Delta State (21.9%) and Rivers State (21.6%). Ash content ranged from 2.492% to 3.392%; crude fibre ranged from 7.18% to 9.54%. Similarly, carbohydrate content was highest in the sample from Bayelsa sample (16.124%), while Delta (12.907%) and Rivers (12.607%) State samples were comparably lower.

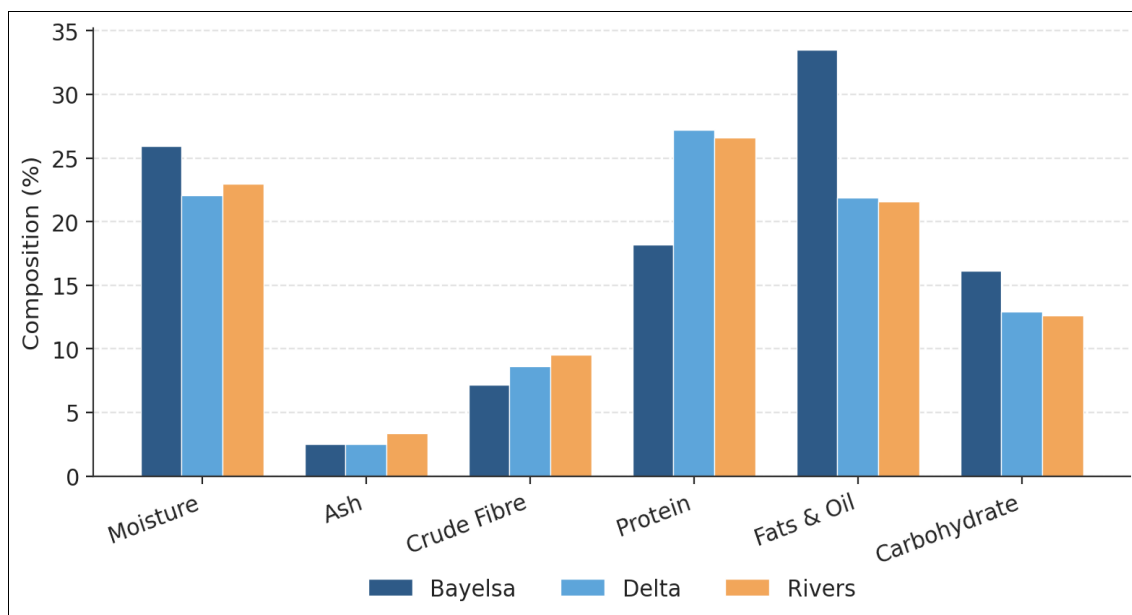


Fig 1: Proximate composition of palm grubs from Bayelsa, Delta and Rivers States, Nigeria

Mineral Element Composition

The content of mineral element from the palm grubs is shown in Figure 2 with phosphorus been the most abundant mineral in all three states, with the highest concentration recorded in the sample from Delta State (0.967 mg/g), followed by Rivers (0.945 mg/g) and Bayelsa (0.537 mg/g) States. Sodium, potassium and magnesium were present at broadly

similar concentrations across the three states, while calcium and manganese concentrations were highest in the sample from Bayelsa State. Copper concentration was markedly higher in the samples from Delta (0.219 mg/g) and Rivers (0.222 mg/g) States than in the sample from Bayelsa State (0.031 mg/g). Iron was present at the lowest concentration of all minerals analyzed, ranging from 0.004 to 0.007 mg/g.

