

Production and Quality Assessment of Breakfast Cereals from Blends of Broken Rice and Acha Flours Enriched with Crayfish

Unaji, Cecilia; and Effiong, Bartholomew N.

Department of Food Science and Technology, University of Uyo, Uyo. Akwa Ibom State, Nigeria.

Corresponding author: cecilia_unaji@yahoo.com

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Abstract

Study on the development and quality evaluation of breakfast cereals from blends of broken rice and acha flour enriched with crayfish was conducted using standard procedure. Four formulations were developed with varying ratios of broken rice, acha, and crayfish: 80:10:10 (A), 70:20:10 (B), 60:30:10 (C), and 50:40:10 (D). The samples were evaluated for functional properties, proximate composition, mineral content, and sensory attributes. Functional properties such as water absorption capacity (1.66–2.33 ml/g), oil absorption capacity (1.06–1.83 ml/g), and swelling capacity (64.67–74.67%) decreased with increasing levels of acha and crayfish, while bulk density (0.80–0.87 g/ml), foaming capacity (20.67–45.67%), and dispersibility (34.00–50.33%) increased. There were significant differences ($p < 0.05$) among the samples, with sample A having the highest value in water absorption, oil, and swelling capacity, and sample D having the highest in bulk density, forming capacity, and dispersibility. Mineral content showed that potassium (63.12 – 115.22 mg/100g), calcium (33.93 – 94.26 mg/100g) and iron (1.84 – 2.66 mg/100g), increased significantly ($p < 0.05$) with increased incorporation of acha and crayfish in the blends whereas (sodium (3.14 – 1.73 mg/100g), manganese (0.83 – 2.78 mg/100g), 18.52 – 22.35 mg/100g) decreased with increasing levels of acha and crayfish in the blends. There were significant differences ($p < 0.05$) among the samples. Sensory evaluation revealed that the control sample (Golden Morn) was most preferred, likely due to consumer familiarity. However, the sample containing 50% broken rice, 40% acha, and 10% crayfish (Sample D) was rated second in preference and compared favourably with the commercial product, suggesting good consumer acceptability.

Keywords: Breakfast Cereal, Broken Rice, Crayfish, Flour Blends, Acha.

Introduction

Breakfast cereal is a food made from processed grains, such as wheat, maize, oat or rice and is usually eaten for breakfast with milk and sometimes sugar. It is one of the most important meals of the day, as it comes after several hours of night fasting, and literally “breaks the fast”. (Owheruo *et al.*, 2023). In recent years, the breakfast cereal market has witnessed remarkable growth, driven by a rising demand for healthier and more nutritionally balanced options. As consumers become increasingly health-conscious, there is a heightened scrutiny of the ingredients used in cereal production and their impact on the overall nutritional quality. Conventionally, breakfast cereals have been predominantly crafted from a variety of grains, including corn, rice, wheat, and oats. However, there exists a

noticeable research gap regarding the utilization of alternative and locally sourced ingredients. Broken rice, often considered a by-product of rice milling, is frequently underutilized or discarded, despite its potential to reduce food waste and enhance the value of the rice processing industry (Nath *et al.*, 2024).

Acha, scientifically known as finger millet, is a nutritionally rich cereal crop that has historically served as a dietary staple in certain regions. Renowned for its elevated protein content, dietary fiber, and mineral composition, Acha emerges as a promising candidate for inclusion in breakfast cereal blends (Eke-Okoro, 2019).

Crayfish, a seafood delicacy, possesses a nutritional profile replete with essential nutrients, including protein, vitamins, and minerals like calcium and iron. Enriching breakfast cereal blends with crayfish not only elevates their nutritional value but also introduces a unique and savoury flavor profile that may resonate with consumers. Moreover, the incorporation of locally sourced ingredients like broken rice, Acha flour, and crayfish holds the potential to bolster food security, support local agriculture, and reduce the environmental impact associated with importing raw materials from distant sources (Iwar and Amu, 2021).

