Proximate and Mineral Composition of Powdered Akamu Fortified With Edible Palm Weevil (*RHYCHOPHORUS PHOENICIS*)

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DOI: https://dx.doi.org/10.51244/IJRSI.2026.1303000047

Received: 09 March 2026; Accepted: 14 March 2026; Published: 28 March 2026

ABSTRACT

Complementary foods are foods other than breast milk or infant formula introduced to infants to supply additional nutrients required for proper growth and development. In many developing countries, traditional complementary foods are mainly cereal-based and are often characterized by low protein quality, low energy density and high bulk. These limitations contribute to protein-energy malnutrition among infants and young children during the complementary feeding period. This study evaluated the nutritional quality of complementary food formulated from powdered akamu (fermented maize flour) fortified with *Rhynchophorus phoenicis* (edible palm weevil larvae) powder. Yellow maize grains were processed into powdered akamu through cleaning, steeping, fermentation, wet milling, sedimentation, drying and sieving. Fresh larvae of *Rhynchophorus phoenicis* were washed, fried, defatted, oven-dried, milled and stored as powder. Complementary food blends were formulated at different substitution levels of powdered akamu and *R. phoenicis* powder: 100:0, 95:5, 90:10, 85:15 and 80:20. Proximate and mineral compositions of the formulated samples were determined using standard AOAC methods, while data obtained were analyzed using analysis of variance (ANOVA). Results showed that moisture content ranged from 5.84% to 6.78%, protein from 8.99% to 19.68%, fat from 5.21% to 14.45%, crude fibre from 1.85% to 2.93%, ash from 0.80% to 3.28% and carbohydrate from 53.82% to 76.38%. Mineral composition revealed calcium (87.66–101.00 mg/100 g), sodium (54.11–59.00 mg/100 g), potassium (40.02–54.28 mg/100 g) and iron (30.68–40.08 mg/100 g). Protein, fat, fibre, ash, and mineral contents increased significantly ($p < 0.05$) with increasing levels of *R. phoenicis* powder, while moisture and carbohydrate contents decreased. The fortified samples therefore showed improved nutritional quality compared with the control sample. The study concluded that fortification of powdered akamu with *Rhynchophorus phoenicis* powder significantly enhances the nutritional value of complementary foods. The incorporation of edible insects into complementary food formulations could serve as a sustainable and affordable strategy to combat protein and micronutrient malnutrition among infants in developing countries.

Keywords: powdered akamu, Edible palm weevil, Proximate composition, Mineral composition, Complementary foods.

INTRODUCTION

Complementary foods refer to foods other than breast milk or infant formula that are introduced to infants in liquid, semi-solid or solid forms to provide additional nutrients required for growth and development. In many developing countries, traditional complementary foods are often nutritionally inadequate. These foods are typically cereal-based and are characterized by low protein content, low energy density, and high bulk. Cereals such as maize and guinea corn, which are commonly used in the preparation of complementary foods, contain proteins of relatively poor quality because they are deficient in essential amino acids such as lysine and tryptophan that are crucial for the proper growth of infants and young children. Consequently, commonly consumed cereal gruels such as maize pap (akamu or koko) have been associated with the development of protein–energy malnutrition among infants during the complementary feeding period due to their low protein content and poor amino acid profile (Onabanjo et al., 2016). In recent years, insects have attracted considerable attention as alternative and sustainable food sources capable of addressing both nutritional deficiencies and environmental challenges associated with conventional livestock production. Edible insects are recognized as valuable sources of high-quality protein, essential fatty acids, vitamins and minerals. In addition, insect production has ecological advantages such as high feed conversion efficiency, minimal land and water requirements, and lower greenhouse gas emissions compared with traditional animal farming (Belluco et al., 2013). In many African communities, insects are widely consumed and are often processed into palatable products that enhance the flavor of soups and stews while contributing significant protein to diets that are otherwise nutritionally deficient (van Huis et al., 2013). Increasing interest in edible insects as sustainable dietary options is therefore justified because many species possess substantial nutritional, economic and ecological value.