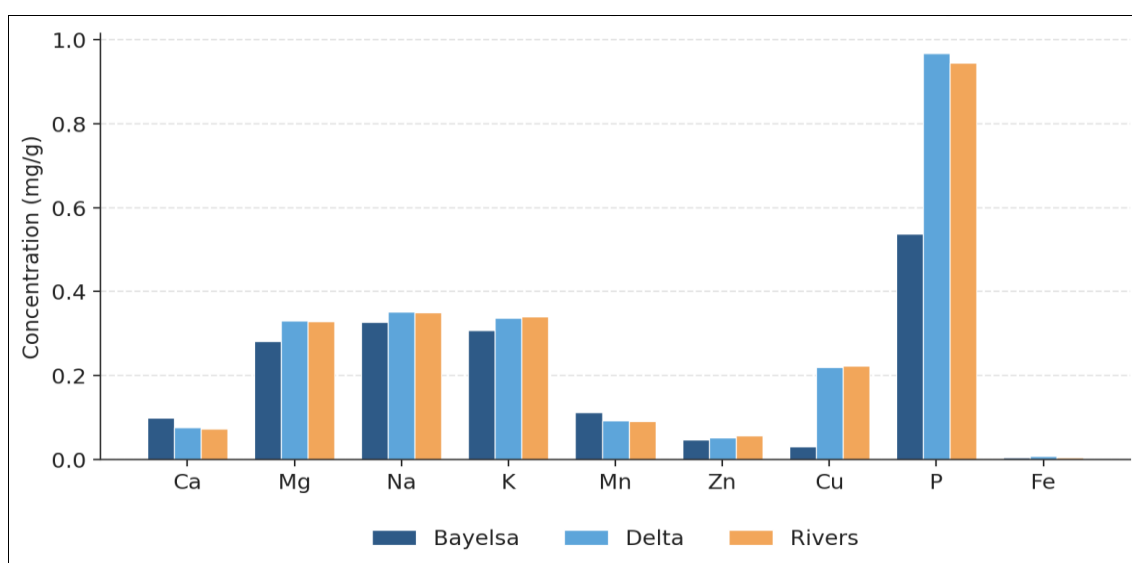


Fig 2: Mineral element composition of palm grubs from Bayelsa, Delta and Rivers States, Nigeria

Fatty Acid Profiles

Twelve fatty acids were identified across the three states (Figure 3). In Bayelsa State samples, oleic acid was the predominant fatty acid (20.85% of total fatty acids), followed by lignoceric acid (14.32%) and linoleic acid (9.21%); docosahexaenoic acid (8.71%) and lauric acid (6.69%) were detected only in sample from Bayelsa State, and were not present in the samples from Delta or Rivers State. In contrast, samples from Delta and Rivers States showed broadly similar profiles

dominated by palmitic acid (15.51% and 15.28%, respectively), alpha-linolenic acid (16.57% and 16.97%) and linoleic acid (12.98% and 13.80%); arachidonic acid (11.18% and 11.29%) and erucic acid (4.13% and 4.06%) were detected only in the samples from Delta and Rivers State, and were absent from Bayelsa State samples. Total fatty acid content was highest in the sample from Bayelsa State (148.27 µg/mL) compared with that of Delta (99.54 µg/mL) and Rivers (97.32 µg/mL) State.

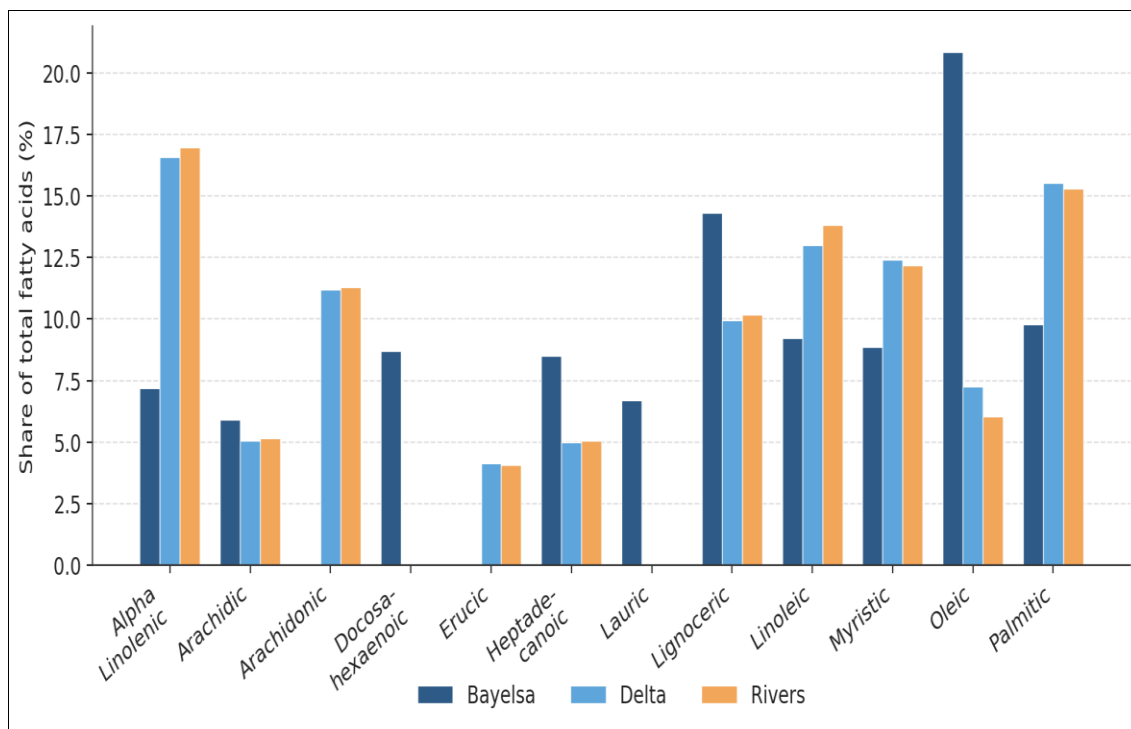


Fig 3: Fatty acid profile of palm grubs from Bayelsa, Delta and Rivers States, Nigeria