Notwithstanding the promising prospects of these ingredients, there is a conspicuous scarcity of comprehensive research exploring their utilization in breakfast cereal production. This study seeks to address this research gap by delving into the entire production process, scrutinizing the nutritional attributes, and evaluating the sensory appeal of breakfast cereals. The outcome of this research is poised to diversify the breakfast cereal market by offering consumers a nutritious option grounded in locally sourced ingredients. Additionally, the study can provide invaluable insights to food manufacturers and processors, fostering innovation in the development of sustainable and nutritious breakfast cereal products. With a focus on using underutilized or readily available ingredients.

Literature Review

Breakfast cereals play a significant role in the human diet by offering a convenient and nutritious option for the morning meal. Often enriched with essential vitamins and minerals such as iron and B vitamins, they contribute to overall nutrient intake (Akonor *et al.*, 2023; Lu, 2023). Many breakfast cereals are also high in dietary fiber, which supports digestive health and helps regulate blood sugar levels. Those made with whole grains contribute to a well-rounded diet and may reduce the risk of chronic conditions like heart disease and diabetes. Additionally, the wide variety and accessibility of breakfast cereals make them appealing to a broad audience, encouraging healthier eating habits. They provide a simple and healthful way to start the day (Lu, 2023).

Rice contributes 20% of global calories and is an important source of minerals and vitamins. Bran contains bioactive phytochemicals and essential food components (Fukagawa and Ziska, 2019).

Acha is a nutrient-rich grain with a long history of cultivation in West Africa. It is a valuable source of protein (Chinwe *et al.*, 2015). This protein is of high quality, containing essential

amino acids needed for growth and maintenance. Its flour is rich in dietary fiber, particularly soluble fiber. It also contains essential vitamins, including B vitamins like thiamin (vitamin B₁) and riboflavin (vitamin B₂), which play vital roles in energy metabolism (Chinwe *et al.*, 2015). Acha is a good source of minerals such as magnesium, phosphorus, and iron, which are essential for various physiological functions (Chinwe *et al.*, 2015).

Crayfish is a nutritious freshwater crustacean known for its high protein content, making it beneficial for muscle growth and repair (Adegbusi *et al.*, 2023). It is low in fat, especially saturated fat, making it heart-healthy. Crayfish also provides essential minerals like calcium, phosphorus, and magnesium for bone health, as well as important vitamins such as B₁₂ for nerve function and red blood cell production. Additionally, it may contain omega-3 fatty acids that support heart health and reduce inflammation. Overall, crayfish offers several health benefits, contributing to muscle, bone, and overall vitality (Iwar and Amu, 2021).

Materials and Methods

Materials Procurement/Collection

Broken rice was procured from a rice mill in Ini L.G.A. while crayfish was purchased from Itam Market, Itu L.G.A. both in Akwa Ibom State. Acha was purchased from Iddah Main Market, Kagoro, in Kaduna state, Nigeria. All reagents used were of analytical grade, purchased from credible chemical stores in Uyo, Akwa Ibom State

Production of Flour

The broken rice flour was produced following the method described by Okpala and Egwu (2015), acha flour was prepared according to the method of Olapade *et al.* (2010), and crayfish flour was prepared according to the method described by Oti and Akobundu (2008).

Formulation of Flour Blends

Composite flours were formulated by mixing broken rice flour, acha flour, and enriching it with crayfish flour in the following ratios as shown in Table 1. Sample A - 80% broken rice flour, 10% acha flour, 10% crayfish flour; Sample B - 70% broken rice flour, 20% acha flour, 10% crayfish flour; Sample C - 60% broken rice flour, 30% acha flour, 10% crayfish flour; Sample D – 50% broken rice flour, 40% acha flour, 10% crayfish flour.

The ingredient combination of the breakfast cereals formulation is shown in Table 2.

Table 1: Composite flour formulation for breakfast cereal made from blends of broken rice, acha and crayfish flours.

