



Formulation and Quality Evaluation of Breakfast Cereals from Acha, Bambara Groundnut and Carrot Composite Flours

**Okoye, J. I. ^{a*}, Igwego, N. G. ^a, Ajawobu, I. O. ^b
and Onwuchuruba–Nwadike, S. C. ^c**

^a *Department of Food Science and Technology, Enugu State University of Science and Technology, Enugu, Nigeria.*

^b *Department of Pharmaceutical and Medicinal Chemistry, Faculty of Pharmaceutical Sciences, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria*

^c *Sm-Jendil Enterprises Ltd, Ogidi, Anambra State, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: <https://doi.org/10.9734/acri/2025/v25i41172>

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://pr.sdiarticle5.com/review-history/132321>

Original Research Article

Received: 29/01/2025

Accepted: 31/03/2025

Published: 16/04/2025

ABSTRACT

The aim of this present study was to evaluate the proximate composition, microbiological, functional and pasting properties of breakfast cereals produced from acha, Bambara groundnut and carrot flour blends. Breakfast is regarded as the most important meal of the day because food consumed at breakfast seems to be more utilized than the same amount eaten at night. Breakfast

*Corresponding author: Email: okoyejoseph6@gmail.com;

cereals are commonly known as foods which have been fully or partially prepared that may need to be reconstituted, preheated in a vessel or allowed to thaw if frozen before consumption or eaten directly without further treatment. Acha grains, Bambara groundnut seeds and carrot fruits which were sourced locally were separately processed into flours. The Bambara groundnut and carrot flours were used at varying replacement levels (5-30%) with malted acha flour to produce breakfast cereals with the breakfast cereal produced from 100% malted acha flour as control. The proximate composition, microbiological, functional and pasting properties of the breakfast cereal products were determined using standard methods. The proximate composition of the samples revealed that the moisture, crude protein, fat, ash and crude fibre contents of the products increased significantly ($p < 0.05$) with increased substitution of Bambara groundnut and carrot flours, while the carbohydrate and energy contents decreased. The microbial counts of the breakfast cereals showed that the total viable count ranged from 0.50×10^4 to 1.60×10^4 cfu/g, while the coliform and fungal counts were nil. The functional properties also showed that the bulk density, solubility index, water absorption, oil absorption and foam capacities of the samples increased significantly ($p < 0.05$) with increase in the addition of Bambara groundnut and carrot flours, while the gelation and swelling capacities decreased. The pasting properties (peak, trough, breakdown, setback and final viscosities), as well as the peak time and pasting temperature of the samples, also increased significantly ($p < 0.05$) with increased substitution of Bambara groundnut and carrot flours from 37.15 to 92.83 RVU, 58.15 to 116.70 RVU, 48.89 to 91.05 RVU, 38.27 to 88.28 RVU, 63.03 to 93.53 RVU, 7.73 to 8.85 min and 31.17 to 98.37°C, respectively. The study, therefore, revealed that the addition of Bambara groundnut and carrot flours to acha flour at the levels of 20 to 30 % in the preparation of breakfast cereals increased the crude protein, fat, ash and crude fibre contents as well as the pasting and some functional properties of the composite flour breakfast cereals compared to the control.

Keywords: Breakfast cereals; acha flour; Bambara groundnut flour; food components; functional foods.

1. INTRODUCTION

Breakfast cereals are regarded as foods which have been fully or partially prepared, in which significant preparatory input, culinary skills and energy have been transferred from the home maker's kitchen to the food processor's factory. Such foods may need to be reconstituted, preheated in a vessel or allowed to thaw if frozen before consumption (Ahmadu et al., 2023) or eaten directly without further treatment (Okoye et al., 2023). Breakfast cereals contain bioactive compounds which make them to be considered as functional foods. Functional foods are defined as foods that not only fulfill their basic nutritional functions, but also benefit the body by improving health and reducing the risk of diseases (Adeoye et al., 2019). Functional foods are foods and food components that have health benefits beyond their basic nutrition. Although these foods are similar in appearance to conventional foods, functional foods are consumed as part of the normal diet. Functional foods supply the body with the needed amount of vitamins, fats, proteins and carbohydrates, etc that are required for its healthy survival (Nwadi et al., 2020). It is vital for our body and mind to eat breakfast because the brain and muscles would be short of

caloric energy to work after 8 – 12 h without food. The typical Nigerian diet contains foods that are mainly focused on carbohydrates. There is therefore, the need for strategic use of inexpensive sources of high quality protein that would complement the staple diet's amino acid profile to increase its nutritional value. Protein deficiency has become a dietary issue facing the world, particularly in underdeveloped and developing countries (Olurin et al., 2021; Nwankwegu and Mbaeyi-Nwachua, 2024).

Breakfast is one of the most important meals of the day which comes after several hours of night fasting and it is literally known as "break the fast". Several epidemiological and intervention studies have shown the major role of breakfast consumption in the maintenance of cardiovascular health and the improvement of cognitive functions (Clayton and James, 2016).

Breakfast is the first meal of the day which is used to break the fast after a prolonged period of sleep and it is consumed within 2 to 3 h of waking. It is also comprised of food or beverage from at least one food group and may be consumed at any location.

Nutritionists have referred to breakfast as the most important meal of the day because food consumed at the breakfast seems to be more utilized than the same amount eaten at night. Most researchers who have studied the effect of eating breakfast have suggested that the benefits are mainly due to the protein that is eaten from the meal because high protein breakfasts were found to be better than low protein breakfast in helping to maintain a normal blood sugar level between mid-morning and lunch (O'Neil et al., 2014; Adeoye et al., 2019; Odimegwu et al., 2019). Breakfast is basically produced from cereals which are the dry seeds of those members of the grass family grown for their grains and are by far the most important plants eaten by man. Cereal is typically a low-fat, nutrient-dense food with many essential vitamins and minerals such as zinc, phosphorus, calcium among others. In addition to supplying important nutrients and essential vitamins such as iron, B-vitamins and magnesium, cereals also provide the important benefits of grains. Breakfast cereal could be defined as a dry cereal eaten at breakfast which has been processed into different forms by soaking, swelling, roasting, grinding, rolling, flaking, shredding or puffing of any cereal and is eaten as breakfast. Breakfast cereal which consists of vegetable protein foods (bread, cereals and soybean milk) has been reported to be as effective as those that are made mostly of animal protein foods (eggs, meat and milk) in keeping the blood at a normal level (O'Neil et al., 2014; Qaku et al., 2020). The level of protein eaten as breakfast cereal may depend partly upon the amount supplied by the cereal.

