ISSN: 2338-1345 e ISSN 2808-8948 – Vol. 13 (2) 66-77 https://ojs.bakrie.ac.id/index.php/APJSAFE/about

Asia Pacific Journal of Sustainable Agriculture Food and Energy (APJSAFE)

Proximate, functional, microbia, and sensory qualities of complementary food produced from acha (*Digitaria exillis*), malted pigeon pea (*Cajanus cajan*), grasshopper (*Caelifera*), and beetroot (*Beta vulgaris* L.) flour blends

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Received: 22nd Sept 2025 | Revised: 28th Oct 2025| Accepted: 10th Nov 2025

Abstract—Complementary feeding is the introduction of other foods (solid and liquids) when breast milk alone is no longer sufficient to support the nutritional requirements for the infant. This study evaluated the quality of complementary foods produced from acha, malted pigeon pea, grasshopper, and beetroot flours blends at varied ratios (100:0:0:0; 85:5:5:5;75:15:5:5; 80.10:5:5;75::15:5:5 and 70:5:20:5 respectively); focusing on functional, microbial, and sensory properties for infants with age range from 6 to 24 months. The data obtained were analysed statistically using Statistical Package for Social sciences (25.0) and the average mean scores separated using Duncan's Multiple Range Test (DMRT) at $p<0.05$. Results shows that the incorporation of these ingredients significantly enhanced functional characteristics such as bulk density, water absorption, swelling capacity and foaming capacity with a reduced bulk density from 0.68 to 0.41%, while foaming capacity increased from 21.00 to 59.00% respectively, water absorption capacity and swelling capacity ranged 57.67 to 90.40, 55.60 to 80.63 g/cm³ respectively, with added malted pigeon pea making the blends more suitable for infant feeding. Total heterotrophic fungal count total and heterotrophic bacteria count in samples (C1 to F3) decreased from 2.3×10^2 to $1.9\times10^2$and 2.7×10^5 to 2.1×10^5cfu respectively, in samples fortified with increased malted pigeon pea. While (F4 to F6) range from 3.1×10^2 to $4.3\times10^{2,}$ 3.8×10^2 to $5.7\times10^2$$3.2\times10^2$ to 4.2×10^2cfu with addition in grasshopper this, increase has been associated with moisture. The total coliform count, total heterotrophic bacteria count and total heterotrophic fungal count of the produced complementary food were however, better than *ogi* ranged from 1.6×10^{2} – 2.8×10^2, 2.7×10^5 - 3.8×10^5 and1.5×10^5 - 3.1×10^3 cfu respectively while, cerelac recorded none. The possible bacteriaare *Staphylococcus aureus, Bacillus cereus, Pseudomonas aeruginosa, Aspergillus niger, A. flavus, A. parasiticus, E. coli, Yeast*. Sensory qualities showed acceptability in F3 and F6 respectively. These findings suggest that the blends, particularly F3 and F6 (Acha75%+Malted Pigeon pea15%+Grasshopper5%+Betroot5% and Acha70%+Malted Pigeon pea5%+Grasshopper20%+Betroot5%) are nutritionally adequate, safe, and highly acceptable complementary foods with strong potential to address protein-energy malnutrition and micronutrient deficiencies in infants. The study recommends further optimization, vitamin fortification, and strict hygienic processing to enhance the quality and scalability of these complementary foods.

***Keywords*—acha flour, functional, microbial and sensory qualities**

INTRODUCTION

A transitional phase known as the time of complementary feeding is when food other than breast milk is anticipated to provide an increasing percentage of a child's nutritional needs. Lots many babies and inadequate breastfeeding and complementary feeding practices have detrimental short- and long-term health consequences on young children in underdeveloped nations, which further hinders social and economic development (Paul *et al.*, 2025) Protein energy deficiency has been found to be highly prevalent in babies older than six months of age (Ayo *et al.*, 2025).

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https://doi.org/10.36782/apjsafe.v13i2.546

prevalent in babies older than six months of age (Ayo *et al.,* 2025).

Many traditional complementary diets are mainly based on plants; cereals, or roots, and the large amounts of starches in these plant sources result in a thick, gelatinous porridge, which often has a low nutrient content (Ayo *et al.,* 2025). In addition, mineral bioavailability is poor in many plant-based foods (Ijarotimi, 2022). However, these traditional complementary foods could be improved by combining locally available plant based foods that complement each other in such a way that new patterns of amino acids are created (Adepeju *et al.,* 2014). Enrichment of cereal-based food with other protein source such as legumes, oilseeds etc, have received considerable attentions since investigations have revealed that cereals are deficient in lysine and tryptophan but have sufficient Sulphur containing amino acids which are limiting in legumes (Abiose *et al.,* 2015). In view of these nutritional challenges, quite a number of studies have investigated ways of formulating quality complementary foods through a combination of available plant based foods to meet the nutritional demands of infants of weaning age (Paul *et a.,* 2025; Ijarotimi, 2022)

Acha (fonio), a tropical millet native to West Africa, one of the most nutritious of all grains rich in methionine and cystine, amino acids vital to human health and deficient in today's major cereals has the advantage to be minimally processed which limited the loss of the native nutritional value during milling (Ayo *et al.,*2025).

Acha can be used for complementary foods of low dietary bulk and high calorie density. It content 8.5% of protein, fat 3.25%, ash 3.50, fibre 3.71 and 79.00% of carbohydrate (Jideani, 2019).

Pigeon pea (*Cajanus cajan*) is an important food legume cultivated mainly as a subsistence crop in the tropics and sub-tropics of Africa Ayo *et al*., 2025) . Pigeon pea is rich in protein, calcium, magnesium, crude fiber, fat, trace elements and minerals.

Beside its high nutritional value, pigeon pea is also used as traditional folk medicine in India, China and some other countries. It is capable of preventing and curing a number of human ailments such as cough, pneumonia, respiratory infections, dysentery, tooth ache, wounds among others (Saxena *et al*., 2010). Pigeon pea contains 20-26% protein, 1-2% fat, 53-65% carbohydrate, and 7.01% ash (Ajayi *et al*., 2010; Saxena and Kumar, 2010).

