

Functional properties and sensory evaluation of powdered akamu fortified with edible palm weevil (*RHYCHOPHORUS PHOENICIS*)

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ABSTRACT

This study evaluated the functional properties and sensory acceptability of powdered akamu (fermented maize porridge) fortified with edible palm weevil (*Rhynchophorus phoenicis*) larvae powder as a potential complementary food. Yellow maize and fresh *R. phoenicis* larvae were processed into fine powders and blended at varying ratios (100:0, 95:5, 90:10, 85:15, 80:20) to formulate complementary food samples. Functional properties, including bulk density, oil absorption capacity, swelling index, gelatinization temperature and viscosity, were determined, while sensory evaluation assessed appearance, mouthfeel, aroma, taste and overall acceptability using a 9-point hedonic scale by 25 trained panelists. Results showed that fortification significantly influenced functional properties: bulk density decreased from 0.64 g/ml (control) to 0.40 g/ml (80:20 blend), indicating suitability for nutrient-dense complementary foods; oil absorption capacity increased from 2.35 g/ml to 2.92 g/ml, enhancing flavour retention and mouthfeel; swelling index, gelatinization temperature and viscosity were also significantly affected ($p < 0.05$). Sensory evaluation revealed that higher levels of fortification slightly reduced scores, with overall acceptability ranging from 6.80 (control) to 4.50 (80:20 blend), reflecting familiarity preference for unfortified akamu. The study demonstrates that *R. phoenicis* larvae can be successfully incorporated into powdered akamu to improve protein content and functional properties, offering a sustainable and nutritionally enriched complementary food option, though sensory optimization may be needed for higher fortification levels.

Keywords: powdered akamu, Edible palm weevil, Functional properties, Sensory evaluation, 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 functional and sensory properties of powdered akamu fortified with edible palm weevil (*Rhynchophorus phoenicis*). Specifically, the study sought to:

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, Idemili South Local Government Area, Anambra State, Nigeria. All chemicals and reagents used for laboratory analyses were of analytical grade and sourced from reputable chemical suppliers in Lagos State, Nigeria.

Sample Formulation

Powdered akamu and *Rhynchophorus phoenicis* larvae powder were blended at predetermined substitution levels to produce composite samples. The formulations consisted of 100:0 (control), 95:5, 90:10, 85:15, and 80:20 ratios of akamu flour to larvae powder, respectively. The blends were thoroughly mixed to ensure homogeneity and packaged in airtight containers pending analysis.

Production of Powdered Akamu

Powdered akamu was produced according to the method described by Onabanjo et al. (2016) with slight modifications. Yellow maize grains were manually sorted to remove stones, broken kernels, and other foreign materials, followed by washing with potable water. The cleaned grains were steeped in tap water at room temperature ($28 \pm 2^\circ\text{C}$) for 48 hours to allow natural fermentation. The steeping water was replaced after every 24 hours to minimize undesirable microbial growth.

At the end of fermentation, the grains were drained and wet-milled using a hydraulic milling machine to obtain a slurry. The slurry was sieved through a clean muslin cloth with the addition of excess water to separate the bran and coarse particles. The filtrate was allowed to sediment for 12 hours, after which the supernatant was decanted. The resulting sediment was dewatered by pressing and subsequently dried in a hot-air oven at 60°C for 12 hours. The dried cake was milled into flour and sieved through a 250 µm mesh sieve to obtain a uniform powdered akamu flour. The flour was packaged in airtight plastic containers and stored at ambient conditions until use.

Processing of *Rhynchophorus phoenicis* Larvae into Powder

The larvae were processed into powder following the method of St-Hilaire et al. (2012) with slight modifications. Fresh larvae were sorted and thoroughly washed with potable water to remove adhering dirt and contaminants.

The cleaned larvae were fried at approximately 120–130°C for 10–15 minutes to reduce moisture content and microbial load. Excess oil was removed by pressing the fried larvae using absorbent materials.

The defatted larvae were dried in a hot-air oven at 50°C for 72 hours until a constant weight was achieved. The dried larvae were milled using an electric blender and sieved through a 250 µm mesh sieve to obtain a fine powder. The powder was packaged in airtight containers and stored at room temperature until required for formulation and analysis.

Determination of Functional Properties

All functional property determinations were carried out in triplicate, and mean values were reported.

Swelling Index

The swelling index was determined according to the method of Awuchi et al. (2019). One gram (1 g) of sample was weighed into a 10 mL graduated cylinder, and 5 mL of distilled water was added. The initial volume occupied by the sample was recorded. The mixture was allowed to stand undisturbed for 1 hour at room temperature, after which the final volume was measured.