Breakfast cereal products were originally sold as milled grains of wheat and oats that required further cooking in the home before consumption. In recent times, due to efforts to reduce the amount of in-home preparation time, breakfast cereal technology has evolved from the simple procedure of milling of grains for cereal products that require cooking to the production of highly sophisticated ready-to-eat products that are convenient and quickly prepared (Clayton and James, 2016; Okoye et al., 2025).

Composite flour can be defined as a mixture of different ratios of non-wheat flours that are obtained from roots, tubers, cereals, legumes, oil seeds, fruits and vegetables, etc with or without the addition of wheat flour (Nwankwegu and Mbaeyi-Nwaoha, 2024). They are considered to be beneficial in developing countries because they help to reduce over-dependence on

imported wheat flour and also encourage the utilization of locally grown food crops as flours.

Acha (*Digitaria exilis*) is one of the fastest-growing cereal grains that is highly nutritious. It is a cereal crop of West African origin that has been cultivated in various parts of Nigeria, Sierra Leone, Ghana, Guinea Bissau, Senegal, Togo, Mali, Benin Republic and Cote' d'Ivoire (Agu et al., 2015). This cereal crop has various local names such as fundi, findi, acha, or "hungry rice". It is highly rich in carbohydrate and protein as well as Sulphur-containing essential amino acids such as methionine and cystine compared to legumes (Belton and Taylor, 2002; Vodouhé et al., 2012). The mineral elements that are present in acha are zinc, manganese, magnesium and potassium, while the vitamins which are found naturally in acha are thiamine (vitamin B₁) and riboflavin (vitamin B₂) (Ayo et al., 2007). Acha is a cereal grain with very tiny seeds which possess difficulty in processing but is rich in amino acids and need to be supplemented with a legume for higher nutrient-dense product (Vodouhe et al., 2012). It is a traditional cereal crop of West Africa that is very popular because it is well adapted to local conditions and has good nutritional and culinary properties (Mbosso et al., 2020). Acha is one of the oldest and richest cereals of West Africa that is not well known to many people. It can be adapted to poor soils and limited water supply. It is an excellent dry area crop which grows and produces where other crops fail (Vodouhe et al., 2012). Acha has the potential to boost food security, improve nutrition, foster rural development and support sustainable use of land (Ayo et al., 2007; Anon, 2012).

Bambara groundnut (*Vigna subterranean* (L.) Verdc.) is an indigenous underutilized legume that is grown throughout the sub-Sahara African countries nowadays (Mkandawire, 2007; Okonkwo and Opara, 2010; Bamshaiye et al., 2011). It can grow under conditions that is unsuitable for groundnut. It is resistant to pests and diseases, and is also has high tolerance to drought and poor soil where many other leguminous crops cannot thrive. Bambara groundnut is a relatively rich source of dietary protein, especially when animal proteins are very limited or unavailable. When compared to other legumes, Bambara groundnut is rich in iron and its protein contains high amounts of lysine and methionine and can therefore complement cereals in the formulation of foods such as breakfast cereals and snacks (Awolu et al., 2017; Chude et al., 2018). Bambara groundnut seeds

are highly nutritious, thereby making them relevant in the nutritional formulation of foods for people that cannot afford expensive protein sources, especially animal-based proteins (Nddi et al., 2014). The seeds have a higher content of high quality amino acids such as arginine, leucine, valine, methionine and lysine when compared to cowpea, soybean and groundnut which may potentially complement the deficient essential amino acid contents in cereal-based foods (Mazahib et al., 2013).

Carrots (*Daucus carota* L.) are the most important crop of *Apiaceae* family. It is a root vegetable that is scattered all over the world which is also regarded as good source of fibre and bioactive compounds including β -carotene which manifests as a neutralizer of reactive species and also a precursor of retinol (vitamin A) (Stahl, 2016). It also contains vitamins such as vitamin K, ascorbic acid, thiamine, riboflavin, pyridoxine and folate which are necessary for the metabolism of carbohydrate and protein and the maintenance of healthy growth in the human body (USDHHS, 2010; Dias, 2012a; Dias, 2012b). Carrots like many other coloured vegetables are rich in antioxidants. The carotenoids, polyphenols and vitamins which are naturally present in carrots act as antioxidants, anticarcinogens and immune inducers in the human body (Calderaro et al., 2020). Antioxidants found in carrots and other vegetables play a significant role in the prevention of oxidative stress-related diseases such as cancer and cardiovascular diseases through the reduction in oxidative potential or increase in the production of oxygen or nitrogen radicals (Domej et al., 2014; Calderaro et al., 2020). Thus, the combination of acha, Bambara groundnut and carrot flours in the production of breakfast cereals would not only improve their nutrient contents but would also increase the quality of such food products. The objective of this study was to evaluate the proximate, microbiological, functional and pasting properties of acha-based breakfast cereals enriched with Bambara groundnut and carrot flours.

2. MATERIALS AND METHODS

2.1 Procurement of Raw Materials

Mature acha (*Digitaria exilis*) grains, cream variety of Bambara groundnut (*Vigna subterranea* L.) seeds and carrots (*Daucus carota* L.) used for this study were purchased from Ose Okwodu Market, Onitsha, Anambra

State, Nigeria. The chemicals used for the analyses of the samples were of the analytical grade.

2.2 Preparation of Acha Flour

The malted acha flour was prepared according to the method described by Mbaeyi-Nwaoha and Uchendu (2016) with slight modifications. Three kilograms (3kg) of acha grains was manually sorted to remove dirt and other extraneous materials. The sorted grains were cleaned with 2.5 liters of tap water for 20 min and steeped in a plastic bowl with 3.5litres of tap water containing 5% of Sodium hypochlorite in a ratio of 1:3 for 24 h at room temperature ($30\pm 2^{\circ}\text{C}$) to disinfect the grains. After that, the soaked grains were drained, rinsed repeatedly five times with excess water and cast on a wet jute bag, covered with a polyethylene bag and left for 24 h to accelerate sprouting. The sprouted grains were spread carefully on the wet jute bag and allowed to germinate in the germinating chamber at room temperature ($30\pm 2^{\circ}\text{C}$) and relative humidity of 95% for 96 h. The sprouted grains were sprinkled with water at intervals of 6 h to facilitate germination. Non-germinated grains were handpicked and discarded. The germinated grains were collected, spread on the trays and dried in a tray dryer (Model HR 6200, UK) at 60°C for 12 h with occasional stirring of the grains at intervals of 30 min to ensure uniform drying. The rootlets of the dried malted acha grains were removed by rubbing them in-between palms followed by winnowing. The dried malted acha grains were milled in the hammer mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an air-tight plastic container, labelled and stored in a refrigerator until needed for further use.