Sample	Broken rice flour (%)	Acha flour (%)	Crayfish flour (%)
A	80	10	10
B	70	20	10
C	60	30	10
D	50	40	10

Table 2: Ingredients Combination for Breakfast Cereals made from Blends of Broken Rice, Acha and Crayfish Flours (per 100g)

Ingredients	Sample A	Sample B	Sample C	Sample D	Sample E
Composite flour (g)	200	200	200	200	200
Sugar (g)	6.2	6.2	6.2	6.2	6.2
Salt (g)	0.45	0.45	0.45	0.45	0.45
Water (ml)	132	132	132	132	132

Breakfast Cereal Production

The breakfast cereals were produced using the method described by Okafor and Usman (2014). 85g of the composite flour was measured into a mixing bowl, and the ingredients were added to the bowl. Water was added and thoroughly mixed until a dough was obtained. The dough was kneaded on a flat surface and passed through an extruder (model: MC-8830). The extruded dough was placed in an oven (Model pp22 US, Genlab, England) and toasted at 110°C for 1 hour until a dry extruded breakfast cereal was obtained. The products were allowed to cool and packaged in an air-tight container



Figure 1. Sample of breakfast cereal produced.

Determination of Functional Properties of the Flour Blends

Bulk Density, Water and Oil Absorption Capacities were determined using the method described by Onwuka (2005). Swelling Capacity was determined using the method of Abbey and Ibeh (1988). Foaming capacity (FC) and Dispersibility were determined by the method of Coffman and Garcia (1977) and Kulkarni (1991).

For proximate analysis of the raw materials, the standard method described by AOAC (2005) was used to determine moisture content, crude fat, crude protein, Ash, crude fiber, and carbohydrate. while caloric value was calculated using the Atwater factor as described by Osborne and Voogt (1978). The mineral content was determined using the method described by Onwuka (2005).

Sensory Evaluation of Breakfast Cereal

Sensory characteristics of the coded breakfast cereals were evaluated for different sensory attributes by twenty (20) semi-trained panelists drawn from the Department of Food Science and Technology, University of Uyo, Uyo. The rating was on a nine-point hedonic scale ranging from 9 (like extremely) to 1 (dislike extremely) (Ihekoronye and Ngoddy, 1985).

Statistical Analysis

All the data were subjected to statistical analysis using Analysis of Variance (ANOVA). The means were then separated using the Duncan New Multiple Range Test (DMRT) using the Statistical Package for the Social Sciences (SPSS) 23.0 software.

Results and Discussion

Proximate Composition of Acha Flour, Broken Rice Flour, and Crayfish Flour

Rice has high levels of carbohydrates that contribute to energy value in foods and contribute to 75 % of the total energy (Bandarl *et al.*, 2024). However, rice is a poor source of other nutrients of interest. On the other hand, acha has protein, fat, fibre, ash and carbohydrate approximately 7 %, 2 %, 4.29 % and 77.25 % respectively Jideani and Jideani, (2011), while crayfish has protein, fat, fibre, ash, and carbohydrate approximately 77 %, 4.23%, 3.66 %, 5.89 %, and 8.93 % respectively (Tchouatang-de-Yaya *et al.*, 2022). Unlike rice and acha, crayfish are rich sources of protein, ash, fibre and contain a small amount of fat, which forms a source of energy for the human body. Thus, incorporating crayfish and acha into broken rice would be the next niche in tackling food insecurity. The study by Anaememe *et al.* (2024) reported proximate composition values for crayfish powder as follows: 6.22% moisture, 6.17% fat, 54.56% protein, 13.43% ash, and 18.81% carbohydrate. These values are notably higher than those observed in the current study. The differences in proximate composition between the two studies could be attributed to variations in the species or variety of crayfish used, as well as differences in processing methods, environmental factors, or analytical techniques. The moisture content of the broken rice (3.33 %) was significantly lower compared to acha (3.85 %) and crayfish (4.74 %), respectively. The low moisture content of the raw individual flours may be attributed to the drying to constant weight during the processing of their flours. The moisture content of the samples was low across all the raw materials used. Singh *et al.* (2023) reported that the acceptable moisture content of a food product must be less than or equal to 10 % moisture. The moisture content in the present study for the individual flours was less than 10 %, which could help in reducing the losses during storage and improve the shelf-life of the flour samples.