The practice of entomophagy, which refers to the consumption of insects by humans, has existed since early human civilization. Insects have long played an important role in human nutrition across regions such as Africa, Asia and Latin America, where hundreds of edible species are still consumed today (van Huis et al., 2016; Payne et al., 2016). In Nigeria, several insect orders are commonly consumed and highly valued as food sources. These include Coleoptera, Hymenoptera, Isoptera, Lepidoptera, Odonata and Orthoptera, which contribute significantly to the traditional diets of many communities (Kinyuru et al., 2018). Examples of edible insects in Nigeria include the palm weevil larva (*Rhynchophorus phoenicis*), termites (*Macrotermes nigeriense*), the larva *Cirina forda*, and the variegated grasshopper (*Zonocerus variegatus*) (Payne et al., 2016). Among these species, the larvae of *Rhynchophorus phoenicis* are particularly valued due to their high lipid and protein content, making them an important dietary resource.

The larva of *Rhynchophorus phoenicis*, a beetle belonging to the family Curculionidae, is widely consumed as a traditional delicacy in several tropical regions, particularly in West and Central Africa, where it is valued for its nutritional benefits and role in local diets, especially in communities with limited access to conventional animal proteins (Egonyu et al., 2024). Although species of *Rhynchophorus* are recognized as agricultural pests of palm trees, including coconut, oil and date palms as well as sugarcane, their larvae are highly nutritious and have considerable potential for use in food formulations and complementary diets (Egonyu et al., 2024). Palm weevil larvae are rich in protein and represent an affordable and sustainable source of nutrients. When defatted, they can contain over 70–80% high-quality protein with a favorable essential amino acid profile suitable for human nutrition (Egonyu et al., 2024; Payne et al., 2016). This nutritional composition makes palm weevil larvae suitable for incorporation into various food products to enhance protein content and overall nutritional quality, particularly in complementary and fortified foods (Payne et al., 2016).

Therefore, this study aimed to determine the proximate and mineral composition of powdered akamu fortified with edible palm weevil (*Rhynchophorus phoenicis*). Specifically, the study sought to:

1. Determine the proximate composition (moisture, ash, crude protein, crude fat, crude fibre and carbohydrate) of powdered akamu fortified with edible palm weevil.
2. Evaluate the mineral composition of the fortified akamu samples.
3. Compare the nutritional composition of fortified akamu with that of the unfortified (control) akamu sample.

MATERIALS AND METHODS

Materials

Yellow maize (*Zea mays*) was purchased from Eke-Ukwu Market, Owerri, Imo State, Nigeria, while fresh larvae of *Rhynchophorus phoenicis* were obtained from Akukwu Market in Idemili South Local Government Area, Anambra State, Nigeria. All chemicals and reagents used for the laboratory analyses were of analytical grade and were purchased from chemical supply shops in Lagos State, Nigeria.

Methods

Production of Powdered Akamu

The method described by recent studies on cereal-based complementary foods, with slight modifications, was used in the production of powdered akamu from yellow maize (*Zea mays*) (Onabanjo et al., 2016). The yellow maize grains were sorted and cleaned to remove stones, dirt, and other contaminants. The cleaned grains were steeped in tap water for 48 hours in a large basin and allowed to ferment naturally at room temperature. The steeping water was replaced with fresh water every 24 hours. After fermentation, the steeped grains were drained and wet-milled using a hydraulic mill to obtain a slurry.

The slurry was sieved through a muslin cloth with the addition of excess water to remove the seed coat and other coarse particles. The filtrate was allowed to settle, after which the supernatant water was decanted and the sediment was squeezed to remove excess water. The resulting paste was dried in a hot air oven at 60°C for 12 hours. The dried material was then milled again and sieved to obtain a fine powdered flour, which was stored in airtight plastic containers until further use.

Processing of *Rhynchophorus phoenicis* Larvae into Powder

The method described by St-Hilaire et al. (2012), with slight modification, was used in processing the larvae into powder. The larvae were washed thoroughly with clean water to remove dirt and contaminants. The cleaned larvae were fried to reduce moisture and microbial load. The fried larvae were then pressed to remove excess oil and subsequently dried in a hot air oven at 50°C for 72 hours.

After drying, the larvae were milled using a blender to obtain a fine powder. The powdered larvae were stored in airtight plastic containers prior to use.

Determination of Proximate Composition

The proximate composition of the samples was determined using the standard methods of the Association of Official Analytical Chemists (AOAC, 2016). All analyses were carried out in triplicate.

Moisture Content

Two grams (2 g) of the sample were weighed into previously dried and weighed crucibles with lids. The crucibles were placed in a hot air oven (Astel Hearson, England) and dried at 105°C for 24 hours. After drying, the crucibles were cooled in a desiccator and weighed. The drying process was repeated until a constant weight was obtained.