Amino Acid Profiles

Thirteen amino acids were identified across the three states (Figure 4). Histidine was the most abundant amino acid in all three states, ranging from 22.3% in Bayelsa State samples to 25.7% in Delta State samples. Isoleucine, leucine, lysine and valine were present at higher relative concentrations in Delta and Rivers State samples than in

Bayelsa State samples, while methionine and threonine were more concentrated in Bayelsa State samples. Notably, glycine (15.491%), glutamate (7.768%), aspartate (1.112%) and tryptophan (5.614%) were detected exclusively in Bayelsa State samples, whereas alanine (10.942% and 10.872%) and cysteine (5.319% and 5.229%) were detected only in Delta and Rivers State samples.

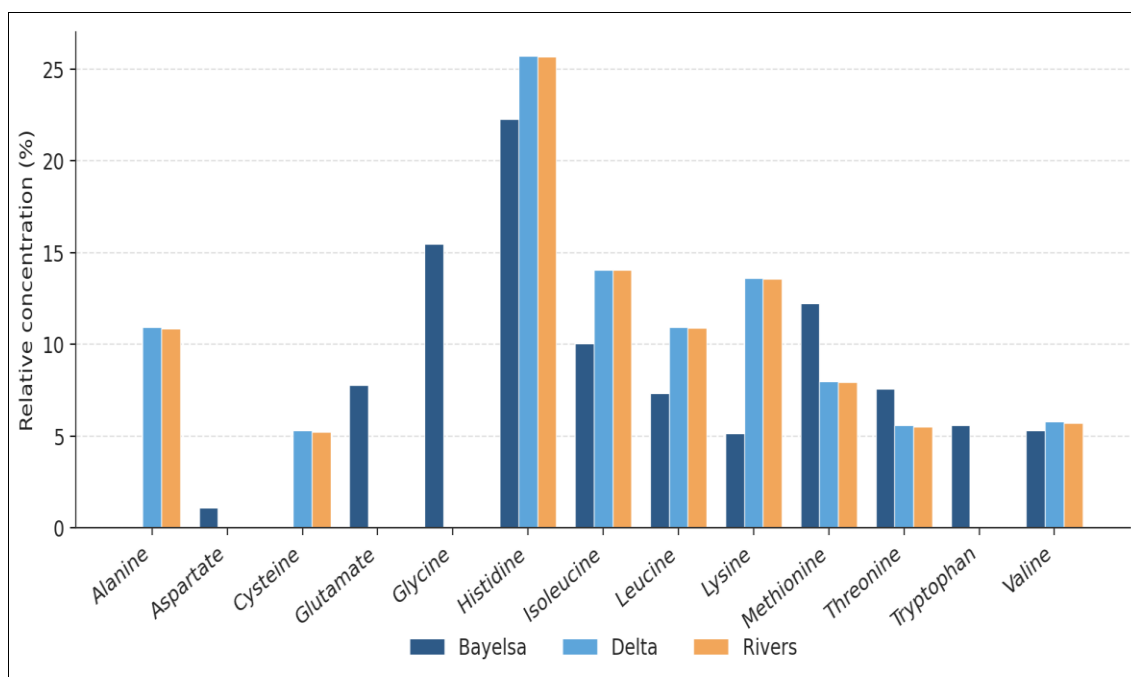


Fig 4: Amino acid profile of palm grubs from Bayelsa, Delta and Rivers States, Nigeria

Heavy Metal Content

The concentrations of selected heavy metals in palm grubs from the three states are presented in Figure 5. Lead (0.00068 mg/g), cadmium (0.00049 mg/g) and arsenic (0.00017 mg/g)

were detected only in samples from Bayelsa State; all four metals, including mercury, were below the limit of detection in Delta and Rivers State samples. Mercury was not detected in samples from any of the three states.