The protein content of broken rice (7.32 %) in the present study was significantly higher than (8.25 %) reported by Bandarl *et al.* (2024) for Broken basmati rice flour. Similarly, the protein content of acha (8.47 %) in the present study was slightly higher than 7.00 % reported by Jideani and Jideani (2011) for acha. Conversely, the protein content of crayfish in this study was 26.25 %, which was significantly lower than 77.00 % reported by

Tchouatang-de-Yaya *et al.* (2022). The high protein content was not surprising because crayfish is a rich source of protein with a good array of amino acids and minerals, as reported by Tchouatang-de-Yaya *et al.* (2022).

Fat content was low in all the flour samples. The fat content of broken rice (0.88 %), acha (2.24 %) and crayfish (3.12%) was significantly lower than that reported by Bandarl *et al.* (2024), Jideani and Jideani (2011) and Tchouatang-de-Yaya *et al.* (2022), respectively. The low fat observed in the present study showed that the individual raw materials are not good sources of fat.

Ash content is known to show the composition of total inorganic minerals in foods. Ash content of the broken rice in the present study was 2.69 %, which was significantly higher than 1.33 % reported by Bandarl *et al.* (2024) for broken basmati rice flour. Ash content of acha (2.76%) in the present study was significantly lower than 4.29 % reported by Jideani and Jideani (2011) for acha. Also, the ash content of crayfish in this study was 2.38 %, which was lower than 5.89% reported by Tchouatang-de-Yaya *et al.* (2022). The lower ash content of this present study could be due the the difference in the variety of the raw material

Fibre content in foods refers to the part of the diet that cannot be degraded by digestive enzymes but helps to improve the bulk of stool and protect the body from degenerative diseases (Otitolaiye *et al.*, 2021). Fibre content of broken rice flour (2.16 %), acha flour (2.76 %) and crayfish flour (0.97 %) in the present study was in agreement with the reports of Bandarl *et al.* (2024), Jideani and Jideani (2011) and Tchouatang-de-Yaya *et al.* (2022), respectively.

Carbohydrate content of broken rice (83.59 %), acha flour (79.99 %) and crayfish flour (62.52 %) in the present study was similar to the findings of Bandarl *et al.* (2024), Jideani and Jideani (2011) and Tchouatang-de-Yaya *et al.* (2022), respectively. The high carbohydrate content noticed in all the raw materials was because broken rice and acha are rich sources of carbohydrate. Crayfish is low in carbohydrates, signifying that crayfish is not a rich source of carbohydrates but of protein.

Table 4.1: Proximate Composition of Raw Materials

Sample	Moisture (%)	Protein (%)	Lipid (%)	Ash (%)	Fiber (%)	Carbohydrates (%)
Broken rice	3.33 ^c ±0.06	7.32 ^c ±0.03	0.88 ^c ±0.07	2.69 ^b ±0.03	2.16 ^b ±0.05	83.59 ^a ±0.06
Acha	3.85 ^b ±0.05	8.47 ^b ±0.02	2.24 ^b ±0.04	2.76 ^a ±0.04	2.67 ^a ±0.06	79.99 ^b ±0.05
Crayfish	4.74 ^a ±0.05	26.25 ^a ±0.05	3.12 ^a ±0.03	2.38 ^c ±0.06	0.97 ^c ±0.03	62.52 ^c ±0.07

Values are means of the triplicate determination ± standard deviation. Means with different superscripts in the same column are significantly (p<0.05) different