2.3 Preparation of Bambara Groundnut Flour

The malted Bambara groundnut flour was prepared according to the method described by Nwadi et al. (2020) with slight modifications. Two kilograms (2kg) of Bambara groundnut seeds was sorted manually to remove dirt and other extraneous materials. The sorted seeds were cleaned with 3 liters of tap water and steeped in a plastic bowl with 3.5litres of tap water containing 5% of Sodium hypochlorite in a ratio of 1:3 for 24 h at room temperature ($30\pm 2^{\circ}\text{C}$) to disinfect the seeds. Thereafter, the soaked seeds were drained, rinsed repeatedly five times with excess water and cast on a wet jute bag,

covered with a polyethylene bag and left for 24 h to accelerate sprouting. The sprouted seeds were spread carefully on the wet jute bag and allowed to germinate in the germinating chamber at room temperature ($30\pm 2^{\circ}\text{C}$) and relative humidity of 95% for 96 h. The sprouted seeds were sprinkled with water at intervals of 6 h to facilitate germination. Non-germinated seeds were handpicked and discarded. The germinated seeds were collected, spread on the trays and dried in a tray dryer (Model HR 6200, UK) at 60°C for 14 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The rootlets of the dried malted Bambara groundnut seeds were removed along with the hulls by rubbing them in-between palms followed by winnowing. The dried malted Bambara groundnut seeds were milled in the hammer mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an air-tight plastic container, labelled and stored in a refrigerator until needed for further use.

2.4 Preparation of Carrot Flour

The carrot flour was prepared according to the method described by Okoye et al. (2025) with slight modifications. Three kilograms (3kg) of carrot fruits was manually sorted to remove dirt and other contaminants. The sorted carrots were cleaned with 2.5 liters of tap water and cut into smaller slices with a kitchen knife. The carrot slices were rinsed, placed into a stainless-steel pot and blanched with 3 liters of tap water at 80°C for 10 min on a hot plate. The blanched carrot slices were drained, rinsed, spread on the trays and dried in a tray dryer (Model HR 6200, UK) at 60°C for 10 h with occasional stirring of the slices at intervals of 30 min to ensure uniform drying. After drying, the carrot slices were milled in the hammer mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an air-tight plastic container, labelled and stored in a refrigerator until needed for further use.

2.5 Formulation of Flour Blends

Malted acha flour was mixed thoroughly with Bambara groundnut and carrot flours in varied proportions of 100:0:0, 85:10:5, 80:15:5, 70:20:10, 60:25:15 and 50:30:20, respectively in a rotary mixer (Philips, type HR, 1500A Holland) to obtain homogenous samples of composite flour. The composite flours produced were separately packaged in air-tight plastic containers, labelled and stored in a refrigerator

until needed for the preparation of breakfast cereals.

2.6 Preparation of Shredded Breakfast Cereals

The shredded breakfast cereals were prepared according to the method described by Ishiwu et al. (2019) with slight modifications. The shredded breakfast cereals were prepared by mixing the composite flours with small quantity of water, sugar and salt so as to obtain a homogenous mixture. The mixture was steamed individually for 10 min and then allowed to age at a temperature of 4°C for 6 h in a plastic bowl. The resultant doughs were separately cut into smaller sizes using a manually operated hand extruder. Thereafter, the dough pieces obtained were placed separately into flat greased baking trays and toasted in an electric oven (Gallenkamp oven, size one, England) at a temperature of 120°C for 1 h. After that, the products were separately shredded using a manual wooden roller. The shredded breakfast cereals produced were allowed to cool at room temperature ($30\pm 2^{\circ}\text{C}$). After cooling, they were packaged separately in air-tight plastic containers, labelled and stored in a refrigerator until needed for analysis. Breakfast cereal produced using the same procedure from 100% malted acha flour was used as control.

2.7 Proximate Analysis

The moisture, crude protein, ash, fat and crude fibre contents of the samples were determined on dry weight basis according to the standard analytical methods of AOAC (2016). The carbohydrate content was calculated by difference. $\% \text{ Carbohydrate} = 100\% - (\% \text{ Moisture} + \% \text{ Crude Protein} + \% \text{ Ash} + \% \text{ Fat} + \% \text{ Crude Fibre})$. The energy content was calculated by multiplying the percentage values of crude protein, fat and carbohydrate by the Atwater factors of 4, 9 and 4, respectively (AOAC, 2016). All determinations were carried out in triplicate samples.

2.8 Microbiological Evaluation

The total viable count, coliform and fungal counts of each sample were determined in triplicate using the pour plate culture method described by James (2003). Two grams (2g) of each sample was weighed and poured into a sterile test tube. Nine milliliters (9mL) of Ringer solution was poured into it and also into other test tubes that

were arranged for serial dilution. The sample with the solution was homogenized by shaking. After that, one milliliter (1 mL) of the homogenized sample solution was pipetted into the test tube and used for serial dilution. One milliliter (1mL) of each dilution was pipetted and transferred into the sterile petri dish and 20mL of sterile Nutrient agar was poured into the same petri dish. The mixture was thoroughly mixed together by rocking using hand until it was solidified. When it solidified, it was turned upside down and cultured by incubating at a temperature of 37°C for 24 h. At the end of the incubation period, the colonies formed were counted using a digital electronic colony counter (Gallenkamp colony counter, Model CNW 330-010X, China) and the mean values of the colonies were separately recorded accordingly.

The above procedure was repeated for coliform and fungal counts except that MacConkey agar was used in place of Nutrient agar for coliform count and samples were incubated at 37°C for 96 h, whereas Potato dextrose agar was used for fungal count and incubation was done at 37°C for 120 h. After incubation, the colonies formed were counted using the same digital electronic colony counter (Gallenkamp colony counter, Model CNW 330-010X, China) and the mean values of the colonies were separately recorded in each case.

2.9 Functional Properties

The bulk density, solubility index and gelation capacity of the samples were determined on dry weight basis according to the methods of AOAC (2016). The water and oil absorption capacities were determined according to the methods described by Asaam et al. (2018). The foam and swelling capacities were determined using the methods described by Eze et al. (2024). All determinations were carried out in triplicate samples.

2.10 Pasting Properties

The pasting properties of the samples were determined using Rapid Visco Analyzer (RVA) (Model Newport Scientific Property Limited, Warne-Wood NSW 2012, Australia) according to the method of AOAC (2016). The pasting properties of the samples were read from the pasting profile with the aid of thermocytline for windows software that was connected to a computer. All determinations were carried out in triplicate samples.

2.11 Statistical Analysis

The data generated were subjected to one-way analysis of variance (ANOVA) using Statistical Package for Service Solution (SPSS, Version 21) software. Significant means were separated using the Tukey's test at $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of Breakfast Cereal Samples

The proximate composition of the breakfast cereals are presented in Table 1.