Swelling Index =

$$\text{Swelling Index} = \frac{\text{Volume after swelling} - \text{Initial volume}}{\text{Initial volume}}$$

Bulk Density

Bulk density was determined using the method of Onwuka (2005). Ten grams (10 g) of sample was transferred into a 50 mL graduated cylinder. The cylinder was gently tapped 10 times from a height of 5 cm to achieve uniform packing. The final volume occupied by the sample was recorded.

Bulk Density (g/mL) =

$$\text{Bulk Density (g/mL)} = \frac{\text{Weight of sample (g)}}{\text{Volume after tapping (mL)}}$$

Oil Absorption Capacity

Oil absorption capacity was determined according to Onwuka (2005). One gram (1 g) of sample was mixed with 10 mL refined corn oil in a centrifuge tube and allowed to stand at room temperature (30 ± 2°C) for 1 hour. The mixture was centrifuged at 1600 × g for 20 minutes. The unabsorbed oil was decanted and measured.

Oil Absorption Capacity (%) =

$$\frac{\text{Oil added} - \text{Free oil}}{\text{Weight of sample}} \times \frac{\text{Density of oil} \times 100}{\text{Weight of sample} \times \text{Density of oil} \times 100}$$

Gelatinization Temperature

Gelatinization temperature was determined using the method of Onwuka (2005) with slight modification. Two grams (2 g) of sample was dispersed in 20 mL distilled water in a 50 mL Pyrex beaker. The suspension was heated on a hot plate while being stirred continuously. A calibrated thermometer was immersed in the suspension, and the temperature at which visible gel formation commenced was recorded as the gelatinization temperature.

Viscosity

Viscosity was determined using a Brookfield Synchro-Electric Viscometer. Twenty grams (20 g) of flour sample was mixed with 200 mL of water to form a slurry. The slurry was heated at 100°C for 15 minutes to achieve complete gelatinization and then cooled to approximately 45°C before measurement. Viscosity readings were obtained at a spindle speed of 60 rpm and expressed in centipoise (cP).

Sensory Evaluation

Sensory evaluation was conducted to assess consumer acceptability of the akamu samples. Twenty-five (25) semi-trained panelists comprising undergraduate and postgraduate students and staff members aged between 18 and 50 years were recruited from the Department of Human Nutrition and Dietetics. Panelists were selected based on their willingness to participate, regular consumption of cereal-based porridges, and absence of known allergies to insect-derived foods.

Akamu porridge was prepared by dispersing 30 g of each flour sample in 15 mL of potable water. The slurry was mixed with boiling water while stirring continuously until gelatinization occurred. Nine grams (9 g) of sugar was added to each sample to standardize sweetness. The samples were served hot in identical disposable cups and coded with three-digit random numbers to eliminate bias.

The evaluation was conducted in a well-lit and ventilated sensory laboratory. Water was provided for mouth rinsing between samples. Panelists evaluated colour/appearance, flavour, consistency, taste, and overall acceptability using a 9-point hedonic scale, where 9 = Like Extremely and 1 = Dislike Extremely, as described by Iwe (2014).

Statistical Analysis

All analyses were conducted in triplicate, and results were expressed as mean ± standard deviation. Data obtained from functional properties and sensory evaluation were subjected to one-way Analysis of Variance (ANOVA) using appropriate statistical software. Differences among treatment means were separated using Tukey's Honestly Significant Difference (HSD) post hoc test at a 95% confidence level ($p < 0.05$). Statistical significance was accepted at $p < 0.05$. This approach enabled the determination of the effects of varying levels of *Rhynchophorus phoenicis* larvae powder incorporation on the functional and sensory characteristics of the akamu samples.

RESULTS AND DISCUSSION

The functional properties of the food formulations are presented in Table 2.

Result obtained from the functional properties analysis of the complementary food formulations showed that bulk density of the samples ranged from 0.40g/ml to 0.64g/ml, oil absorption capacity ranged from 2.35g/ml to

2.92g/ml, swelling index ranged from 1.66g/g to 1.96g/g, gelatinization temperature ranged 72°C and 84°C and viscosity ranged from 1058cp to 1570cp respectively. Samples differed significantly ($p < 0.05$) from each other.