Grasshoppers are increasingly recognized as a valuable source of nutrition, particularly as an alternative protein source. Their nutritional content varies depending on species and environmental factors (Ahmed and İnal, 2024). Grasshopper contains 36 – 77% protein, 2.5 – 54.9 crude fat, 3-9% ash, 10-15% dietary fiber and 2.5 – 16% carbohydrate (Ahmed and İnal, 2024: Harinder *et al*., 2023). This makes them comparable to traditional protein sources like beef and chicken, offering about 20 grams of protein per 100 grams of weight (Ahmed and İnal, 2024).

Beetroot (*Beta vulgaris* L.) is a root crop belonging to the family Chenopodieacea and it is an excellent source of red and yellow pigments (Abiodun *et al*., 2020). Red beetroot is a rich source of minerals (manganese, sodium, potassium, magnesium, and iron, copper), vitamins (A, C, B), phenolic compounds and betalain, which have antioxidant properties that help to protect against heart disease and certain type of cancers (Kavalcova *et al*., 2015). Beetroot contains 1.61% protein, 0.17% total fat, 2.8% fibre, 4.9 vitamins C, 23 % magnesium (Otegbayo *et al*., 2020).

Acha, Pigeon pea and Beetroot fruit are cultivated in Nigeria. These crops are naturally nutrient dense and can contribute immensely to good health. The crops are available and affordable all year round, but the masses are not aware of the numerous nutritional benefits to human health. Hence traditional weaning foods in West Africa kept been of low nutritive value (Ayo *et al*., 2025), and are characterized by low protein, low energy density and high bulk, cereal based diets have been implicated in protein-energy malnutrition. The problems inherent in the traditional West Africa weaning foods and feeding practices predispose the infants to malnutrition, growth retardation, infection and high mortality. Therefore, blending acha, with malted pigeon pea and beetroot fruit flour would help to improve nutrient density of the complementary food and improve nutrients intake, which resulted in the prevention of malnutrition problem. Acha is underutilized but yet highly nutritious cereal, known for it being filling and rich in amino acids like methionine cysteine. It has low glycemic index, making it beneficial in reducing blood glucose levels and contributing to diabetes management (Ibrahim *et al*., 2022). Acha can be used in making pudding, complementary food and also in baking and confectionaries. Pigeon pea is plant –based protein source with fiber that is supporting digestive health pigeon is a gluten free flour good for pap and baking (Balete, 2022). Beetroots are rich in bioactive compounds they are rich in minerals like potassium, phosphorus, magnesium, iron and calcium. They are known for their inflammatory and antioxidant properties, it has distinctive flavor and can add a vibrant colour to food.(Stoica *et al*., 2025).

The aim of this study evaluated the functional, microbial and sensory properties of complementary food produced from Acha- malted pigeon pea, grasshopper and Beetroot fruit flour.

MATERIALS AND METHODS

*A. **Materials***

Acha grains (*Digitaria exilis*), Pigeon pea (*Phaseleous vulgaris*), Grasshopper and Beetroot (*Beta vulgaris*) were purchased from Kaduna and (Jos) Plateau State Nigeria respectively. Wister Albino rats were purchased from Veterinary Research Institute Vom Jos.

https://doi.org/10.36782/apjsafe.v13i2.546

Material Preparations

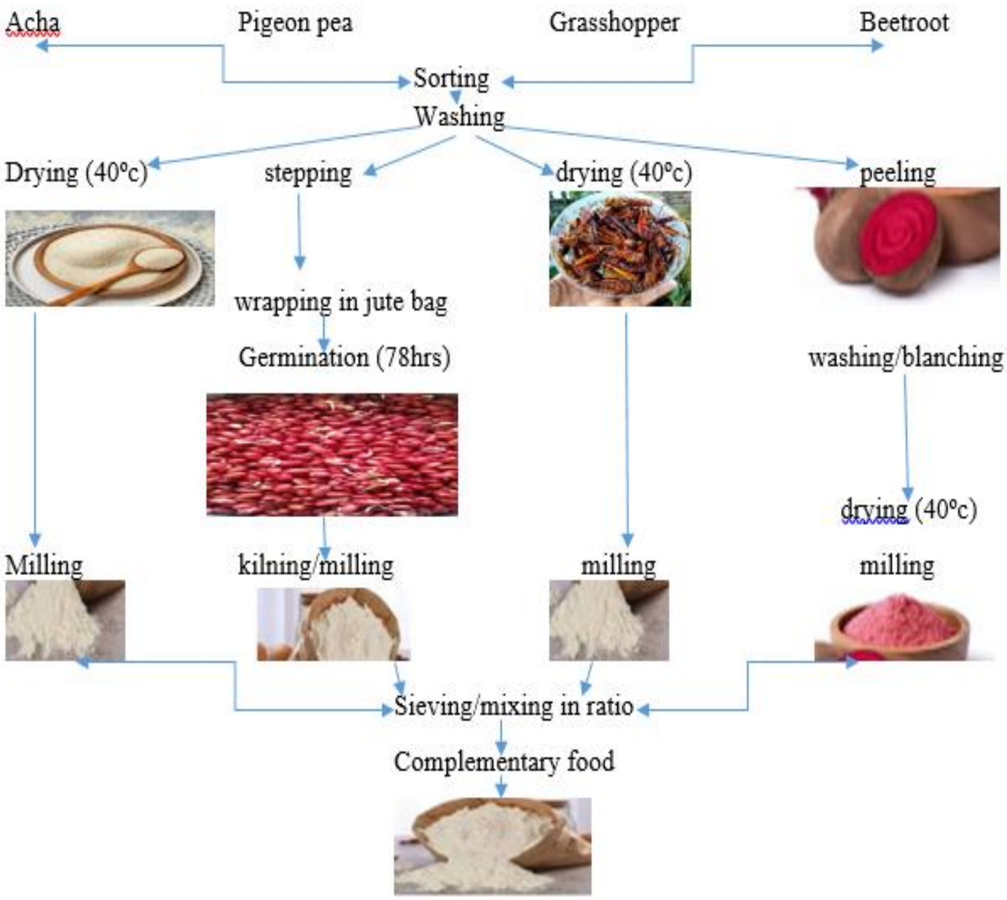

Figure 1. Material preparation flowchart

Production of Complementary Food from Different Grains Acha-Pigeon Pea-Grasshopper-Beetroot Blend Flours

Complementary food was prepared from different blends of refined Acha flour, malted pigeon pea flour and beetroot in the respective ratios of 100:0:0,0; 85:5:5:0; 80:10:5:5; 75:15:5:5; 80:5:10:5, 75: 5:15: 5; 70:5:20:5 and 70:25:5.(Table 2.1).