Functional properties of the flour blends from broken rice, acha and crayfish

Bulk density (BD) is a measure of heaviness of a flour sample, thus indicating that the relative volume of the composite flour in a package would not reduce excessively during storage (Alawode *et al.* 2017). The bulk density of this study for blends of broken rice, acha and crayfish (0.63-2.68 g/ml) was lower than reported for maize and cooking banana by Asouzu *et al.* (2020). Alawode *et al.* (2017) reported that high bulk density makes the flour suitable for use in food preparations. Therefore, this study shows that the high bulk density of the composite flour indicates suitability for use as a thickener in food products and for use in food preparation since it helps to reduce paste thickness, which is an important factor in convalescent and child feeding. The bulk density of the composite flours increased significantly as Acha and crayfish flour increased. Similar findings were reported by Adeyanju *et al.* (2021) for composite flour from wheat, African yam beans and acha flours. The foaming capacity of the flour samples in this study increased with increased incorporation levels of acha and crayfish flours in the formulation. The increase in the foaming capacity could be due to the protein content inherent in crayfish. The range of (20.67 – 45.67 %) for foaming capacity in the present study differs significantly from 9.11 - 12.92 % reported by Nawaza *et al.* (2015) for flour blends of refined wheat, maize and cowpea. Foaming capacity affects the consistency and appearance of foods. High foaming capacity implies a better continuous cohesion of the flour protein around air bubbles and this is very good for bakery products like cakes (Nawaza *et al.*, 2015).

The swelling capacity is an important factor used to determine the amount of water that food samples would absorb as well as the degree of swelling within a given time (Ijarotimi and Keshinro, 2012a). The swelling capacity (64.67 – 74.67 %) in the present-day study decreased with an increase in acha flour, possibly due to its low starch content. The swelling capacity (64.67 – 74.67 %) of this study was significantly higher than the range value (2.50-3.10 %) and (6.05-8.84 %) for blends of maize flour and almond and yellow maize, soybeans and jackfruit respectively as reported by Adesanmi *et al.* (2020) and Meka *et al.* (2019).

Water absorption capacity (WAC) is an index of the maximum amount of water that a food product would absorb and retain (Marero *et al.* 1988). A product can also be associated with water under a limiting water condition. WAC is desirable for food systems to improve yield and consistency. (Osundahunsi *et al.*, 2003). The water absorption capacity (1.66 – 2.33 ml/g) in the present study decreased with increasing quantity of acha and crayfish flour. The result of the WAC in the present study was within the same range of values (1.00 – 2.90 ml/g) reported by Obinna-Echem *et al.* (2020) for cowpea-tigernut flour blends. Water absorption characteristics represent the ability of a product to associate with water under conditions where water is limiting, such as dough and pastes.

Oil absorption capacity (OAC) of the flour blend is the ability of its protein to physically bind fat by capillary attraction and it is of great importance since fat is well known as a flavour retainer to increase the mouth-feels of foods (Omueti *et al.* 2009). Oil absorption capacity (OAC) of the flour samples decreased with increasing amount of acha and crayfish flours in the formula. Adesanmi *et al.* (2020) reported a higher range of (150.00-350.00 ml/g) for blends of maize and almond flour. However, the result for OAC in the present study was in

line with the findings (1.70 - 1.90 g/g) reported by Bello *et al.* (2019) for flour blends of sorghum, African yam bean and soybean.

Dispersibility in the study increased with increasing amounts of acha and crayfish flour blends in the formulation. The value of dispersibility (34.00 – 50.33 %) was similar to the findings of Adeyanju *et al.* (2021), who reported the dispersibility of 73.75–75.25 in wheat, African yam bean and acha flours. Dispersibility is an index that measures how well flour or flour blends can be rehydrated with water. The higher the dispersibility value of a flour blend, the better and easier the reconstitution of the flour (Adeyanju *et al.*, 2021). Since the dispersibility value for all the flour blends was relatively high, it implies that they will reconstitute easily into a fine, consistent dough during mixing.