The moisture content of the breakfast cereals ranged from 6.18 to 7.31%. The control (Breakfast cereal made with 100% malted acha flour) had the least moisture content (6.18%), while the sample substituted with 30% malted Bambara groundnut and 20% carrot flours had the highest value (7.31%). There were significant ($p < 0.05$) differences in the moisture content of the samples. The differences in the moisture content of the samples could be attributed to variation in the moisture contents of the raw materials used for the preparation of the breakfast cereal products. The moisture content (6.18 to 7.31%) obtained in this study was lower than the values (6.71 to 9.88%) reported by Mbaeyi-Nwaoha and Uchendu (2016) for breakfast cereals made from blends of acha and fermented soybean paste (okara). The low moisture content reported in this study would be highly beneficial because the reduction in moisture content has the potential to reduce the growth and proliferation of spoilage and pathogenic micro-organisms especially bacteria and moulds, thereby resulting in the extension of the shelf life of the products during storage (James et al., 2018).

The protein content of the breakfast cereals ranged from 9.17 to 22.91%. The result showed that the control (Breakfast cereal made with 100% malted acha flour) had the least value (9.17%) compared to the formulated breakfast cereal samples supplemented with various proportions of Bambara groundnut and carrot flours. The protein content of the samples was observed to increase with increased substitution of malted Bambara groundnut flour. This observation is in agreement with the reports that Bambara groundnut has the potential to improve the protein contents of cereal-based products (Dikshit et al., 2003; Maphosa and Jideani,

2007). The protein content (9.17 to 22.91%) obtained in this study was lower than the values (9.00 to 33.53%) reported by Mbaeyi-Nwaoha and Uchendu (2016) for breakfast cereals made from blends of acha and fermented soybean paste (okara). The result showed that the increase in the addition of the Bambara groundnut flour led to a significant increase in the protein content of the products. This clearly demonstrated that the composite flour breakfast cereals produced in this study would serve as a good source of protein because it has been reported that plant proteins contribute reasonable amount of amino acids that are essential in human nutrition ((Makame et al., 2019; Hussin et al., 2020). Proteins are important in the production of new cells, enzymes and hormones in the human body (Chude et al., 2018).

The fat content of the breakfast cereals ranged from 6.09 to 7.22%. There were significant ($p < 0.05$) differences in the fat content of the samples. The result showed that the fat content of the control (Breakfast cereal made with 100% malted acha flour) was significantly ($p < 0.05$) lower than the fat contents of all the composite flour breakfast cereal products produced in this study. The sample supplemented with 30% Bambara groundnut and 20% carrot flours had the highest fat content compared to the control. The result is in agreement with the findings of Mbaeyi (2005) for breakfast cereals made from blends of sorghum and pigeon pea flour. The values (6.09 to 7.22%) obtained in this study were lower than the fat content (8.70 to 14.20%) reported by Agu et al. (2015) for breakfast cereals produced from malted acha and soybean flour blends. The result also showed that the fat contents of all the formulated breakfast cereal samples were generally higher than that of the control. The relatively-low fat contents of the breakfast cereal products produced in this study would guarantee the extension of their shelf life by preventing the development of rancidity and other deteriorative changes during the storage of the products (Ajibade and Ijabadeniyi, 2019). Fat is an important component of tissues and is also regarded as a vital source of fat-soluble vitamins in human diets (Rousseau et al. 2020).

The ash content of the breakfast cereals ranged from 3.20 to 4.86%. The result revealed that the control (Breakfast cereal made with 100% malted acha flour) and the sample substituted with 30% malted Bambara groundnut and 20% carrot flours had the least (3.20%) and highest (4.86%) values, respectively. The ash content (3.20 to

4.86%) obtained in this study was higher than the values (1.36 to 2.44%) reported by Agunbiade and Ojezele (2010) for instant breakfast meals produced from maize, sorghum, soybean and African yam bean composite flours. The increase in the ash content observed in the composite flour breakfast cereal samples could be attributed to high mineral contents of Bambara groundnut and carrot flours used for the preparation of the breakfast cereal products. The high ash content of the product would be of immense benefit nutritionally because it would help in the metabolism of other macro-nutrients such as protein, fat and carbohydrate when consumed and utilized by the body (Agu et al., 2015; Asaam et al., 2018).

The crude fibre content of the breakfast cereals ranged from 3.37 to 4.89%. The result showed that the control (Breakfast cereal made with 100% malted acha flour) and the sample enriched with 30% Bambara groundnut and 20% carrot flours had the least (3.37%) and highest (4.89%) values, respectively. The crude fibre content of the samples was observed to increase with increased substitution of malted Bambara groundnut and carrot flours and this is an indication that Bambara groundnuts and carrots are rich sources of dietary fibre (Chau et al., 2004; Afolabi et al., 2018). Fibre helps in the absorption of some micro-nutrients and also has the potential to increase the utilization of nitrogen in the body (Okaka et al., 2006). It equally plays an important role in the maintenance of moist and soft condition of faecal mass which in turn facilitates the easy passage of it through the bowel of large intestine in the human body (Onwuama et al., 2023). Crude fibre slows down the release of glucose into the blood and decreases the intercolonic pressure, thereby reducing the risk of colon cancer in humans (Folake and Bolanle, 2006; Awobusuyi and Siwela, 2019).

The carbohydrate content of the breakfast cereals ranged from 52.79 to 71.97%. The result revealed that the control (Breakfast cereal made with 100% malted acha flour) had the highest value (71.97%), while the sample substituted with 30% malted Bambara groundnut and 20% carrot flours had the least carbohydrate content (52.79%). The result showed that there was a slight decrease in the carbohydrate content of the composite flour breakfast cereal products with increased substitution of malted Bambara groundnut and carrot flours compared to the control. The variation in the carbohydrate content

could be due to differences in the composition of the raw materials used for the formulation of the breakfast cereals (Awobusuyi and Siwela, 2019). The values (52.79 to 71.97%) obtained in this study were higher than the carbohydrate content (59.99 to 62.31%) reported by Mbaeyi (2005) for breakfast cereals produced from blends of sorghum and pigeon pea flour. Carbohydrate provides the body with glucose, which when converted to energy, is used to support physical activity as well as physiological functions in the human body (Hussin et al., 2020).