Table 1. Proportion of Acha flour, Malted Pigeon pea flour grasshopper flour and beetroot flour used for complementary food formulation.

Diets	Acha flour (%)	Malted Pigeon pea flour (%)	Grasshopper flour (%)	Beetroot flour (%)
C1	100	0	0	0
F1	85	5	5	0
F2	80	10	5	5
F3	75	15	5	5
F4	80	5	10	5
F5	75	5	15	5
F6	70	5	20	5

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Preparation of Media for Mould Counts

Sabour and dextrose agar was prepared for the determination of mold and yeast counts. The sabour and dextrose agar (62g) was suspended in 1 liter of deionized water and soaked for 10 minutes in a volumetric flask, swirled to mix and sterilized in an autoclave for 15 minutes at 121ºC, cooled at 47ºC.

*B. **Methods***

Determination of the Proximate Composition of the Formulated Complementary Food

The protein, moisture, crude fibre, fats and ash content of the samples were determined using the AOAC (2012) method. The carbohydrate content was determined by simple difference: CHO=100 (% protein + % moisture + % crude fibre + % fat + % ash) and energy value was calculated using Atwater conversion factor.

Functional Properties of Flours and Flour Blends

Bulk density was determined by the method of Mshelia *et al.* (2018). Weight 10 g of samples into a graduated cylinder 100ml. The bottom of the cylinder was tapped gently on a laboratory bench several times. This continues until no further diminution of the test flour in the cylinder after filling to mark, was observed. Weight of cylinder plus flour was measured and recorded.

Bulk Density(g/ml)=

$$\frac{weight\ of sample\ (g)}{volume\ of\ sample\ (after\ tapping)}$$

Water Absorption Capacity method of Ayo *et al* (2025). Weigh 10g of sample into a 100mL graduated cylinder. 50mL distilled water was added. The suspensions were allowed to stand at room temperature (30 ± 2 °C) for 1 hour. The suspension was centrifuged at 2000 rpm for 30 minutes. The volume of water on the sediment was measured and the absorbed water was expressed as percent water absorption based on the original sample weight. Calculate the water absorption capacity using the formula:

Water Absorption Capacity=

$$\frac{Weight\ after\ absorption - Initial\ Weight}{Initial\ Weight}\ x100$$

Swelling Capacity was determined by the method of Zakari *et al.* (2018). 10 grams of the samples were weighted and Transfer into clean, dry graduated (100 mL) cylinder. The transferred samples were levelled gently and the volume recorded. Add 50ml distilled water and allowed to stand for 60 minutes. After the soaking period, carefully drain or filter the excess liquid from the swollen samples and record the changes after 15 minutes. The swelling index of the sample of the samples is calculated by this formula:

Swelling capacity =

$$\frac{volume\ of\ sample\ after\ swelling}{volume\ of\ sample\ before\ swelling}\ x\ 100$$

Foam capacity was determined according to the method described by Paul *et al.* (2025). 10g of flour sample was weighed in a 100ml measuring cylinder and 50ml distilled water added to the sample. The suspension was mixed and vigorously shaken to foam and the total volume after 30 seconds was recorded. The percentage increase in volume after 30 seconds is expressed as foaming capacity.

$$\frac{volume\ after\ whipping - volume\ before\ whipping}{volume\ after\ whipping}$$

Determination of Microbial Properties of the Flour Blends

The samples were processed to identify the various microbial components present in the samples. Various foods have specific nutrients that help in microbial growth because microorganisms also need nutrients for their growth. This analysis identified the microorganisms present in each sample and their effects. The method used was described by Ayo *et al*. (2024) and adopted slight modification by Paul *et al.* (2025)

Sensory Evaluations

The reconstituted slurry was served warm to fifty (50) panellists at the Faculty of Agriculture Shabu-Lafia campus in Nasarawa state, Nigeria, after being coded (in three letters or three digits). Each Panellists was score each of the samples based on the appearance, aroma, taste, consistency and overall acceptability using A 9-point Hedonic scale was used to determine the overall acceptability of the 'complementary food'using: 1 = dislike extremely, 2 = dislike very much, 3 =dislike moderately, 4= dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely according to Ijarotimi (2022).

Statistical Analysis

The data obtained was analysed using Statistical Package for Social Sciences (SPSS, Version 25.0). The mean± and standard deviations (SD) of the results was calculated. The data generated was subjected to one a way analysis of variance (ANOVA). The significant means was separated using Duncan's New Multiple Range Test (DNMRT) at $p < 0.05$.

RESULTS AND DISCUSSIONS

Chemical Composition of Complementary Food Blends

Table 2 presents the proximate composition of the food blends. Significant differences ($p<0.05$) were observed in crude protein, fat, ash, fibre, moisture, carbohydrate and energy, while ash content did not significantly different ($p>0.05$) improved. Protein, fat, ash, crude fibre increased significantly ($p<0.05$) across all samples values ranged from 11.81 to 18.64, 2.23 to 5.59, 0.83 to 3.48, 0.59 to 5.46% respectively. However, moisture, carbohydrate and energy increased from 4.06 to 5.69, 67.53 to 78.86% and 379.67 to 384.07kcal, respectively, with increase in added malted pigeon pea from 5 – 15%. While decreased values where recorded in samples with increase (5 – 20%) in added grasshopper 4.14% to 3.64, 70.06 to 63.20 % and 382.66 to

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377.57kcal/g, respectively. The control samples: *ogi* and *cerelac* recorded increased in crude protein (6.71 to 17.89%), ash (1.10 to 3.52%), and fibre (0.90 to 4.31%), respectively, and were lower than the produced samples. While fat, (3.58 to 6.99%), moisture (4.17 to 6.77%), carbohydrate (65.75 to 80.94%) and energy (400.35 to 434.07kcal/g) respectively, were higher than the produced samples.