Table 4.2: Functional Properties of the Composite Flours

Samples	Bulk density (g/ml)	WAC (ml/g)	OAC (ml/g)	Swelling capacity (%)	Forming capacity (%)	Dispersibility (%)
A	0.80 ^d ±0.01	2.33 ^a ±0.05	1.83 ^a ±0.05	74.67 ^a ±1.52	20.67 ^d ±0.57	34.00 ^d ±1.00
B	0.83 ^c ±0.01	2.06 ^b ±0.05	1.56 ^b ±0.05	71.33 ^b ±1.52	25.00 ^c ±2.00	42.67 ^c ±0.57
C	0.85 ^b ±0.01	1.76 ^c ±0.05	1.26 ^c ±0.05	68.00 ^c ±1.00	31.67 ^b ±1.52	47.33 ^b ±0.57
D	0.87 ^a ±0.01	1.66 ^d ±0.11	1.06 ^d ±0.05	64.67 ^d ±1.52	45.67 ^a ±0.57	50.33 ^a ±0.57

Values are means of the triplicate determination ± standard deviation. Means with different superscripts in the same column are significantly (p<0.05) different

Mineral composition of the breakfast cereals from broken rice, acha and crayfish

The mineral composition of the breakfast cereals showed an increase in mineral content with increasing levels of acha and crayfish flours. The magnesium content of this study (18.52 – 28.99 mg/100g) was significantly lower than (28.20 – 45.60 mg/100g) for local rice, African yam bean and coconut breakfast cereal reported by Edima-Nyah *et al.* (2019) and (184.62 – 207.87 mg/100g) reported by Odimegwu *et al.* (2019) for breakfast cereal samples made from blends of maize and jackfruit seed flours. Magnesium is an essential component of all cells and is necessary for the functioning of enzymes involved in energy utilization. It is also an important mineral in bone formation, especially in the presence of calcium (Ayuk *et al.*, 2019). As a cofactor with over 300 enzyme systems, it regulates diverse biochemical reactions in the body, including protein synthesis, muscle and nerve function, blood glucose control, and blood pressure regulation (Aydin *et al.*, 2010). The values for magnesium obtained in this study were appreciably higher (28.99 mg/100g) than the control (18.52 mg/100g), especially for the sample containing the highest number of crayfish (sample D). This means that crayfish contribute to improved magnesium content.

Potassium is necessary for the normal functioning of all cells. It regulates the heartbeats, ensures proper functioning of the muscles and nerves. However, excessive intake of potassium may upset homeostatic balance and cause toxic side effects (Parr *et al.*, 2012).

Gerlin *et al.* (2007) reported that potassium plays a key role in skeletal and smooth muscle contraction. The potassium content of the breakfast cereal increased with increasing levels of acha and crayfish flours. It was higher (63.12 – 115.22 mg/100g) than (70.62-78.53 mg/100g) reported by Odimegwu *et al.* (2019) for breakfast cereal samples made from blends of maize and jackfruit seed flours. This could be a result of the difference in the raw material. It is important to note that the potassium content reduced from 115.22 mg/100g in the control sample to 63.12 mg/100g in sample A. The calcium content of the breakfast cereal in the present day study increased with increasing levels of acha and crayfish flours and the value (33.93 – 35.69 mg/100g) was lower than (159.02-184.14 mg/100g) reported by Odimegwu *et al.* (2019) for breakfast cereal samples made from blends of maize and jackfruit seed flours and (110.22 – 195.65 mg/100g) reported by Edima-Nyah *et al.* (2019) for breakfast cereal from local rice, African yam bean and coconut flour blends. It was also lower than the US Recommended Daily Allowance-RDA (1000mg). Calcium is an essential macronutrient, and its deficiency is more prevalent than any other mineral (Kanu *et al.*, 2009).