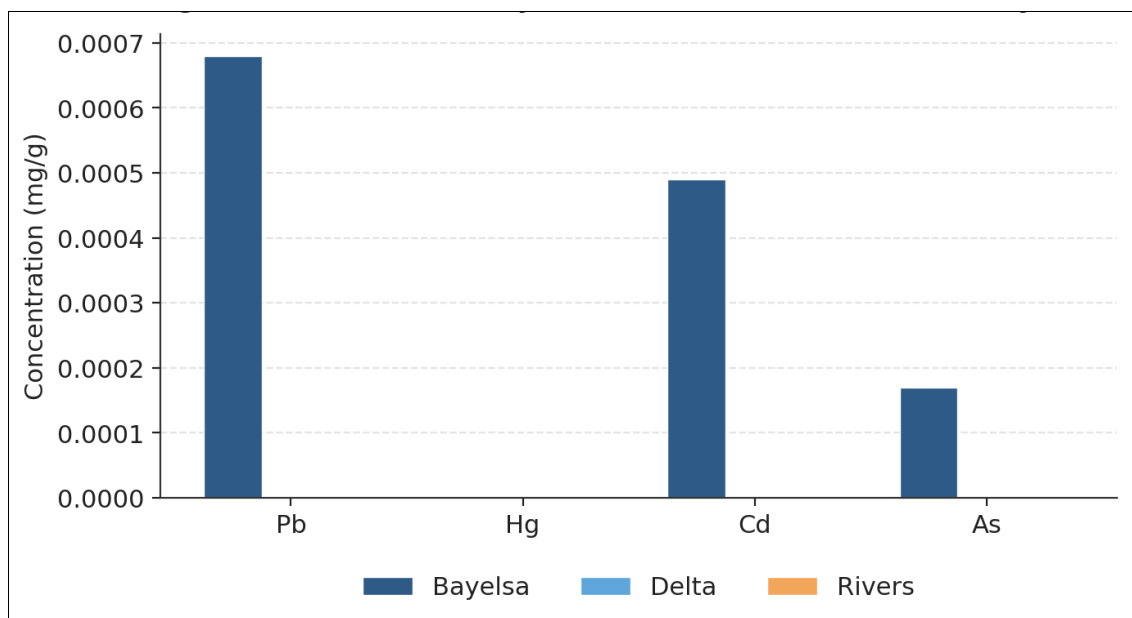


Fig 5: Selected heavy metal content of palm grubs from Bayelsa, Delta and Rivers States, Nigeria

Discussion

According to Gautam *et al.* ^[15], edible insects are generally enriched essential nutrients, emit low greenhouse gases, negligibly affect land use, and convert feed efficiently. Thus, insects can mitigate food and feed security, particularly now that traditional animal-based protein is a luxury. In this study, the proximate composition results confirm that *Rhynchophorus phoenicis* (grubs) is one of the edible insects that is a rich source of both protein and fat, consistent with the general recognition of edible insects as nutrient-dense, energy-rich foods that compete favourably with conventional animal protein sources such as beef, poultry and fish. The relatively high fat content observed in the samples across the states, underscores the potential of palm grubs as a concentrated dietary energy source. Also, the substantial protein content recorded in the grubs supports their value as a complementary or alternative protein source, especially in communities where access to conventional meat and fish is limited by cost or availability. These results are in line with previous studies by Omotoso and Adedire ^[16], and Okunowo *et al.* ^[17] who respectively reported similar but varied values of protein and fat in palm grubs (*R. phoenicis*). The inverse relationship observed between fat and protein contents in the previous studies, and across the three states may reflect differences in the methodological techniques, substrate on which the grubs fed, larval maturity at harvest, and environmental factors affecting the host palm trees. The variation in this study therefore, warrants further investigation anchored on statistical inference rather than descriptive intuition.

The mineral analysis indicates that palm grubs are a useful dietary source of phosphorus, potassium, sodium, and magnesium, all of which play essential roles in bone health, electrolyte balance, and enzymatic and metabolic processes. These mineral elements reported herein except iron, agree with the report of Elemo *et al.* ^[18]. The comparatively low iron content across all three states suggests that palm grubs alone may not meet the full iron requirements of vulnerable groups such as children and pregnant women, and should be considered as a complement to, rather than a replacement for, iron-rich foods in the diet. This is however

contradictory to the report of Elemo *et al.*, where the value of iron content was higher with emphasis that the quantity was enough to meet up with the minimum dietary requirement estimated for daily consumption.