The crude protein content of the blends ranged from 11.81% (C1) to 18% (F6). These values indicate a substantial improvement in protein quality, especially in blends fortified with grasshopper and beetroot flours which are rich in protein and mineral sources. This protein range exceeded the minimum requirement of 16% protein recommended by FAO/WHO (Food Agriculture Organisation/World Health Organisation, 2021) as described by Paul *et al.* (2024): WFP, (World Food Program,2021), for complementary foods for infants aged 6-24 months. Protein is essential for tissue building, enzyme formation, and immune function in growing infants. Blends F3 and F6, with protein values above 16%, demonstrate strong potential to support adequate growth and development. These results are consistent with findings by Mbaeyi-Nwaoha and Uchendu (2021). However the protein content of the produced foods samples were higher than the control samples (ogi 6.71 and cerelac 17.89). Crude fat content, the values ranged from 4.2% to 5.59%, the observed values is within the acceptable range of 4-10% fat content for complementary foods, as outlined by FAO/WHO (2019). Fat is essential for energy, brain development, and absorption of fat-soluble vitamins. The higher fat levels in F3, F5 and F6 are attributed to the inclusion of grasshopper, known for their lipid richness according to Sanni *et al.* (2021). Thes agree with the findings of Sanni *et al.* (2021) and Nnam (2020), who emphasized that inclusion of insect-based or oil-rich flours can improve energy density and palatability of complementary foods. Fat in the control sample ogi is lower but cerelac is higher than the produced food samples.

The ash content of the formulated blends, ranged between 0.8 to 3.48%, the values fall within the recommended level by World Health Organization (WHO, 2021). Control samples recorded values ranged: ogi 3.58 while cerelac 6.99%. Cerelac higher ash content is as the results of the ingredient used and the processing methods. The results of this finding reflects the total mineral content present in the food and the increased in the value is as the result of added grasshopper and beetroot flour. Higher ash values indicate a richer mineral profile, particularly calcium, potassium, iron, and zinc - all of which are vital for immune function, bone development, and enzymatic activity in children Akubor and Ukwuru (2019).

Crude fibre content ranged from 0.59 to 5.62%, values higher than control samples. Fibre plays a key role in digestive health and bowel regularity, excessive fibre can displace caloric and nutrient intake in infants according to Ijarotimi and Keshinro (2020). The FAO/WHO (2017) recommends fibre content 10 -15% in infant foods. The slightly higher fibre content in F4 may be attributed to acha (80%, and beetroot (5%) flours, which are naturally high in dietary fibre. Similar fibre ranges were reported by Ijarotimi and Keshinro (2020):Ogunba and Hassan (2019) in their studies on legume-vegetable blends.

The moisture content across samples decreased significantly from 5.69% (C1) to 3.64% (F6). Control samples ogi (6.77%) cerelac has higher moisture due to processing method but they are within safe limit of moisture in complementary food. The decreased values is the effect of the increased added grasshopper (5 – 20%). Moisture is critical for microbial stability and shelf life, and its high presence beyond recommended levels can predispose foods to spoilage. According to the Codex Alimentarius (2007) and Standard Organization of Nigeria (SON, 2021).

Carbohydrate content, calculated by difference, increases from 63.20 - 78.86 with the increased in malted pigeon pea (5 -15%). Carbohydrates serve as the primary energy source in infant diets. The observed values align with the FAO/WHO (2008) recommendation that >64% of daily energy for infants and young children should come from carbohydrates. C1 (100:0:0:0 Acha), F1 (85:5:5:5), and F2 (80:10:5:5) had higher carbohydrate contents, while slightly lower values were the effect of the increased inclusion of protein and fat-rich components. This balance of macronutrients is beneficial, as Ibeanu *et al.* (2021) noted that complementary foods with moderate carbohydrates and balanced protein/fat levels improved overall nutritional adequacy and growth outcomes. The result of this finding agreed with results recorded by Paul *et al.* (2024). Ogi is energy dense and has the highest value for carbohydrate (80.94%), while cerelac recorded (65.75%).

Energy values 377 to 382 (kcal/g/100) of the complementary food is lower than the reference value (425cal/1g) by FAO/WHO (1991). High energy density is crucial for infant foods as they require more calories per gram for growth and development. Control samples, that is, ogi and cerelac, had the energy value 400 and 434kcal respectively; this may be because of the type of raw material used. The result of this finding agreed with result from Ijarotimi, (2022): Dagnaw (2019); Ikujenola and Ogumba 2018; Verma and Srivastav (2017).

Table 2. Proximate composition of complementary foods produced from Acha malted pigeon pea grasshopper and beetroots flour blends (g/100g of dry weight materials)

Sample	Crude Protein	Fat	Ash	Crude Fibre	Moisture	Carbohydrate	Energy
C1	11.81 ± 0.02^{f}	2.22 ± 0.03^{g}	0.83 ± 0.06^{h}	0.59 ± 0.04^{h}	5.69 ± 0.03^{b}	78.86 ± 0.32^{b}	382.66 ± 0.54^{c}
F1	15.29 ± 0.03^{e}	4.03 ± 0.04^{e}	2.44 ± 0.03^{f}	3.23 ± 0.01^{e}	4.45 ± 0.06^{c}	70.56 ± 0.12^{c}	379.67 ± 0.21^{d}
F2	16.56 ± 0.31^{c}	4.23 ± 0.03^{d}	2.47 ± 0.02^{f}	2.50 ± 0.02^{f}	4.28 ± 0.02^{d}	70.00 ± 0.54^{c}	382.31 ± 0.33^{c}