The iron content (1.84 – 2.66 mg/100g) obtained in this study were lower than the values reported in breakfast cereal samples made from AYB, Maize and defatted coconut flour (9.81 – 14.10mg/100g) reported by Usman, (2012) and 13.46±1.74mg/100g for a breakfast cereal made from maize, sorghum, soybean and AYB composite flour reported by Agunbiade and Ojezele, (2010). The Iron content in the breakfast cereal samples was also lower than the US RDA (10-15mg/100g). Inadequate iron intake causes iron deficiency anemia (IDA), which is very common worldwide, especially in women and children in developing nations. Symptoms of iron deficiency include fatigue, weakness, and shortness of breath (Odimegwu *et al.*, 2019). The low iron content in this study could be due to the difference in the raw material used. Nutrient interaction in the formulation could also contribute to the difference in iron content in this study.

The result of the sodium content shows significant ($P < 0.05$) differences in the samples with values ranging from 1.73 in the control sample to 4.93 mg/100g in sample D. Higher values (97.5-187.3mg/100g) were reported for fortified breakfast cereals (Mbaeyi, 2005). These values were far less than the US RDA (500mg/100g). The generally low amount of sodium observed in the breakfast cereals could be attributed to the low amount of salt added during the preparation of the breakfast cereals. The control sample, however, had the least amount of sodium content compared to other formulated samples. Sodium is normally consumed as a form of salt, and it is essential in the regulation of water content and in the maintenance of osmotic pressure of the body fluid. It also aids in the transportation of CO_2 in the blood. However, sodium is one of the minerals whose intake is considered a factor in the etiology of hypertension, hence, its low intake is encouraged (Odimegwu *et al.* 2019). Manganese content (18.52 – 22.35 mg/100g) of the breakfast cereals was significantly lower than the US RDA (38 mg/100g), although it competes favourably with the standard. The control sample had the least amount of manganese content compared to other formulated samples. This could be attributed to the composition of the raw material used for the production of the breakfast cereals

Table 4.3: Mineral Composition of Breakfast Cereals

Samples	Potassium (Mg/100g)	Calcium (Mg/100g)	Iron (Mg/100g)	Sodium (Mg/100g)	Manganese (Mg/100g)	Magnesium (Mg/100g)
A	63.12 ^e ±0.03	33.93 ^e ±0.04	1.84 ^e ±0.04	3.14 ^d ±0.56	2.87 ^a ±0.03	22.35 ^d ±0.04
B	67.49 ^d ±0.03	35.69 ^d ±0.01	2.50 ^d ±0.03	3.75 ^c ±0.04	2.15 ^b ±0.05	25.13 ^c ±0.05
C	74.26 ^c ±0.04	36.87 ^c ±0.06	2.87 ^b ±0.06	4.42 ^b ±0.04	1.62 ^c ±0.04	27.15 ^b ±0.05
D	76.65 ^b ±0.05	38.14 ^b ±0.04	3.65 ^a ±0.05	4.93 ^a ±0.03	1.11 ^d ±0.02	28.99 ^a ±0.05
E	115.22 ^a ±0.03	94.26 ^a ±0.05	3.66 ^c ±0.03	1.73 ^e ±0.07	0.83 ^e ±0.05	18.52 ^e ±0.04

Values are means of the triplicate determination ± standard deviation. Means with different superscripts in the same column are significantly (p<0.05) different

Sensory Properties of the Breakfast Cereals Produced from Broken Rice, Acha and Crayfish

Sensory analysis includes all the sensations that a person may experience when holding or eating food. It is also used to determine the texture of foods (Bello *et al.*, 2020). Kim *et al.* (2009) reported that the sensory characteristics of cereal snack bars go a long way to influence the acceptability of the product by consumers. Sample E golden more (control) was best accepted in taste, colour, appearance, consistency, mouthfeel and overall acceptability. This is because the panelists are more familiar with the product. Sample D (50% broken rice, 40% acha, 10% crayfish) showed superiority in taste and flavour. This may be due to the moderate protein level improving the structure of acha and crayfish without overpowering the starch level of the broken rice, leading to a better taste and flavour than other formulated samples. Edima-Nyah *et al.* (2019) reported a sensory score for appearance (5.00-6.93), taste (5.36-7.56), texture (5.96-7.30) and overall acceptability (5.63-7.80) for local rice, African yam bean and coconut breakfast cereal which were within the range observed in this study. On the whole, Consumer quality is a major factor for selecting a product, and among the main characteristics related to quality are appearance, aroma, texture, taste, and the general acceptability of the breakfast cereals (Omoba and Omogbemile, 2013). This product could be developed into a low-cost, nutritious breakfast alternative for school feeding programs in rural areas. Its use of locally available ingredients like broken rice and crayfish supports smallholder economies and reduces food waste.