Moisture content was calculated using the formula:

Moisture (%) =

$(W2 - W3) / (W2 - W1) \times 100$

Where:

W1 = Weight of empty crucible

W2 = Weight of crucible + sample before drying

W3 = Weight of crucible + sample after drying

Ash Content

Ash content was determined according to the AOAC (2016) method. Two grams (2 g) of the sample were weighed into a clean ceramic crucible and incinerated in a muffle furnace at 550°C for 3 hours until a light grey ash was obtained. The crucible was cooled in a desiccator and weighed.

Ash (%) was calculated as:

Ash (%) =

$(W2 – W1) / \text{Weight of sample} \times 100$

Where:

W1 = Weight of empty crucible

W2 = Weight of crucible + ash

Crude Protein

Crude protein content was determined using the Kjeldahl method as described by AOAC (2016). One gram of the sample was digested using concentrated sulfuric acid in the presence of a Kjeldahl catalyst (selenium tablet). The digest was distilled and titrated to determine the nitrogen content.

Crude protein was calculated using the formula:

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

Crude Fibre

Two grams (2 g) of the sample were digested with 0.1 M sulfuric acid under reflux for 30 minutes. The mixture was filtered and the residue washed with hot distilled water until it was free from acid. The residue was then digested with 0.3 M sodium hydroxide for another 30 minutes. The resulting residue was filtered, washed with hot water, 1% hydrochloric acid, and finally ethanol. The residue was transferred into a pre-weighed crucible and dried in an oven at 70°C for 2 hours. After cooling in a desiccator, it was weighed and then incinerated in a muffle furnace at 550°C for 3 hours. The difference in weight was used to calculate crude fibre content.

Crude Fat

Crude fat content was determined using the Soxhlet extraction method. Five grams (5 g) of each sample were wrapped in filter paper and placed in a Soxhlet extraction apparatus. The extraction flask contained 200 ml of petroleum ether as solvent. The solvent was heated, vaporized, and condensed repeatedly, allowing continuous extraction of fat from the sample. After extraction, the defatted sample was dried in an oven at 60°C for 30 minutes, cooled in a desiccator, and weighed.

Fat content was calculated as:

Fat (%) =

$(W2 – W3) / (W2 – W1) \times 100$

Where:

W1 = Weight of empty filter paper

W2 = Weight of filter paper + sample before extraction

W3 = Weight of filter paper + defatted sample

Carbohydrate Content

Carbohydrate content was determined by difference using the AOAC (2016) method:

Carbohydrate (%) =

100 – (Moisture + Protein + Fat + Fibre + Ash)

Determination of Mineral Composition

Mineral elements including calcium, magnesium, sodium, potassium, phosphorus and iron were determined using the standard procedures described by AOAC (2005). The samples were first dry-ashed and the resulting ash was dissolved in acid solution. The mineral contents were then determined using Atomic Absorption Spectrophotometry (AAS) and flame photometry where appropriate. All mineral determinations were carried out in triplicate.

Statistical Analysis

All laboratory analyses were conducted in triplicate, and results were expressed as mean ± standard deviation. Data obtained were subjected to Analysis of Variance (ANOVA) to determine significant differences among sample means. Mean separation was performed using Tukey's multiple comparison test at a 95% confidence level ($p < 0.05$) as described by Iwe (2014). Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) software version 23.0.

RESULTS AND DISCUSSION

Proximate Composition of the Complementary Food Formulations

The proximate composition of the complementary food formulations is presented in Table 2.

The results of the proximate composition analysis showed that the moisture content of the samples ranged from 5.84% to 6.78%, protein content ranged from 8.99% to 19.68%, fat content ranged from 5.21% to 14.45%, crude fibre ranged from 1.84% to 2.93%, ash content ranged from 0.80% to 3.28%, while carbohydrate content ranged from 53.82% to 76.38%. Significant differences ($p < 0.05$) were observed among the samples.

The results showed that protein, fat, ash and fibre contents increased significantly ($p < 0.05$) with increasing substitution of powdered akamu with *Rhynchophorus phoenicis* powder. In contrast, moisture and carbohydrate contents decreased as the proportion of R. phoenicis powder increased in the formulations.