https://doi.org/10.36782/apjsafe.v13i2.546

F3	17.57±0.01[b]	4.63±0.03[c]	2.83±1.97[d]	3.93±0.03c	4.06±0.04[f]	67.53±0.30[d]	384.07±0.61[c]
F4	15.74±0.26[d]	3.85±0.04[e]	2.59±0.01[e]	5.62±0.01a	4.14±0.05[e]	70.06±0.32[c]	377.57±0.39[f]
F5	16.53±0.03[c]	4.62±0.06[c]	3.24±0.02[c]	3.92±0.01[c]	4.03±0.02[f]	67.66±0.81[d]	378.34±0.19[e]
F6	18.64±0.03[a]	5.59±0.09[b]	3.48±0.02[b]	3.46±0.06[d]	3.64±0.03[g]	63.20±0.19[f]	379.67±0.67[d]
Ogi	6.71±0.32[g]	3.58±0.24[f]	1.10±0.05[g]	0.90±0.01[g]	6.77±0.37[a]	80.94±0.53[a]	400.35±0.17[b]
Cerelac	17.89±0.3[b]	6.99±0.32[a]	3.52±0.45[a]	4.31±0.12[b]	3.07±0.16[h]	65.75±0.37[e]	434.07±0.34[a]
RV	18	4 - 10	3	10 – 15	5	64	425

Data presented as the mean ± standard deviation with different alphabetical superscripts in the same column significantly different (p< 0.05).

C1 = 100:0:0:0 Acha
F1 = 85:5:5:5= Acha 85% + Malted Pigeon pea 5% + Grasshopper 5% + Betroot 5%
F2 = 80:10:5:5= Acha 80% + Malted Pigeon pea 10% + Grasshopper 5% + Betroot 5%
F3 = 75:15:5:5= Acha 75% + Malted Pigeon pea 15% + Grasshopper 5% + Betroot 5%
F4 = 80:5:10:5= Acha 80% + Malted Pigeon pea 5% + Grasshopper 10% + Betroot 5%
F5 = 75:5:15:5= Acha 75% + Malted Pigeon pea 5% + Grasshopper 15% + Betroot 5%
F6 = 70:5:20:5= Acha 70% + Malted Pigeon pea 5% + Grasshopper 20% + Betroot 5%

Functional Properties of the Complementary Food Blends

Figure 1. Showed the functional properties of the produced complementary food that is the bulk density (BD), water absorption capacity (WAC), swelling capacity (SC), and foaming capacity (FC). Significant differences (p<0.05) were observed across all parameters. Bulk density (BD) decreased from 0.68 to 0.41, with increase (5 – 15%), in the added malted pigeon. Water absorption capacity(WAC), and swelling capacity (SC), increased from 57.67g/cm³ to 90.40, 55.60 to 80.63, respectively, with added malted pigeon pea while foaming capacity (FC) increased in food samples with added grasshopper (5 -20%) value observed ranged from 21.00 to 59.00. However, control samples (*ogi* and *cerelac*) showed values ranged from 0.10 to 0.85, 58.67 to 64.01, 23.30 to 51.92 and 15.23 to29.07%, respectively.

Bulk density of the produced food blends showed decrease values ranged with the effect of increased (5 -15%) added malted pigeon pea, grasshopper (5 – 20%) and beetroot flour (5%). However control samples showed values range 0.85 (ogi) and 0.10 cerelac. Bulk density affects packaging requirements and the energy density of foods. Lower bulk density is desirable for infant food, as it allows for higher caloric intake per unit volume - suitable for infants with small gastric capacity (Rajeswari *et al.*, 2010: Paul *et al.,* 2025). According to FAO/WHO (2008) guidelines, complementary foods should ideally have a bulk density below 0.8 g/cm³ to ease infant consumption.

Water absorption capacity (WAC) ranged from 57.67 to 90.40% with the increase values in samples F1 to F3 with the effect of added malted pigeon pea(5 – 15%), while a decreased values were observed in samples F4 to F6 values ranged 87.67 to 82.26% with increase in added grasshopper (5-20%). The control samples recorded values 64.01(ogi) and 58.67(cerelac WAC indicates the ability of flour to bind water during preparation, affecting consistency and palatability ensuring ease of swallowing and digestion Fasasi *et al.* (2022). The highest WAC observed in F3 can be linked to the hydrophilic nature of malted pigeon pea and beetroot. Similar values were reported by Onweluzo and Nwabugwu (2020): Paul *et al*., (2024).

Swelling index of flours are influenced by the particle size, species variety of food used and method of processing or unit operations Ayo *et al*., (2024).It was observed that the swelling capacity of the produced food blends increase from 55.60 to 71.13%. While control samples recorded 51.92 (ogi) and 23.30 (cerelac). Swelling capacity affects the viscosity and volume of gruels during preparation of food. Blends like F6 (Acha 70% + Malted Pigeon 5% + Grasshopper 20% + Betroot 5%) with higher swelling capacity was due to addition of grasshopper at (5- 20%). The result of this study is in agreement with Nnam (2020) Akinola *et al*. (2022).

The forming capacity is crucial for flavour retention and mouth feel, especially in fat-containing baby foods. The observed values observed ranged from 21.00 to 59.00%. These results is in trend with findings by Ogunbanwo *et al*. (2023) and Nnamani *et al*. (2020), who reported increased form capacity in insect-fortified flours, enhancing sensory properties and energy density.The foam capacity (FC) values obtained in this study showed significant increase in the samples with added grasshopper flour (5-20%) which is protein- and fat-rich, improving lipid interaction and decreased foam in the samples with addition malted pigeon pea (5 -15 %). Foaming capacity is relevant for texture and mouthfeel, particularly in products intended to be creamy or airy. The high foaming capacity in sample F6 (70:5:20:5 = Acha 70% + Malted Pigeon 5% + Grasshopper 20% + Betroot 5%) indicates that this formulation could offer a light texture, which might be more acceptable to infants. (Ojo and Ade, 2015).While, control samples ogi and cerelac have lower values.