The fatty acid profile revealed a predominance of oleic, palmitic, linoleic and alpha-linolenic acids, reflecting a mixture of monounsaturated, saturated and polyunsaturated fatty acids broadly comparable to profiles reported for other edible insect species and for palm-derived oils. The presence of linoleic and alpha-linolenic acids, both essential polyunsaturated fatty acids that the human body cannot synthesize, further supports the nutritional value of palm grubs. The presence of palmitic acid in the palm grubs as found in palm oil emphasizes its biological and nutrient values in line with the reports of Mancini *et al.* ^[19]. These fatty acids may as well be useful in pharmaceutical and food processing industries in consonance with the projection of oils from crickets by Murugu *et al.* ^[20]. The state-specific occurrence of certain fatty acids, such as docosahexaenoic acid and lauric acid in Bayelsa State samples alone, and arachidonic and erucic acids in Delta and Rivers State samples alone, may reflect differences in the composition of decaying palm substrates or other environmental and dietary factors specific to each location. For safety and quality control, commercialization of palm grubs is steadily dominating in Asian countries especially in Thailand, and their nutritional values more stable reliable due to control environment ^[21]

The amino acid profile confirms that palm grubs contain a range of essential and non-essential amino acids, with histidine, isoleucine, leucine, lysine and valine present in appreciable amounts across all three states. According to Adobeze and Enemor ^[22], these amino acids are peculiar to palm grubs irrespective of their geographical depiction, and are laden with carbohydrate. The sustainability of insect proteins has been advocated for by Akande *et al.* ^[23] against conventional proteins to quench some gaps in food needs of some people. Thus, the amino acid profile compares favourably with recommended dietary patterns for essential amino acid intake and reinforces the potential of palm grubs to contribute meaningfully to protein quality in diets where

access to diverse protein sources is limited. A projection, which is an inferential belief in relation to the report of Olaleye ^[24], and Anankware *et al.* ^[25] that profiled essential nutrients of five eatable insect species in Southwestern Nigeria and West Africa respectively. As with the fatty acid data, some amino acids were detected only in specific states, which may again reflect differences in larval diet, environmental conditions, or analytical detection limits across sample batches, and future studies with larger sample sizes would help clarify whether these patterns are consistent and biologically meaningful.

The heavy metal results are reassuring from a food-safety perspective. Although the Niger Delta region has a well-documented history of petroleum exploration and gas flaring, which has been linked in other studies to elevate heavy metal levels in soil, water and some food crops, the concentrations of lead, cadmium and arsenic detected in this study, where present, were extremely low, and mercury was not detected in any sample. The detection of trace levels of lead, cadmium and arsenic exclusively in Bayelsa State samples may reflect localized environmental factors, such as proximity to specific oil and gas installations or differences in soil composition, and highlights the value of continued, geographically resolved monitoring rather than treating the Niger Delta as a homogenous zone of contamination risk. Even where detected, the recorded concentrations were well below levels typically associated with acute or chronic toxicity risk, suggesting that palm grub consumption, at least based on this dataset, does not represent an immediate heavy metal exposure concern. This contradicts the reports of Abalist and Ukoroije ^[26] who reported that reported that lead and cadmium exceeded the permissible limits of WHO and FAO. Though both *Oryctes owariensis* in their study against *Rhynchophorus phoenicis* in this study generally feed on decaying raphia and palm trees, the samples in this study were sourced from a local market with claims that they were domesticated against theirs that were collected from gas flaring communities. Interestingly, only samples from Bayelsa State showed traces of heavy metals in support of Thomas *et al.* ^[27] with the report that cadmium and manganese concentrations in the palm grubs (*Rhynchophorus phoenicis*) in Bayelsa State, Nigeria were slightly above permissible limit.

Taken together, these findings support the continued promotion of *Rhynchophorus phoenicis* as a nutritionally valuable and comparatively safe food resource within the Niger Delta and beyond. Nonetheless, the state-to-state variation observed in both nutrient and trace metal profiles emphasize that nutritional and safety claims about palm grubs should not be generalised across the entire region without location-specific data, and periodic re-assessment is warranted given the dynamic nature of environmental contamination in oil-producing areas.

Conclusion

This study demonstrates that *Rhynchophorus phoenicis* (grubs) from Bayelsa, Delta and Rivers States are rich in protein, fat and essential minerals, and contain a diverse and nutritionally favourable profile of fatty acids and amino acids, including several essential amino acids and polyunsaturated fatty acids. Selected heavy metals were detected only at trace levels, and only in samples from Bayelsa State, while mercury was undetected across all locations, indicating a generally low heavy metal burden in

the samples analysed. These findings support the value of palm grubs as a sustainable, nutrient-dense and comparatively safe source of dietary protein and micronutrients for communities in the Niger Delta, while underscoring the importance of continued, location-specific monitoring of heavy metal contamination in edible insects harvested from oil-producing regions.

Limitations of the study

The data recorded in this study were not statistically evaluated due to financial constraints; hence, the data were descriptively presented as single numerical values for each parameter without replications. It thus underscores the need for reinvestigation to assess the reliability of the differences in the results.

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