The bulk density of the complementary food samples ranged from 0.40g/ml in Sample E (80: 20% Powdered Akamu - *Rhychophorus phoenicis* Powder) to 0.64 in Sample A (100% Powdered Akamu). Ikya et al. (2013) reported bulk density of 0.76 – 0.83 for properties of fermented maize, and full fat soy flour blends for “agidi” production. The bulk density is generally affected by particle size and the density of flour or flour blend and it is very important in determining the packaging requirement, raw materials handling and application in wet processing in food industry (Ajanaku et al., 2012). It has been reported that bulk density of foods increases with increase in starch content (Bhattacharya and Prakash, 1994). The lower bulk density exhibited by formulated samples could be as a result of the lower starch content.

High bulk density of protein material is also important in relation to its packaging (Onimawo et al., 1998). The low bulk density of the fortified complementary flours samples will be suitable for the formulation of high nutrient density weaning food (Mepba et al., 2007).

The oil absorption capacity of the complementary food samples ranged from 2.35g/ml in Sample A (100% Powdered Akamu) to 2.92g/ml in Sample E (80: 20% Powdered Akamu - *Rhychophorus phoenicis* Powder).

It was observed that the oil absorption capacity of the unfortified sample (control) was significantly ($p < 0.05$) lower than that of the fortified samples (B, C, D and E). This increase may be attributed to the higher protein content contributed by the fortifying ingredient. Heat treatment during processing can cause protein denaturation and dissociation, which exposes hydrophobic groups and non-polar amino acid residues that were previously buried within the protein structure, thereby enhancing the ability of the proteins to bind lipids (Foegeding and Davis, 2011; Mutungi et al., 2019). Oil absorption capacity is largely associated with the interaction between oil molecules and the hydrophobic side chains of proteins as well as the physical entrapment of oil within the protein matrix (Onimawo and Egbekun, 1998). The ability of proteins to retain oil is an important functional property because it improves flavor retention, mouthfeel and texture in food systems (Carvalho et al., 2006). Oil gives soft texture and good flavour to food. Therefore, the absorption of oil by food products improves mouth feel and flavour retention. A high oil absorption capacity is valuable in ground meat formulations, meat replacers and extenders, doughnuts, pancakes and soups (Onimawo and Egbekun, 1998).

The swelling index of the complementary food samples ranged from 1.66g/g in Sample E (80: 20% Powdered Akamu - *Rhychophorus phoenicis* Powder) to 1.96g/ml in Sample A (100% Powdered Akamu). Samples differed significantly ($p < 0.05$) from each other. This result is in line with the result of Abioye et al. (2011) who reported decrease in swelling capacity of soy – plantain flour.

The swelling power of flour granules indicates the degree of molecular interactions and associative forces within the starch granule structure. It reflects the ability of starch to absorb water and swell when heated in excess water. Studies have shown that swelling capacity is closely related to the water absorption index of starch-based flours during thermal processing, as the disruption of intermolecular bonds within starch granules allows water penetration and granule expansion (Zhu, 2018; Hoover, 2019). In the present study, the starch granules in the fortified complementary food samples exhibited relatively weak structural strength, which may have limited their ability to swell and consequently resulted in a lower swelling capacity. Variations in swelling behavior may also be influenced by the presence of proteins, lipids, and other non-starch components that interact with starch granules and restrict their expansion during heating (Adebawale et al., 2020; Shi et al., 2021). The gelatinization temperature of the complementary food samples ranged from 72°C in Samples D (70: 30% Powdered Akamu - *Rhychophorus phoenicis* Powder) and E (80: 20% Powdered Akamu - *Rhychophorus phoenicis* Powder) to 84°C in Sample A (100% Powdered Akamu). Samples differed significantly ($p < 0.05$) from each other.

The viscosity of the complementary food samples ranged from 1058cp in Sample E (80: 20% Powdered Akamu - *Rhychophorus phoenicis* Powder) to 1570cp in Sample A (100% Powdered Akamu). Samples differed significantly ($p < 0.05$) from each other. The difference in viscosities can be due to differences in ratio of amylose to amylopectin for the different flour samples. According to Onimawo and Egbekun (1998), viscosity is defined

as the internal friction acting within a liquid. Protein content and functionality is also associated with viscosity (Kethireddipalli et al., 2002). In this present study, formulations that contain *Rhychophorus phoenicis* powder were found to have the lower viscosity; this means that the protein in cowpeas played a role in the viscosity. The low viscosity in the fortified samples (samples B, C, D and E) could be due to amylose content. This knowledge is beneficial since it lets scientists know the concentration of flour and time needed to cook for various porridges.

Sensory Scores of the Complementary Food Formulations

The results of the sensory (organoleptic) evaluation of the complementary food formulations are presented in Table 3. Sensory evaluation is an important quality assessment method used to determine consumer perception and acceptability of food products based on attributes such as appearance, aroma, taste, mouthfeel and overall acceptability (Lawless & Heymann, 2019).