https://doi.org/10.36782/apjsafe.v13i2.546

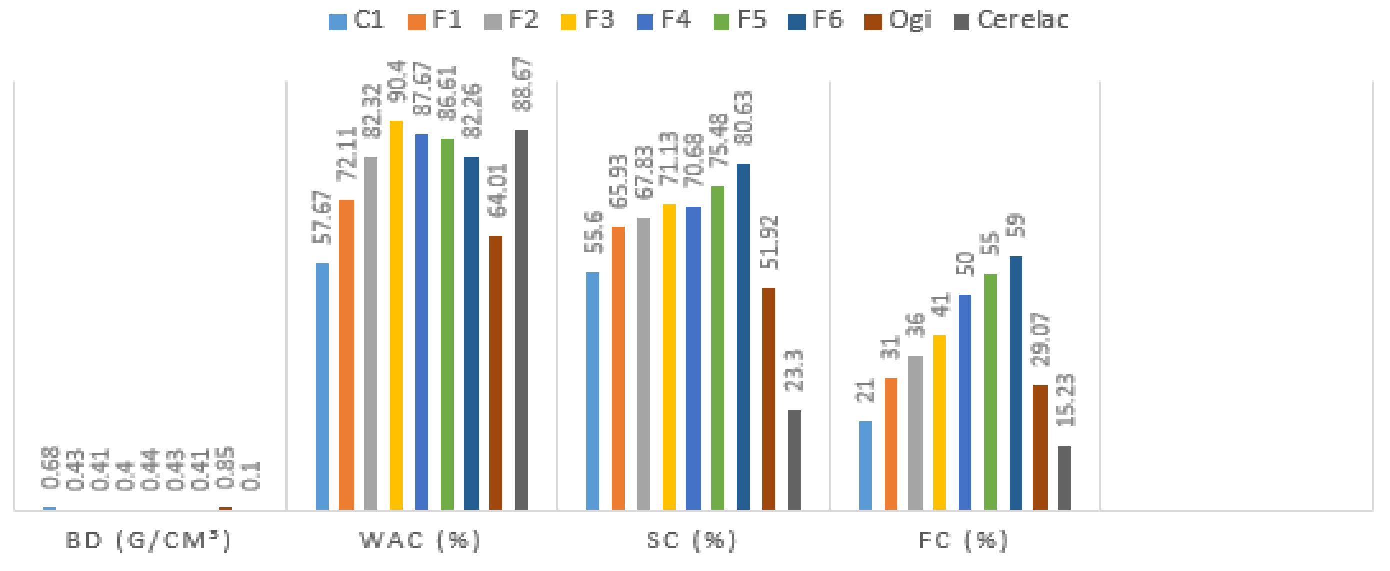

Figure 2. Functional properties of Acha, malted pigeon pea, grasshopper and beetroots flour blends

Data presented as the mean ± standard deviation with different alphabetical superscripts in the same column significantly different ($p < 0.05$), Means (±SEM) with different alphabetical superscripts in the same column are significantly different at ($P<0.05$).
C1 =100:0:0:0 Acha
F1 = 85:5:5:5 = Acha 85% + Malted Pigeon pea 5% + Grasshopper 5% + Betroot 5%
F2 = 80:10:5:5 = Acha 80% + Malted Pigeon pea 10% + Grasshopper 5% + Betroot 5%
F3 = 75:15:5:5 = Acha 75% + Malted Pigeon pea 15% + Grasshopper 5% + Betroot 5%
F4 = 80:5:10:5 = Acha 80% + Malted Pigeon pea 5% + Grasshopper 10% +Betroot 5%
F5 = 75:5:15:5 = Acha 75% + Malted Pigeon pea 5% + Grasshopper 15% + Betroot 5%
F6 = 70:5:20:5 = Acha 70% +Malted Pigeon pea 5% + Grasshopper 20% + Betroot 5%

Microbial Analysis of Produced Complementary Food and Control Samples (Ogi and Cerelac)

Microbial Count of the Produced Complementary Food from malted pigeon pea, grasshopper and beetroot flour blend, is presented in Table 3.2 Total heterotrophic fungal count total and heterotrophic bacteria count in samples (C1 to F3) decreased from 2.3×10^2 to $1.9\times10^2$and 2.7×10^5 to 2.1×10^5cfu respectively, in samples fortified with increased malted pigeon pea and the total coliform count increase from1.8×10^3 to 3.3×10^3cfu this could be due contamination of water and environment of processing of the produced complementary flour blend. However, there were relative increase in total heterotrophic fungal count total heterotrophic bacteria count total coliform count in samples (F4 to F6) range from 3.1×10^2 to 4.3×10^2, 3.8×10^2 to $5.7\times10^2$$3.2\times10^2$ to 4.2×10^2cfu with addition in grasshopper this, increase has been associated with moisture, P^H (neutral or slightly acidic), protein-rich environment and warmness. However, cerelac had none while ogi ranged from 1.6×10^2 – 2.8×10^2, 2.7×10^5 - 3.8×10^5 and1.5×10^5 - 3.1×10^3 cfu respectively. The results showed that the possible organism are both positive and negative meaning presence and absence of micro-organisms in the complementary food. This possible organism are *Klebsiella spp, Staphylococcus aureus, Pseudomonas aeruginosa, E. coli, Micrococcus spp Samonella spp, Proteus spp, Bacillus spp, Shigella spp and Streptococcus spp*.

Microbiological evaluation was carried out on complementary foods to assess their wholesomeness for Consumption. The microbial count obtained In this study fall within the recommended safe limit of microbial guidelines for ready-to-eat foods adopted by the International Commission of Microbiological Specification of Food (ICMSMF) which states that the microbial safe limit for ready-to-eat food should fall between the range of 10^2 to 10^5Cfu/ml and values of this study agreed with the study carried out by Ayo *et al.* (2024). The produced complementary foods showed lower microbial contamination levels compared to traditional option (Ogi), suggesting they may be safer and more nutritious alternatives (Paul *et al*., 2025). The absence of pathogenic organisms along with an acceptable level of beneficial microbes indicates that these foods are not only safe but may also contribute positively to health when consumed as part

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of a balanced diet. A positive reaction typically indicates the presence of certain microorganisms that may be beneficial or non-pathogenic. Negative reactions usually refer to the absence of harmful pathogens such as *Salmonella*, *Shigella, Staphylococcus*, and *Escherichia coli*. The absence of these organisms in the tested samples indicates good hygiene practices during food preparation and safety for consumer health (Paul *et al*., 2025).