The energy content of the breakfast cereals ranged from 367.86 to 379.43 kJ/100g. The result showed that the control (Breakfast cereal made with 100% malted acha flour) and the sample substituted with 30% malted Bambara groundnut and 20% carrot flours had the highest (379.43 kJ/100g) and lowest values (367.86 kJ/100g), respectively. The energy value of the samples decreased significantly ($p < 0.05$) with increased substitution of malted Bambara groundnut and carrot flours. The low energy values of the composite flour breakfast cereals produced in this study compared to the control could be probably due to reduction in their carbohydrate contents and the volatility of other energy - yielding nutrients like fat during the preparation of the samples (Ahmadu et al., 2023; Okoye et al., 2025). Similar decrease in energy value (339.47 to 326.63 kJ/100g) has been reported by Mbaeyi (2005) for breakfast cereals made from blends of sorghum and pigeon pea flour. Energy value represents the amount of energy in the food that can be supplied to the body for the maintenance of basic body functions (Afolabi et al., 2018; Rousseeau et al., 2020).

The substitution of malted acha flour with malted Bambara groundnut and carrot flours in the production of breakfast cereals generally increased the protein, fat, ash and crude fibre contents of the products.

3.2 Microbial Counts of Breakfast Cereal Samples

The microbial counts of the breakfast cereal samples are presented in Table 2.

The total viable count of breakfast cereals ranged from 0.50×10^4 to 1.60×10^4 cfu/g. The control (Breakfast cereal made with 100% malted acha flour) and the sample substituted with 30% malted Bambara groundnut and 20% carrot flours had the least (0.50×10^4 cfu/g) and highest

(1.60×10^4 cfu/g) values, respectively. The values (0.50×10^4 to 1.60×10^4 cfu/g) obtained in this study were higher than the total viable count (0.50 to 1.51×10^4 cfu/g) reported by Usman (2012) for breakfast cereals produced from African yam bean, maize and defatted coconut flour blends but lower than the values (0.30 to 0.9×10^4 cfu/g) reported by Mbaeyi-Nwaoha and Uchendu (2016) for breakfast cereals produced from blends of acha and fermented soybean paste (okara). The result showed that the increase in the addition of the malted Bambara groundnut flour resulted in a significant increase in the total viable count of the composite flour breakfast cereals compared to the control. This increase could be attributed to the increase in the protein content of Bambara groundnut flour used for the preparation of composite flour breakfast cereal products which has the tendency to encourage the growth and proliferation of spoilage bacteria in the products. The microbial count obtained in this study was within the recommended safe limit (10^2 to 10^5 cfu/g) of the total viable count specified for ready-to-eat foods (ICMSF, 2002).

In addition, the result also showed that no traces of both coliform bacteria and fungi were found in the entire samples. Generally, the total viable count of the samples was relatively low. This implies that the breakfast cereal products produced in this study were safe and would also be stored for a long period of time when kept under good storage conditions. The low level of the total viable count of all the samples reported in this present study showed that the production of the breakfast cereal products was carried out in a hygienic environment and clean containers were also used for their storage after production.

Micro-organisms are important in the determination of shelf life of food products. They are usually responsible for the spoilage of many food products (Okoye et al., 2025).

3.3 Functional Properties of Breakfast Cereal Samples

The functional properties of the breakfast cereal samples are presented in Table 3.

The bulk density of the breakfast cereals ranged from 0.46 to 1.22 g/cm³. The control (Breakfast cereal made with 100% malted acha flour) and the sample enriched with 30% malted Bambara groundnut and 20% carrot flours had the least

(0.46g/cm³) and highest (1.22g/cm³) values, respectively. The values (0.46 to 1.22g/cm³) obtained in this study were lower than the bulk density (2.45 to 2.60g/cm³) reported by Agunbiade and Ojezele (2010) for instant breakfast meals produced from maize, sorghum, soybean and African yam bean composite flours. The result showed that the bulk density of the samples increased significantly ($p < 0.05$) with increased substitution of malted Bambara groundnut and carrot flours. The bulk density of a food material is dependent on several factors such as particle size of the sample, structure of the starch polymers, solid density, method of measurement and surface properties of the molecules (Gulu et al., 2019). Bulk density is important in the determination of the packaging requirement, mixing and material handling. It is also utilized in the wet processing of the food products in the food industry (Agunbiade and Ojezele, 2010; Iwe et al., 2016). The low bulk density recorded by all the samples of breakfast cereal produced in this study would be of great nutritional benefit because the products would be used as supplementary foods in the feeding of infants and young children (Iwe et al., 2016).

The water absorption capacity of the breakfast cereals ranged from 43.53 to 87.01%. The result showed that the control (Breakfast cereal made with 100% malted acha flour) and the sample substituted with 30% malted Bambara groundnut and 20% carrot flours had the least (43.53%) and highest (87.01%) values, respectively. The values (43.53 to 87.01%) obtained in this study were higher than the water absorption capacity (68.31 to 76.39%) reported by Usman (2012) for breakfast cereals produced from blends of African yam bean, maize and defatted coconut flour. The high water absorption capacity of the composite flour breakfast cereals samples compared to the control could be attributed to the presence of many hydrophilic components in the products such as carbohydrate (especially polysaccharides) and protein (polar amino acid residues) which have high affinity for water molecules (Sreerama et al., 2012). Butt and Batool (2010) observed that the changes in water absorption capacity of different foods or flours could be as a result of differences in concentrations, conformational characteristics and degree of interaction of protein with water. Water absorption capacity is an important functional property that is needed in foods especially those that are involved in dough formation, bulking, flaking and baking of the products during preparation.

The oil absorption capacity of the breakfast cereals ranged from 57.36 to 91.65%. The control (Breakfast cereal made with 100% malted acha flour) had the least value (57.36%), while the sample substituted with 30% malted Bambara groundnut and 20% carrot flours had the highest value (91.65%). The values (57.36 to 91.65%) obtained in this study were higher than the oil absorption capacity (0.87 to 1.32%) reported by Usman (2012) for breakfast cereals produced from blends of African yam bean, maize and defatted coconut flour. The increase in the oil absorption capacity of the composite flour breakfast cereal products could be attributed to the presence of non-polar side chains which might have been bound to the oil hydrocarbon side chains of the samples during preparation. Oil absorption capacity is an essential functional property that contributes to the enhancement of the mouth feel, while retaining the aroma of the products (Iwe et al., 2016). The high oil absorption capacity of the supplemented breakfast cereals produced in this study could be due to increase in their protein content which also increased sequentially with increase in the addition of malted Bambara groundnut flour to the products (Okoye et al., 2025). The ability of foods to absorb oil may also help to enhance the flavour retention of such food products.

The solubility index of the breakfast cereals ranged from 73.22 to 152.71%. The control (Breakfast cereal made with 100% malted acha flour) and the sample supplemented with 30% malted Bambara groundnut and 20% carrot flours had the least (73.22%) and highest (152.71%) values, respectively. The result showed that the solubility index of the samples increased significantly ($p < 0.05$) with increase in the addition of malted Bambara groundnut and carrot flours. The solubility index of a food material is controlled or affected by different factors such as temperature, presence of water, species of starch and content of damaged starch due to thermal and mechanical operations during processing (Oppong et al., 2015).