Table 4.5: Sensory Properties of Breakfast Cereals

Samples	Taste	Colour	Appearance	Consistency	Mouthfeel	Flavour	Overall acceptability
A	5.30 ^b ±2.08	6.20 ^b ±1.24	5.95 ^b ±1.39	5.20 ^b ±2.04	5.35 ^b ±1.75	5.05 ^b ±2.13	5.85 ^b ±2.15
B	5.15 ^b ±2.34	5.95 ^b ±1.63	5.30 ^b ±1.80	4.70 ^b ±2.36	4.70 ^b ±2.40	4.60 ^b ±2.23	5.15 ^b ±2.27
C	5.60 ^b ±1.87	5.50 ^b ±1.60	5.70 ^b ±1.30	4.80 ^b ±2.04	5.05 ^b ±2.06	5.20 ^b ±1.85	5.45 ^b ±1.76
D	5.90 ^b ±1.80	6.20 ^b ±1.24	5.65 ^b ±1.75	4.95 ^b ±2.06	5.05 ^b ±1.93	5.45 ^b ±2.06	6.10 ^b ±1.88
E	8.25 ^a ±0.55	8.05 ^a ±0.60	8.00 ^a ±0.72	7.85 ^a ±0.87	8.15 ^a ±0.67	8.00 ^a ±0.97	8.50 ^a ±0.51

Values are means of the triplicate determination $\pm$ standard deviation. Means with different superscripts in the same column are significantly ($p < 0.05$) different

Conclusion

The goal of this study was to develop high high-quality breakfast cereal that is healthy, easy to eat, with good sensory attributes, thereby bridging the gap in the incorporation of local raw materials like acha and crayfish in the production of breakfast cereal. The use of underutilized and locally available ingredients provides a cost-effective approach for small-scale food producers, especially in regions where these raw materials are abundant and affordable. The inclination of consumers is steadily shifting from high-calorie and fat-based snacks to high-protein and fibre snacks, prompting a call for this study. From the research, it can be concluded that flour can be produced from broken rice, acha, and crayfish, using different blending ratios, which can be used to produce high-quality breakfast cereals from their blends with desirable and acceptable sensory attributes. Broken grains have low protein contents, and the study found that adding acha and crayfish to breakfast cereals made with these ingredients can enhance the breakfast cereal's nutritional value. The findings of the study will provide a guide for commercial breakfast cereals for food companies and household food producers to produce high-nutritional and acceptable breakfast cereals with lower production costs. Also, a combination of cereals and crayfish flour blend will increase the utilization of neglected crops (broken rice and acha) as well as ensure healthy quality snacks such as breakfast cereals, which, due to the abundance of nutrients, can help in countering protein energy malnutrition, especially in developing countries. Future studies should investigate the long-term shelf stability of the crayfish-enriched cereal under various packaging conditions. Additionally, consumer acceptability tests should be conducted on a larger and more diverse panel.

Recommendations

The following are recommended;

- Further research may also explore the possibility of fortifying the product with essential vitamins such as A and D, as well as the shelf stability to enhance its nutritional value.
- It is important that further research be recommended to advise policy makers and planners to advise farmers on the planting of appropriate cultivars of acha as raw materials for food industries, which will also encourage the utilization and availability all year round and for industrial purposes.
- Good manufacturing and good hygienic practices should be of utmost importance during production and storage to avoid microbial contamination of any form that any lead to foodborne diseases.

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