Appearance describes the visual appeal of a product and reflects the degree of attraction the food presents to the eyes when light is reflected from its surface. It is often the first attribute considered by consumers during food selection and can strongly influence overall acceptability (Ares & Jaeger, 2015). In this study, the appearance of the samples showed mean scores of 7.66, 7.50, 6.80, 5.50 and 4.70 for samples A, B, C, D, and E respectively, indicating that the control sample was more visually preferred by the panelists.

Mouthfeel refers to the tactile sensation and smoothness perceived in the mouth during food consumption. It is influenced by the physical structure, particle size, viscosity and composition of the food product (Chen & Rosenthal, 2015). The mean scores for mouthfeel ranged from 4.30 for sample E to 6.80 for sample A, suggesting that higher levels of fortification may have affected the texture and smoothness of the product.

The aroma scores of the samples ranged from 4.20 to 6.58, with sample A having the highest score (6.58) while sample E recorded the lowest score (4.20). Aroma is an important sensory attribute because it contributes significantly to flavor perception and influences consumers' acceptance of food products (Spence, 2020).

Taste is another critical parameter in evaluating the sensory quality of food products. The taste score of sample A was superior to those of the other samples, recording the highest score of 7.00, while sample E was the least accepted in terms of taste with a score of 4.10. According to recent studies, taste strongly determines the acceptability of complementary foods, since even nutritionally rich products may be rejected by consumers if the taste is not appealing (Joshua et al., 2023).

The overall acceptability scores were 6.80, 6.00, 5.80, 4.85, and 4.50 for samples A, B, C, D, and E respectively. The higher sensory scores observed for the control sample (100% powdered akamu) may be attributed to the familiarity of the panelists with the traditional product compared to the newly developed fortified complementary foods. Consumer familiarity with traditional foods often leads to higher preference ratings due to established sensory expectations (Jaeger et al., 2017).

CONCLUSION

This study demonstrated that fortification of powdered akamu with edible palm weevil (*Rhyncophorus phoenicis*) larvae powder significantly improved its functional properties and enhanced its nutritional potential as a complementary food. The incorporation of larvae powder resulted in reduced bulk density, a desirable characteristic for infant and young child feeding because it allows the preparation of energy- and nutrient-dense foods without excessive viscosity. In addition, the increased oil absorption capacity observed in the fortified samples suggests improved flavour retention, palatability and overall eating quality.

The sensory evaluation indicated that the fortified akamu samples were generally acceptable to the panelists, although acceptability tended to vary with the level of fortification. This finding suggests that palm weevil larvae powder can be incorporated into traditional cereal-based foods without substantially compromising consumer acceptance when used at appropriate levels.

Overall, the study highlights the potential of *Rhynchophorus phoenicis* larvae powder as an affordable, locally available, and sustainable food ingredient for improving the quality of traditional complementary foods. Its utilization could contribute to addressing protein-energy malnutrition and micronutrient deficiencies, particularly among infants and young children in resource-limited settings. Further studies are recommended to investigate the nutritional composition, shelf-life stability, microbial safety and consumer acceptance of the fortified products among broader population groups to support large-scale adoption and commercialization.

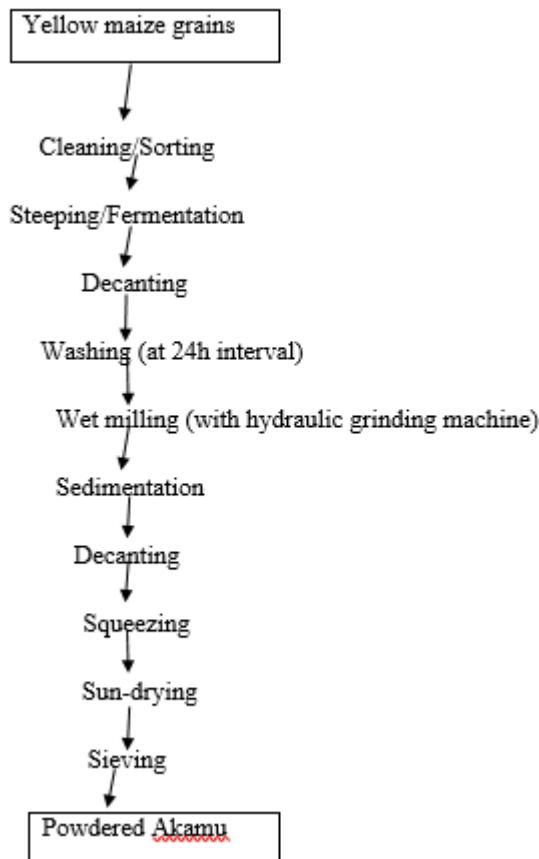


Fig. 1: Flow Diagram for Powdered Akamu Production.