The moisture content decreased from 6.78% to 5.84% with increasing levels of insect powder inclusion. This relatively low moisture content is desirable because it improves the shelf stability of dried food products. Foods with lower moisture content are less susceptible to microbial spoilage and have longer storage life. Similar findings have been reported in recent studies on insect-fortified foods, where moisture levels below 10% were considered suitable for extended shelf stability (Kinyuru et al., 2015).

The significant increase in crude protein content observed in the fortified samples could be attributed to the high protein content of edible palm weevil larvae. The protein content increased from 8.99% in the control sample to 19.68% in the sample containing 20% R. phoenicis powder. This finding agrees with previous studies that reported edible insects as excellent sources of high-quality protein capable of improving the nutritional value of cereal-based foods (van Huis, 2016; Payne et al., 2016). Similar improvements in protein content have also been reported in complementary foods fortified with edible insects such as termites and crickets (Kinyuru et al., 2015).

Edible palm weevil larvae have been reported to contain high levels of protein, ranging from 28.42% to over 60% depending on processing methods (Ekpo et al., 2010). Their incorporation into cereal-based foods therefore significantly enhances protein quality and quantity. This is particularly important in developing countries where protein-energy malnutrition remains prevalent among infants and young children.

Proteins are essential for tissue growth, repair, and overall body development, especially during infancy and childhood. Adequate protein intake is therefore crucial during the complementary feeding period. The improved protein content of the fortified formulations suggests that the product could contribute significantly to meeting the protein requirements of infants.

The fat content increased from 5.21% to 14.45% as the level of R. phoenicis powder increased in the formulations. This increase could be attributed to the naturally high lipid content of palm weevil larvae. Previous studies have reported lipid contents of up to 50% in palm weevil larvae (Opara et al., 2012). Similar increases in fat content have been reported in insect-fortified foods due to the high lipid composition of edible insects (Mlcek et al., 2014; Payne et al., 2016).

Dietary lipids are important because they contribute to energy supply, palatability and the absorption of fat-soluble vitamins. In addition, edible insects contain beneficial fatty acids including polyunsaturated fatty acids (PUFAs) such as omega-3 fatty acids, which are essential for human health (Mlcek et al., 2014).

The crude fibre content increased from 1.85% to 2.93% as the proportion of palm weevil powder increased in the formulations. Although crude fibre does not contribute significantly to energy supply, it plays an important role in digestive health by promoting bowel movement and preventing gastrointestinal disorders. Similar increases in fibre content have been reported in cereal-based foods fortified with edible insects (Adepoju & Ajayi, 2019).

The ash content increased from 0.80% to 3.28% with increasing levels of palm weevil powder inclusion. Ash content is an indicator of the total mineral content of food. The increase in ash content therefore suggests an improvement in the mineral composition of the complementary food formulations. Similar findings have been reported in studies involving insect-fortified foods (Kinyuru et al., 2015; Payne et al., 2016).

Conversely, carbohydrate content decreased from 76.38% to 53.82% as the proportion of R. phoenicis powder increased. This decrease is expected because carbohydrate-rich maize flour was partially replaced with protein and fat-rich insect powder. Similar reductions in carbohydrate content have been reported in other studies involving insect-based food fortification (Adepoju & Ajayi, 2019).

Overall, the observed increases in protein, fat, fibre, and ash contents suggest that fortification of powdered akamu with palm weevil larvae significantly improves the nutritional quality of the complementary food.

Mineral Composition of the Complementary Food Formulations

The mineral composition of the complementary food formulations is presented in Table 3.

The results showed that calcium content ranged from 87.66 to 101.00 mg/100 g, sodium ranged from 54.11 to 59.00 mg/100 g, potassium ranged from 40.02 to 54.28 mg/100 g, and iron ranged from 30.68 to 40.08 mg/100 g. Significant differences ($p < 0.05$) were observed among the samples except between samples A and B.

The results further revealed that the calcium, sodium, potassium, and iron contents increased significantly ($p < 0.05$) with increasing substitution of powdered akamu with *Rhynchophorus phoenicis* powder. This increase may be attributed to the naturally high mineral content of edible palm weevil larvae.

Previous studies have reported that palm weevil larvae contain significant amounts of essential minerals such as calcium, magnesium, phosphorus, iron, and zinc (Ekpo et al., 2010; Payne et al., 2016). Minerals are vital nutrients required for many physiological processes including bone formation, oxygen transport, enzyme activity, fluid balance, and nerve function.