The foam capacity of the breakfast cereals ranged from 11.42 to 21.04 %. The control (Breakfast cereal made with 100% malted acha flour) had the least value (11.42 %), while the sample substituted with 30% malted Bambara groundnut and 20% carrot flours had the highest (21.04 %) value. The values (11.42 to 21.04%) obtained in this study were higher than the foam capacity (2.48 to 3.49 %) reported by Ishiwu et

al. (2019) for breakfast cereals produced from blends of African yam bean and corn flour. The result showed that the foam capacity of the samples increased significantly ($p < 0.05$) with subsequent increase in the addition of malted Bambara groundnut and carrot flours to acha flour in the formulation of the breakfast cereal products. The increase could be due to the high protein contents of the composite flour breakfast cereal samples compared to the control which led to increase in foam capacity of the products (Adegunwa et al., 2014; Mubaiwa et al., 2018).

The gelation capacity of the breakfast cereals ranged from 7.72 to 12.32%. The result showed that the control (Breakfast cereal made with 100% malted acha flour) and the sample enriched with 30% malted Bambara groundnut and 20% carrot flours had the highest (12.32%) and least (7.72%) values, respectively. The values (7.72 to 12.32%) obtained in this study were lower than the gelation capacity (75.32 to 89.66%) reported by Ishiwu et al. (2019) for breakfast cereals produced from blends of African yam bean and corn flour. The gradual reduction in the gelation capacity with increase in the addition of malted Bambara groundnut and carrot flours could be due to their high fibre contents which are known to have high water absorption capacity. Hence, this could not allow the products to easily form gel when heated during baking (Oppong et al., 2015). The gelation capacity of a food product is usually affected by ionic strength, pH and the presence of non-protein components (Chau et al., 2004). Gelation of proteins is one of the principal methods used to impart desirable texture to food products during processing.

The substitution of acha-based breakfast cereals with malted Bambara groundnut and carrot flours increased the bulk density, solubility index, water absorption, oil absorption and foam capacities with slight decrease in the gelation and swelling capacities of the products.

3.4 Pasting Properties of Breakfast Cereal Samples

The pasting properties of the breakfast cereal samples are presented in Table 4.

The peak viscosity of the breakfast cereals ranged from 37.15 to 92.83 RVU. The control (Breakfast cereal made with 100 % malted acha flour) had the least 37.15 RVU value, while the sample supplemented with 30 % malted

Bambara groundnut and 20 % carrot flours had the highest (92.83 RVU) value. The values (37.15 to 92.83 RVU) obtained in this study were lower than the peak viscosity (65.00 to 129.00 RVU) reported by Asaam et al. (2018) for breakfast cereals produced from blends of yellow maize, soybean and pumpkin flour. The observed increase in the peak viscosity of the composite flour breakfast cereal samples could be attributed to the addition of malted Bambara groundnut and carrot flours which had low levels of degraded or damaged starch molecules. The peak viscosity is the maximum viscosity attained by the paste during heating which also determines the ability of starch granules to swell freely. Peak viscosity indicates the water holding capacity of the starch and is often correlated with the final product quality. The peak viscosity of breakfast cereals increased with the level of starch in the products (Okoye et al., 2023). The high peak viscosity observed in all the supplemented breakfast cereal samples showed that the products would not be nutritionally beneficial for use in the feeding of infants and young children (Iwe et al., 2016; Okoye et al., 2023).

The trough viscosity of the breakfast cereals ranged from 58.15 to 116.70 RVU. The control (Breakfast cereal made with 100% malted acha flour) and the sample substituted with 30% malted Bambara groundnut and 20% carrot flours had the least (58.15 RVU) and highest (116.70 RVU) values, respectively. The values (58.15 to 116.70 RVU) obtained in this study were higher than the trough viscosity (60.00 to 113.50 RVU) reported by Asaam et al. (2018) for breakfast cereals produced from blends of yellow maize, soybean and pumpkin flour. The increase in the trough viscosity of the substituted breakfast cereal samples could be attributed to the addition of malted Bambara groundnut and carrot flours which helped to reduce the disruption of starch granules and the leaching out of amylose molecules into the solution during heating (Asaam et al., 2018). Trough viscosity is the maximum viscosity which measures the ability of paste to withstand breakdown during cooling. Trough viscosity gives an indication of hot paste stability, and the lower the trough viscosity, the higher the stability of the paste. The high trough viscosity observed in all the breakfast cereal products produced in this study showed that they have poor hot paste stability, and could not be used for the processes that require the formation of stable paste (Onwuama et al., 2023).

Table 1. Proximate composition (%) of breakfast cereal samples

Samples	Moisture	Crude Protein	Fat	Ash	Crude Fibre	Carbohydrate	Energy Value (kJ/100g)
A	6.18 ^e ± 0.01	9.17 ^f ± 0.03	6.09 ^f ± 0.03	3.20 ^f ± 0.03	3.37 ^f ± 0.05	71.97 ^a ± 0.09	379.43 ^a ± 0.09
B	6.25 ^e ± 0.04	11.42 ^e ± 0.02	6.33 ^e ± 0.02	3.35 ^e ± 0.04	3.64 ^e ± 0.01	69.09 ^b ± 0.03	379.07 ^b ± 0.08
C	6.62 ^d ± 0.08	13.67 ^d ± 0.05	6.64 ^d ± 0.04	3.51 ^d ± 0.07	3.85 ^d ± 0.06	65.69 ^c ± 0.06	377.28 ^c ± 0.17
D	6.87 ^c ± 0.04	17.24 ^c ± 0.04	6.82 ^c ± 0.06	3.79 ^c ± 0.05	4.17 ^c ± 0.07	61.09 ^d ± 0.08	374.76 ^d ± 0.15
E	7.17 ^b ± 0.02	19.53 ^b ± 0.06	7.06 ^b ± 0.05	4.52 ^b ± 0.04	4.48 ^b ± 0.04	57.21 ^e ± 0.06	370.58 ^e ± 0.11
F	7.31 ^a ± 0.03	22.91 ^a ± 0.70	7.22 ^a ± 0.03	4.86 ^a ± 0.02	4.89 ^a ± 0.02	52.79 ^f ± 0.71	367.86 ^f ± 0.11

Values are mean ± standard deviation of triplicate determinations. Means in the same column bearing different superscripts differed significantly ($p < 0.05$) from each other.

A - Breakfast cereal produced from 100% malted acha, B - Breakfast cereal produced from 85% malted acha, 10% malted Bambara groundnut and 5% carrot flours, C - Breakfast cereal produced from 80% malted acha, 15% malted Bambara groundnut and 5% carrot flours, D - Breakfast cereal produced from 70% malted acha, 20% malted Bambara groundnut and 10% carrot flours, E - Breakfast cereal produced from 60% malted acha, 25% malted Bambara groundnut and 15% carrot flours, F - Breakfast cereal produced from 50% malted acha, 30% malted Bambara groundnut and 20% carrot flours.