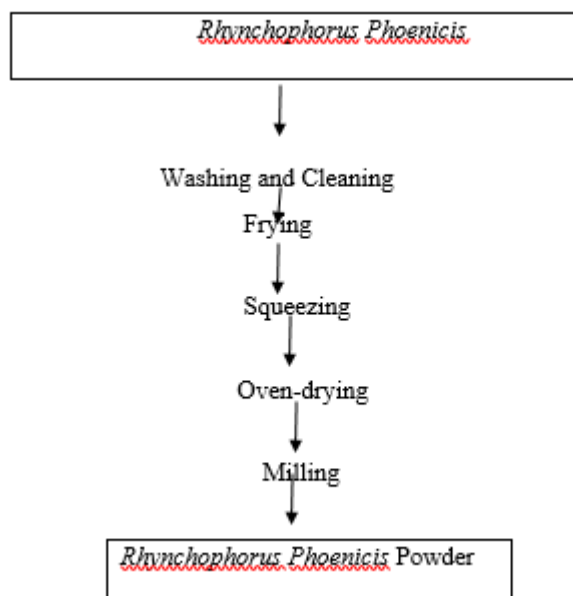


Fig. 2: Flow Diagram for *Rhynchophorus Phoenicis* Powder Production.

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

Sample	Powdered Akamu (%)	<i>Rhynchophorus phoenicis</i> Powder (%)
A	100	0
B	95	5
C	90	10
D	85	15
E	80	20

Table 2: Functional properties of the complementary food formulations.

Sample	Bulk Density (g/ml)	Oil Absorption Capacity (g/ml)	Swelling Index (g/g)	Gelatinization Temperature (°C)	Viscosity (cp)
A	0.64 ± 0.03 ^a	2.35 ± 0.04 ^c	1.96 ± 0.02 ^a	84 ± 0.10 ^a	1570 ± 1.35 ^a
B	0.51 ± 0.01 ^b	2.66 ± 0.02 ^b	1.80 ± 0.02 ^b	83 ± 0.15 ^b	1438 ± 1.02 ^b
C	0.47 ± 0.01 ^{bc}	2.71 ± 0.01 ^b	1.76 ± 0.01 ^{bc}	82 ± 0.12 ^c	1277 ± 2.03 ^c
D	0.41 ± 0.04 ^c	2.88 ± 0.04 ^a	1.70 ± 0.00 ^{bc}	72 ± 0.14 ^d	1134 ± 0.88 ^d
E	0.40 ± 0.02 ^c	2.92 ± 0.02 ^a	1.66 ± 0.03 ^c	72 ± 0.11 ^d	1058 ± 0.90 ^e
LSD	0.10	0.15	0.11	0.85	4.20

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 - *Rhynchophorus phoenicis* Powder)
- C- 90: 10% (Powdered Akamu - *Rhynchophorus phoenicis* Powder)
- D- 85: 15% (Powdered Akamu - *Rhynchophorus phoenicis* Powder)
- E- 80: 20% (Powdered Akamu - *Rhynchophorus phoenicis* Powder)

Table 3: Sensory Scores of the complementary food formulation.

Sample	Appearance	Aroma	Mouthfeel	Taste	General Acceptability
A	7.66 ± 0.08 ^a	6.80 ± 0.14 ^a	6.58 ± 0.17 ^a	7.00 ± 0.14 ^a	6.80 ± 0.14 ^a
B	7.50 ± 0.11 ^a	6.02 ± 0.11 ^b	5.22 ± 0.08 ^b	6.02 ± 0.10 ^b	6.00 ± 0.18 ^b
C	6.80 ± 0.15 ^b	5.80 ± 0.10 ^b	5.00 ± 0.11 ^b	5.50 ± 0.17 ^c	5.80 ± 0.11 ^c

D	5.50 ± 0.08 ^c	4.40 ± 0.08 ^c	4.60 ± 0.10 ^c	4.25 ± 0.08 ^d	4.85 ± 0.08 ^d
E	4.70 ± 0.14 ^d	4.30 ± 0.08 ^c	4.20 ± 0.15 ^d	4.10 ± 0.15 ^d	4.50 ± 0.15 ^c
LSD	0.21	0.35	0.28	0.20	0.30

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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