Iron is particularly important for hemoglobin formation and prevention of iron-deficiency anemia, which is common among infants and young children in developing countries. The increased iron content observed in the fortified samples therefore suggests that the product could help improve the micronutrient intake of children.

Similarly, calcium is essential for bone and teeth development, while potassium and sodium are important for fluid balance, nerve transmission, and muscle function. The increase in these minerals in the fortified formulations indicates that the addition of palm weevil powder improves the micronutrient density of the complementary food.

CONCLUSION

Edible insects can however be incorporated into different food formulations that will be palatable as well as nutritious to consumers especially those that find it difficult to consume edible insects in their forms. More studies can also be carried out on how best to incorporate these edible insects into different food products to create varieties so that their use as sustainable diets will be encouraged since they are nutritionally, economically and ecologically important.

The results of proximate and mineral composition analyses of the samples showed that complementary food samples produced from powdered akamu and *Rhychophorus phoenicis* powder blends were of better nutritional quality than the control sample as well as improved functional properties.

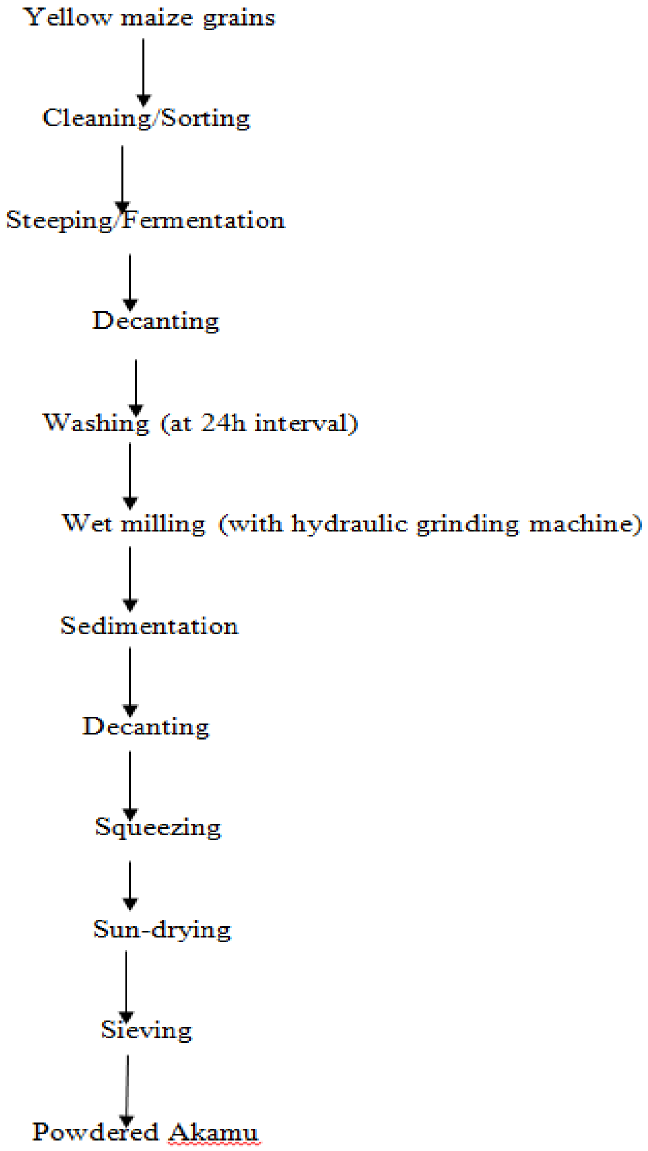

Fig. 1: Flow Diagram for Powdered Akamu Production.