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Table 3. Microbial Count of the Produced Complementary Food and Control Samples (Ogi and Cerelac)

Sample	THFC	THBC	TCC	Gram reaction	Catalase	Coagulase	Citrate	Oxidase	Indole	Motility
C1 100:0:0:0 Acha	2.3x10 E2	2.7X10E2	1.8 X10E2	Negative rods	Positive	0	Positive	Negative	Negative	Negative
				Negative rod	Negative	0	Negative	Positive	Negative	Motile
				Negative rods	Positive	Negative	Negative	Negative	Positive	Motile
				Positive cocci	Positive	Positive	Positive	Negative	Negative	Negative
				Positive cocci	Positive	Positive	Positive	Positive	Negative	Negative
-F1 85:5:5:5	2.1x10E2	2.6 x 10E4	3.1 x 10E2	Positive cocci	Negative	0	Negative	Negative	Negative	-
				Negative rod	Negative	0	Negative	Positive	Negative	-
				Positive rods	Positive	0	Negative	Negative	Negative	-
				Positive cocci	Positive	Positive	Positive	Negative	Negative	-
				Gram positive coccobacilli	Negative	Negative	Negative	Negative	Negative	-
F2 80:10:5:5	1.9X10E2	2.3 X 10E4	3.2 x 10E2	Negative rod	Negative	0	Negative	Positive	Negative	Motile
				Positive cocci	Positive	Positive	Positive	Positive	Negative	Negative
				Negative rods	Positive	0	Negative	Negative	Negative	Motile
				Positive rods	Positive	0	Negative	Negative	Negative	Motile
				Negative rods	Positive	Negative	Negative	Negative	Positive	Motile
F3 75:15:5:5	1.5X10E2	2.1 x 10 E4	3.4 x10 E2	Negative rods	Positive	Negative	Negative	Negative	Positive	Motile
				Positive cocci	Positive	Negative	Negative	Negative	0	Negative
				Positive rods	Positive	0	Negative	Negative	Negative	Motile
				Negative rod	Negative	0	Negative	Positive	Negative	Motile
				Negative rods	Positive	0	Negative	Negative	Negative	Motile
F4 80:5:10:5	3.1X10E2	3.8X10E4	3.2 x 10E2	Negative rod	Negative	0	Negative	Positive	Negative	Motile
				Positive cocci	Positive	Positive	Positive	Positive	Negative	Negative
				Negative rods	Positive	0	Negative	Negative	Negative	Motile
				Negative rods	Positive	Negative	Negative	Negative	Positive	Motile
				Negative rods	Positive	0	Negative	Negative	Negative	Motile
F5 75:5:15:5	3.5X10E2	4.7X10E4	4.2 x 10E2	Negative rod	Negative	0	Negative	Positive	Negative	Motile
				Positive rods	Positive	0	Negative	Negative	Negative	Motile
				Positive cocci	Positive	Positive	Positive	Negative	Negative	Non-motile

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Sample	THFC	THBC	TCC	Gram reaction	Catalase	Coagulase	Citrate	Oxidase	Indole	Motility
				Gram positive coccobacilli	Negative	Negative	Negative	Negative	Negative	Motile
F6 70:5:20:5	4.3X10E2	5.7 X10E2	4.2x10E2	Negative rods	Positive	Negative	Negative	Negative	Positive	Motile
				Positive cocci	Positive	Negative	Negative	Negative	0	Negative
				Negative rods	Positive	0	Positive	Negative	Negative	Negative
				Negative rod	Negative	0	Negative	Positive	Negative	Motile
				Negative rods	Positive	0	Negative	Negative	Negative	Motile
Ogi	1.6×10^2	3.8×10^5	3.1×10^3	Negative rods	Positive	Positive	Negative	Positive	Negative	-
				Positive rods	Positive	Positive	Positive	Positive	Positive	-
				Positive cocci	Positive	Positive	Negative	Positive	Negative	-
				Positive rods	Positive	Negative	Positive	Negative	Positive	-
Cerelac	2.8×10^2	2.7×10^5	1.5×10^3	Negative cocci	Positive	Negative	Positive	Negative	Negative	-
				Negative rods	Negative	Negative	Negative	Negative	Negative	-
				Positive rods	Negative	Negative	Negative	Negative	Positive	-
				Negative rods	Negative	Negative	Negative	Positive	Negative	-

https://doi.org/10.36782/apjsafe.v13i2.546

Sensory Evaluation of the Produced Complementary Foods

Sensory attributes of the formulated complementary foods are shown in figure 2. Parameters included appearance, taste, colour, consistency, flavour, and general acceptability with average means scores increased from 6.09 to 7.70, 7.10 to 7.51, 6.05to 7.40, 6.60 to 7.27, 6.40 to 7.45, and 6.01 to 8.05, respectively, with increase in added malted pigeon pea (5 – 15%).While average means scores of samples (F4-F6) increased from 7.65 to 7.71,6.65 to 7.50,6.97to 7.35, 7.00 to 7.31,7.50 to 7.35, 7.52 to 8.01 respectively, with the addition of grasshopper (5 – 20%). However, lower average means scores were observed in ogi (control) while, cerelac shown significantly ($p < 0.05$) higher values in all the parameters.