Table 2. Microbial Counts (cfu/g) of breakfast cereal samples

Samples	Total viable count	Coliform count	Fungal count
A	0.50×10^4	Nil	Nil
B	0.56×10^4	Nil	Nil
C	1.20×10^4	Nil	Nil
D	1.30×10^4	Nil	Nil
E	1.40×10^4	Nil	Nil
F	1.60×10^4	Nil	Nil

A - Breakfast cereal produced from 100% malted acha, B - Breakfast cereal produced from 85% malted acha, 10% malted Bambara groundnut and 5% carrot flours, C - Breakfast cereal produced from 80% malted acha, 15% malted Bambara groundnut and 5% carrot flours, D - Breakfast cereal produced from 70% malted acha, 20% malted Bambara groundnut and 10% carrot flours, E - Breakfast cereal produced from 60% malted acha, 25% malted Bambara groundnut and 15% carrot flours, F - Breakfast cereal produced from 50% malted acha, 30% malted Bambara groundnut and 20% carrot flours

The breakdown viscosity of the breakfast cereals ranged from 48.89 to 91.05 RVU. The result showed that the control (Breakfast cereal made with 100% malted acha flour) had the least (48.89 RVU) value, while the sample enriched with 30% malted Bambara groundnut and 20% carrot flours had the highest (91.05 RVU) value. The values (48.89 to 91.05 RVU) obtained in this study were higher than the breakdown viscosity (5.00 to 15.50RVU) reported by Agu et al. (2015) for breakfast cereals produced from blends of acha and soybean and pumpkin flour. Breakdown viscosity is essentially a measure of the degree of paste stability or starch granule disintegration during heating (Iwe et al., 2016). The control sample which had a relatively low breakdown viscosity (48.89 RVU) would form a more stable paste during heating than the breakfast cereal enriched with 30% malted Bambara groundnut and 20% carrot flours which had a very high breakdown viscosity (91.05 RVU). In addition, the addition of malted Bambara groundnut and carrot flours increased the breakdown viscosity, thereby making the paste more unstable during heating at high temperature. Breakdown in the viscosity of cooked pastes indicates their stability to shearing during cooking. The ability of starch to withstand heating at high temperature and shear stress is an important phenomenon in many processes. High breakdown viscosities are associated with high peak viscosities which in turn are related to the degree of swelling of the starch granules in food products (Okoye et al., 2023).

The setback viscosity of the breakfast cereals ranged from 38.27 to 88.28 RVU. The control (Breakfast cereal made with 100 % malted acha flour) had the least (38.27 RVU) value, while the sample substituted with 30 % malted Bambara groundnut and 20% carrot flours had the highest

set back viscosity of 88.28 RVU. The values (38.27 to 88.28 RVU) obtained in this study were lower than the setback viscosity (56.50 to 114.50 RVU) reported by Onwuama et al. (2023) for custard supplemented with lima bean and ripe plantain flours. The result showed that the setback viscosity increased with increase in the addition of malted Bambara groundnut and carrot flours to the products. Setback viscosity is usually used as an index for evaluating the retrogradation tendency of the paste prepared from starchy food. The setback viscosity is an indication of the difference between the maximum viscosity during cooling and minimum viscosity during heating. Higher setback viscosity is equivalent to reduced dough digestibility, while lower setback viscosity during the cooling of the paste indicates lower tendency to retrogradation (Iwe et al., 2016; Asaam et al., 2018). Setback viscosity has been correlated with the textural qualities of the food products (Eze et al., 2024).

The final viscosity of the breakfast cereals ranged from 63.03 to 93.53 RVU with the control (Breakfast cereal made with 100% malted acha flour) and the sample substituted with 30% malted Bambara groundnut and 20% carrot flours having the least (63.03 RVU) and highest (93.53 RVU) values, respectively. The values (63.03 to 93.53 RVU) obtained in this study were lower than the final viscosity (116.50 to 228.00 RVU) reported by Okoye et al. (2023) for millet-based breakfast cereals supplemented with soybean and date fruit flours. The addition of malted Bambara groundnut and carrot flours to acha flour in the preparation of breakfast cereals generally increased the final viscosity of the composite flour breakfast cereal samples compared to the control. The final viscosity is the viscosity obtained at the end of pasting test. It is commonly used to define the

Table 3. Functional properties of breakfast cereal samples

Samples	Bulk Density (g/cm ³)	Water Absorption Capacity (%)	Oil Absorption Capacity (%)	Solubility Index (%)	Foam Capacity (%)	Gelation Capacity (%)	Swelling Capacity (%)
A	0.46 ^f ± 0.03	43.53 ^f ± 1.19	57.36 ^f ± 1.36	73.22 ^e ± 1.33	11.42 ^f ± 0.01	12.32 ^a ± 0.02	31.36 ^a ± 0.03
B	0.58 ^e ± 0.04	47.67 ^e ± 0.62	59.96 ^e ± 0.25	84.16 ^d ± 1.44	12.56 ^e ± 0.02	11.41 ^b ± 0.04	29.53 ^b ± 0.02
C	0.77 ^d ± 0.03	61.45 ^d ± 1.40	68.12 ^d ± 0.43	87.40 ^d ± 1.50	14.64 ^d ± 0.07	10.47 ^c ± 0.03	27.78 ^c ± 0.03
D	0.92 ^c ± 0.07	66.33 ^c ± 0.72	75.82 ^c ± 1.28	93.98 ^c ± 0.65	16.72 ^c ± 0.06	9.57 ^d ± 0.02	27.47 ^c ± 0.12
E	1.10 ^b ± 0.08	77.76 ^b ± 1.25	82.51 ^b ± 5.30	111.94 ^b ± 1.97	18.76 ^b ± 0.04	8.67 ^e ± 0.03	26.76 ^c ± 0.09
F	1.22 ^a ± 0.04	87.01 ^a ± 0.65	91.65 ^a ± 1.12	152.71 ^a ± 0.62	21.04 ^a ± 0.03	7.72 ^f ± 0.03	25.57 ^d ± 0.02

Values are mean ± standard deviation of triplicate determinations. Means in the same column bearing different superscripts differed significantly ($p < 0.05$) from any each other.