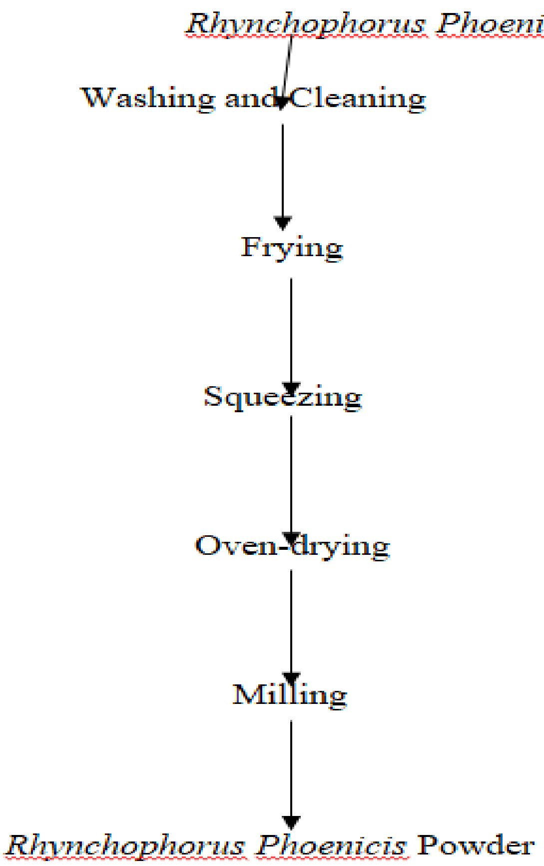

Fig. 2: Flow Diagram for *Rhynchophorus Phoenicis* Powder Production.

Table 1: Formulations for Fermented Maize Flour (Powdered Akamu) and *Rhychophorus phoenicis* Powder Complementary Blend.

Sample	Powdered Akamu	*Rhychophorus phoenicis* Powder
A	100	0
B	95	5
C	90	10
D	85	15
E	80	20

Table 2: Proximate composition of the complementary food formulations.

Sample	Moisture	Protein	Parameters(%)Fat	Fibre	Ash	Carbohydrate
A	6.78 ±0.08^{a}	8.99 ±0.12^{e}	5.21 ±0.04^{e}	1.85 ±0.05^{e}	0.80 ±0.02^{e}	76.38 ±0.08^{a}
B	6.54 ±0.05^{b}	12.11 ±0.01^{d}	8.21 ±0.01^{d}	2.12 ±0.02^{d}	1.08 ±0.02^{d}	69.94 ±0.08^{b}
C	6.33 ±0.04^{b}	15.02 ±0.02^{c}	10.10 ±0.00^{c}	2.43 ±0.04^{c}	1.85 ±0.07^{c}	64.27 ±0.04^{c}
D	6.03 ±0.04^{c}	17.19±0.01^{b}	12.95 ±0.05^{b}	2.68 ±0.05^{b}	2.84 ±0.05^{b}	58.31 ±0.01^{d}

E	5.84 ±0.05^{c}	19.68 ±0.05^{a}	14.45 ±0.03^{a}	2.93 ±0.04^{a}	3.28 ±0.02^{a}	53.82 ±0.02^{e}
LSD	0.20	0.35	0.58	0.18	0.15	1.10

Values are means ± SD. Values on the same column with different superscripts are significantly ($p < 0.05$) different.

Keys

A- 100% Powdered Akamu (Control)

B- 95: 5% (Powdered Akamu - *Rhychophorus phoenicis* Powder)

C- 90: 10% (Powdered Akamu - *Rhychophorus phoenicis* Powder)

D- 85: 15% (Powdered Akamu - *Rhychophorus phoenicis* Powder)

E- 80: 20% (Powdered Akamu - *Rhychophorus phoenicis* Powder)

Table 3: Mineral composition of the complementary food formulations.

Sample	Calcium	Sodium	Parameters(mg/100g) Potassium	Iron
A	87.66 ±0.04^{e}	54.11 ±0.11^{e}	40.02 ±0.10^{e}	30.68 ±0.08^{d}
B	89.18 ±0.06^{d}	55.86 ±0.05^{d}	44.11 ±0.08^{d}	31.22 ±0.04^{d}
C	93.42 ±0.02^{c}	57.04 ±0.06^{c}	47.08 ±0.04^{c}	35.62 ±0.04^{c}
D	97.02 ±0.04^{b}	57.88 ±0.04^{b}	50.00 ±0.02^{b}	38.24 ±0.06^{b}
E	101.00 ±0.10^{a}	59.00 ±0.02^{a}	54.28 ±0.05^{a}	40.08 ±0.05^{a}
LSD	0.58	0.40	0.86	0.64

Values are means ± SD. Values on the same column with different superscripts are significantly ($p < 0.05$) different.

Keys

A- 100% Powdered Akamu (Control)

B- 95: 5% (Powdered Akamu - *Rhychophorus phoenicis* Powder)

C- 90: 10% (Powdered Akamu - *Rhychophorus phoenicis* Powder)

D- 85: 15% (Powdered Akamu - *Rhychophorus phoenicis* Powder)

E- 80: 20% (Powdered Akamu - *Rhychophorus phoenicis* Powder)

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