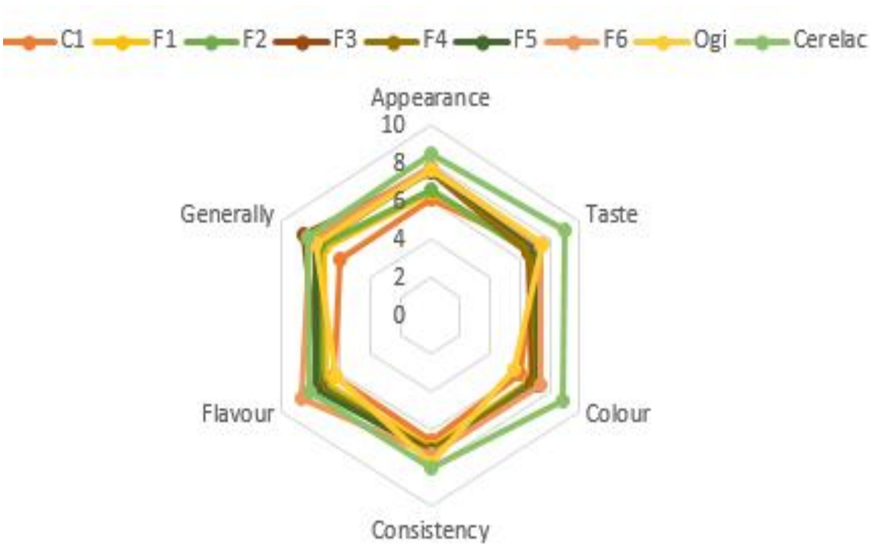

Figure 3. Sensory Evaluation of the Produced Complementary Food from Acha, Malted pigeon pea, Grasshopper and Beetroot Flour Blends

Means (±SEM) with different alphabetical superscripts in the same column are significantly different at ($P<0.05$).
C1=100:0:0:0 Acha
F1 = 85:5:5:5 = Acha 85% + Malted Pigeon 5% + Grasshopper 5% + Betroot 5%
F2 = 80:10:5:5 = Acha80% + Malted Pigeon 10% + Grasshopper 5% + Betroot 5%
F3 = 75:15:5:5= Acha 75% + Malted Pigeon 15% + Grasshopper 5% + Betroot 5%
F4 = 80:5:10:5 = Acha 80% + Malted Pigeon 5% + Grasshopper 10% + Betroot 5%
F5 = 75:5:15:5 = Acha 75% + Malted Pigeon 5% + Grasshopper 15% + Betroot 5%
F6 = 70:5:20:5 = Acha 70% + Malted Pigeon 5% + Grasshopper 20% + Betroot 5%

Appearance and colour scores were highest for samples F3 (7.70), and F6 (7.71), F3 (7.40) and F6 (7.35) respectively. The inclusion of beetroot flour enhanced the visual appeal due to its vibrant pigmentation, which contributed to a reddish hue appreciated by panellists. This aligns with the findings of Onabanjo and Ighere (2018) who reported that the inclusion of natural colorants like beetroot in complementary foods significantly improved colour appeal and acceptance. According to WHO (2003), complementary foods must be visually attractive to stimulate infant interest and caregiver confidence, in feeding practice.

Taste scores were highest for F3 (7.61) likely due to the balanced formulation of legumes, acha, and low-level beetroot, which imparted mild sweetness (malting effect). While F6 had scores (7.50) due to its higher insect content, which may have introduced a stronger, earthy taste not preferred by some panellists. Similar observations were made by Afolabi *et al*. (2019), who noted that while edible insects improve protein content, excessive inclusion may affect palatability if not balanced with sweet or neutral-flavored ingredients. Ogi recorded 7.49 values close to F6, this is because panellist are used to fermented taste and are already familiar with it. Cerelac was observed to have the highest score of (8.95), having creamy and appealing taste.

Consistency is essential in determining infant ease of swallowing and mouthfeel. Samples F3 (7.27) and F6 (7.35) had the best texture scores. The inclusion of grasshopper contributed to a creamy, smooth mouthfeel, while malted pigeon pea reduced grittiness and enhanced solubility. This agrees with the findings of Obadina *et al*. (2021) who demonstrated that germination and malting improve the functional and sensory texture of complementary foods. According to FAO (2011), acceptable complementary foods should have smooth, easy-to-swallow textures, especially for infants aged 6-24 months.

The flavour profile varied across samples, F3 scored highest (7.45). The nutty and slightly earthy aroma imparted by malted pigeon pea and beetroot flour contributed positively to making the flavour acceptable by the panellists.

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The insect (grasshopper) component in moderate quantities F4, (7.50) also provided a savoury flavour, though high inclusion levels in F6 (20% grasshopper) slightly reduced aroma scores (7.35) due to overpowering odour. These results are consistent with those of Ijarotimi *et al*. (2020) who showed that legume-insect flours improved sensory aroma scores.

Overall acceptability was highest for F3 (8.5) and F6 (8.1). These results indicate that moderate incorporation of acha, malted pigeon pea, grasshopper, and beetroot flour produced complementary foods with favourable sensory attributes. These findings are supported by Ekpo *et al*. (2022), who concluded that optimized formulations of cereal-legume-insect blends are more acceptable to consumers, especially when traditional flavours and ingredients are preserved.

The control sample (C1) had comparatively lower scores in taste (6.8) and aroma (6.4), reflecting the bland nature of traditional single-cereal complementary foods. This reinforces the need for diversified and enriched formulations, as advocated by FAO/WHO (2007) and SON (2018), to improve the quality and acceptability of complementary foods in Nigeria.

CONCLUSIONS

The study demonstrated that incorporating malted pigeon pea, grasshopper, and beetroot into acha-based blends significantly improved the protein quality 11.81 to 18% , ash 0.8 to 3.48% , and fibre 0.59 to 5.62% respectively (proximate composition). F**unctional properties** such as bulk density that decreased from 0.68to 0.40 g/cm³, water absorption 87.67 to 82.26%, swelling index, 55.60 to 71.13% and foaming capacity 21.00 to 59.00%., making them more suitable for infant complementary feeding. The **microbial analysis** indicated that all samples were within safe microbial limits (total heterotrophic fungal count total and heterotrophic bacteria count in samples (C1 to F3) decreased from 2.3×10^2 to $1.9\times10^2$and 2.7×10^5 to 2.1×10^5cfu respectively, in samples fortified with increased malted pigeon pea) free from harmful pathogens, and superior to *ogi* in hygienic quality. Finally, **sensory evaluation** showed that fortification enhanced taste, flavour, colour, consistency, and overall acceptability, with sample F6 performing comparably to Cerelac. Overall, the formulated blends, particularly F3 and F6, emerged as nutritionally adequate, safe, and highly acceptable complementary foods with strong potential to combat protein-energy malnutrition and micronutrient deficiencies in infants

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