A - Breakfast cereal produced from 100% malted acha, B - Breakfast cereal produced from 85% malted acha, 10% malted Bambara groundnut and 5% carrot flours, C - Breakfast cereal produced from 80% malted acha, 15% malted Bambara groundnut and 5% carrot flours, D - Breakfast cereal produced from 70% malted acha, 20% malted Bambara groundnut and 10% carrot flours, E - Breakfast cereal produced from 60% malted acha, 25% malted Bambara groundnut and 15% carrot flours, F - Breakfast cereal produced from 50% malted acha, 30% malted Bambara groundnut and 20% carrot flours

Table 4. Pasting properties of breakfast cereal samples

Samples	Peak Viscosity (RVU)	Trough Viscosity (RVU)	Breakdown Viscosity (RVU)	Setback Viscosity (RVU)	Final Viscosity (RVU)	Pasting Temperature (°C)	Peak Time (min)
A	37.15 ^f ± 0.39	58.15 ^f ± 0.69	48.89 ^f ± 0.69	38.27 ^f ± 0.70	63.03 ^f ± 0.70	31.17 ^f ± 0.70	7.73 ^d ± 0.02
B	48.35 ^e ± 0.01	62.76 ^e ± 0.01	52.84 ^e ± 0.70	40.67 ^e ± 0.70	66.33 ^e ± 1.41	38.32 ^e ± 0.49	7.77 ^d ± 0.09
C	52.30 ^d ± 0.05	74.79 ^d ± 1.41	61.87 ^d ± 1.40	46.38 ^d ± 0.69	74.22 ^d ± 1.40	49.19 ^d ± 0.47	8.23 ^c ± 0.10
D	60.93 ^c ± 0.37	86.71 ^c ± 1.19	68.16 ^c ± 0.39	54.25 ^c ± 1.31	71.48 ^c ± 0.72	58.28 ^c ± 0.68	8.36 ^c ± 0.11
E	78.72 ^b ± 0.70	95.68 ^b ± 1.22	74.33 ^b ± 1.42	67.83 ^b ± 0.57	80.00 ^b ± 0.57	75.91 ^b ± 2.73	8.55 ^b ± 0.16
F	92.83 ^a ± 0.71	116.70 ^a ± 0.71	91.05 ^a ± 1.42	88.28 ^a ± 0.71	93.53 ^a ± 1.35	98.37 ^a ± 1.40	8.85 ^a ± 0.04

Values are mean ± standard deviation of triplicate determinations. Means in the same column bearing different superscripts differed significantly ($p < 0.05$) from each other.

A - Breakfast cereal produced from 100% malted acha, B - Breakfast cereal produced from 85% malted acha, 10% malted Bambara groundnut and 5% carrot flours, C - Breakfast cereal produced from 80% malted acha, 15% malted Bambara groundnut and 5% carrot flours, D - Breakfast cereal produced from 70% malted acha, 20% malted Bambara groundnut and 10% carrot flours, E - Breakfast cereal produced from 60% malted acha, 25% malted Bambara groundnut and 15% carrot flours, F - Breakfast cereal produced from 50% malted acha, 30% malted Bambara groundnut and 20% carrot flours

quality of a particular starch-based food product since it indicates the ability of the food to form a viscous paste or gel after cooking and cooling (Arukwe et al., 2017). The final viscosity is usually used as an index for determining the stability of the cooked paste. The high final viscosity reported in this study for supplemented breakfast cereals is an indication that they would be less stable on cooling than the control sample (Asaam et al., 2018).

The pasting temperature of the breakfast cereals ranged from 31.17 to 98.37 °C. The control (Breakfast cereal made with 100 % malted acha flour) had the least (31.17°C) value, while the sample supplemented with 30% malted Bambara groundnut and 20% carrot flours had the highest pasting temperature of 98.37 °C. The values (31.17 to 98.37 °C) obtained in this study were higher than the pasting temperature (72.50 to 77.00°C) reported by Asaam et al. (2018) for breakfast cereals produced from blends of yellow maize, soybean and pumpkin flour. There were significant ($p < 0.05$) differences in the pasting temperature of the samples. The addition of malted Bambara groundnut and carrot flours was observed to increase the pasting temperature of the samples. The pasting temperature is a measure of the minimum temperature required to cook a given food sample (Iwe et al., 2016). The high pasting temperature of the composite flour breakfast cereal products produced in this study is a clear indication that they would take more time to form stable paste on cooking and as such, more energy (fuel) would be also required during cooking when compared to the control sample which had a relatively low pasting temperature.

The peak time of the breakfast cereals ranged from 7.73 to 8.85 min. The control (Breakfast cereal made with 100% malted acha flour) and the sample supplemented with 30% malted Bambara groundnut and 20% carrot flours had the least (7.73 min) and highest (8.85 min) values, respectively. The values (7.73 to 8.85 min) obtained in this study were higher than the peak time (6.84 to 7.00 min) reported by Okoye et al. (2023) for millet-based breakfast cereals supplemented with soybean and date fruit flours. The addition of malted Bambara groundnut and carrot flours to acha flour in the formulation of the breakfast cereals generally increased the peak time of the supplemented breakfast cereal samples compared to the control. Peak time is a measure of cooking time. The peak time is a

measure of minimum time required to cook a food sample. Peak time indicates the total time taken by a food product to attain its peak viscosity, and the lower the peak time, the faster the cooking process (Asaam et al., 2018). Therefore, the breakfast cereal product with lower peak time would cook faster than the one with a higher peak time. The result showed that the composite flour breakfast cereals produced in this study generally had higher peak time than the control, hence, they would not cook faster and would also require more heating to form stable paste during cooking.

The substitution of acha-based breakfast cereals with malted Bambara groundnut and carrot flours generally increased the pasting properties of the composite flour breakfast cereal samples compared to the control.

4. CONCLUSION

The study showed that the supplementation of acha-based breakfast cereals with Bambara groundnut and carrot flours led to a significant increase in crude protein, fat, ash and crude fibre contents of the composite flour breakfast cereal samples compared to the control. The microbial counts of the samples equally showed that the total viable count was relatively low with the absence of coliform bacteria and fungi which is a clear indication that the breakfast cereal products were safe and wholesome, and would also have longer shelf life when properly packaged and stored. The functional properties of the breakfast cereals showed that the bulk density, water absorption, oil absorption and foam capacities as well as the solubility index of the samples increased with increase in the addition of Bambara groundnut and carrot flours with slight decrease in the gelation and swelling capacities of the products. The pasting properties (peak, trough, breakdown, setback and final viscosities), as well as the peak time and pasting temperature of the samples, also increased sequentially with increased substitution of Bambara groundnut and carrot flours. In addition, it was equally observed from the study that the enrichment of acha flour with Bambara groundnut and carrot flours in the production of breakfast cereals could be used to produce nutritious and good quality products especially in Nigeria and other developing countries where these nutrient-dense food crops which are relatively cheap and available are grossly underutilized in food formulations.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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