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Research article

Assessment of mineral content, techno-functional properties and colour of an extruded breakfast cereals using yellow maize, sorghum and date palm

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ABSTRACT

In addressing the challenges of food security and nutritional deficiencies, the study aimed to assess the nutritional and techno-functional attributes of an extruded breakfast cereal composed of yellow maize, sorghum, and date palm. The processing involved transforming yellow maize, sorghum, and date palm into flours, and various samples (MA, MB, MC, SA, SB, SC, and MSD) were blended in different proportions (90:0:10, 80:0:20, 70:0:30, 0:90:10, 0:80:20, 0:70:30, 45:45:10, respectively) to create a nutritionally balanced extruded cereal. Standard methods were employed for the analysis to evaluate techno-functional properties (bulk density, water absorption capacity, oil absorption capacity, swelling power, and dispersability), mineral content (sodium, potassium, calcium, iron, and zinc), and color properties (brightness, redness, and yellowness) of the extruded breakfast cereal samples. Techno-functional property ranges were determined, such as bulk density (ranged from 0.39 g/cm^3 to 0.50 g/cm^3), water absorption capacity (ranged from 1.69 g/ml to 4.43 g/ml), oil absorption capacity (ranged from 1.56 g/ml to 2.14 g/ml), swelling power (ranged from 1.43 g/g to 4.27 g/g), and dispersability (ranged from 23.37% to 60.05%). Mineral content results included sodium (ranging from 10.88 mg/100g to 18.67 mg/100g), potassium (ranging from 253 mg/100g to 351.65 mg/100g), calcium (ranging from 321.50 mg/100g to 421.40 mg/100g), iron (ranging from 9.22 mg/100g to 15.2 mg/100g), and zinc (ranging from 4.11 mg/100g to 5.36 mg/100g). Colour determination exhibited brightness values ranging from 55.31 to 64.48, redness from 0.63 to 2.73, and yellowness from 10 to 17.37.The study demonstrated that extruded breakfast cereals combining yellow maize, sorghum, and date palm met acceptable quality standards in nutritional assessment. The use of date palm as a sugar substitute enhanced mineral bioaccessibility. Furthermore, the incorporation of date palm flour into maize and sorghum-based samples improved both techno-functional properties and mineral content, presenting a novel application for date palm fruits.

1. Introduction

The global challenges posed by an increasing population and rising food prices were threatening food security, particularly in developing countries, resulting in a surge in diet-related deficiencies [1]. Addressing this issue in the food supply chain required

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innovation from food processors to develop alternative high-nutrient foods. In response to the fast-paced lifestyle, people shifted from traditional home-cooked meals to convenient and nutritionally rich foods available in stores. This shift included a diverse range of convenience foods such as ready-to-eat (RTE) meals, breakfast cereals, specialized foods, and snacks.

Breakfast was often considered the most crucial meal, requiring a balance of nutrition and wholesomeness. Breakfast cereal (BFC) emerged as a top-tier source of daily nutrients for both children and adults. It provides a valuable option for those with time constraints or a lack of appetite in the morning due to its high nutritional value and easy preparation [2].

Cereals produced from whole grains, such as maize (corn), offered an abundance of macronutrients and micronutrients along with phytochemicals. These components were essential for maintaining good health and managing diet-related conditions like Protein-Energy Malnutrition (PEM) [3].

The popularity of breakfast cereals was on the rise as RTE foods due to their convenience, ease of consumption, preparation, and storage. These products typically had high starch content, with major ingredients including maize, wheat, rice, potato, and oats [2].

Maize *(Zea mays)*, also known as corn, was a versatile crop originating from Mexico and Central America. It serves as a human food source, livestock feed, and played a crucial role in various industrial products due to its adaptability to diverse environments. Although

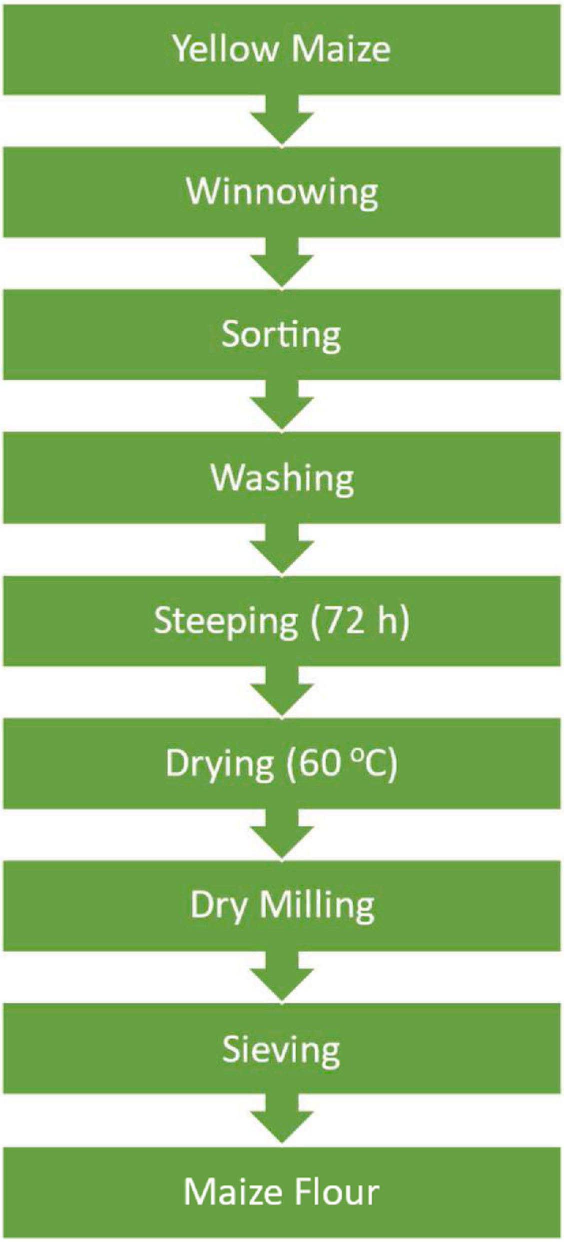

Fig. 1. Processing of maize flour.

maize contains moderate amounts of dietary fiber, magnesium, and phosphorus, its protein level is relatively low [4].

Sorghum, a significant global crop, rank fourth among major food grains in India. It serves as a staple in many Asian and African countries, providing human staple food, animal feed, and industrial raw materials. Sorghum exhibit substantial genetic variability and ie rich in phytochemicals, including phenolic compounds, plant sterols, and other nutraceutical substances [5].

Dates *(Phoenix dactylifera)* offered a natural alternative to added sugar in foods and contributed significantly to the daily nutrition of people in arid regions. Rich with dietary fiber and other antioxidants, dates were found to possess potent antioxidant properties. The presence of insoluble fibers in dates reduced the risk of bowel cancer and promoted cardiovascular health [6].

Extrusion cooking, involving high temperature, high pressure was a method used to create low-density, high-expansion products with a distinctive texture [7]. It had become a prominent method of industrial cooking, leading to physical and chemical transformations in foods, enhancing their technological attributes [8].

This research aimed to assess the nutritional composition of breakfast cereals made from blends of maize, sorghum, and date palm. The goal was to explore innovative ways to address the challenges of food security and nutritional deficiencies in the context of a growing global population and changing dietary preferences.

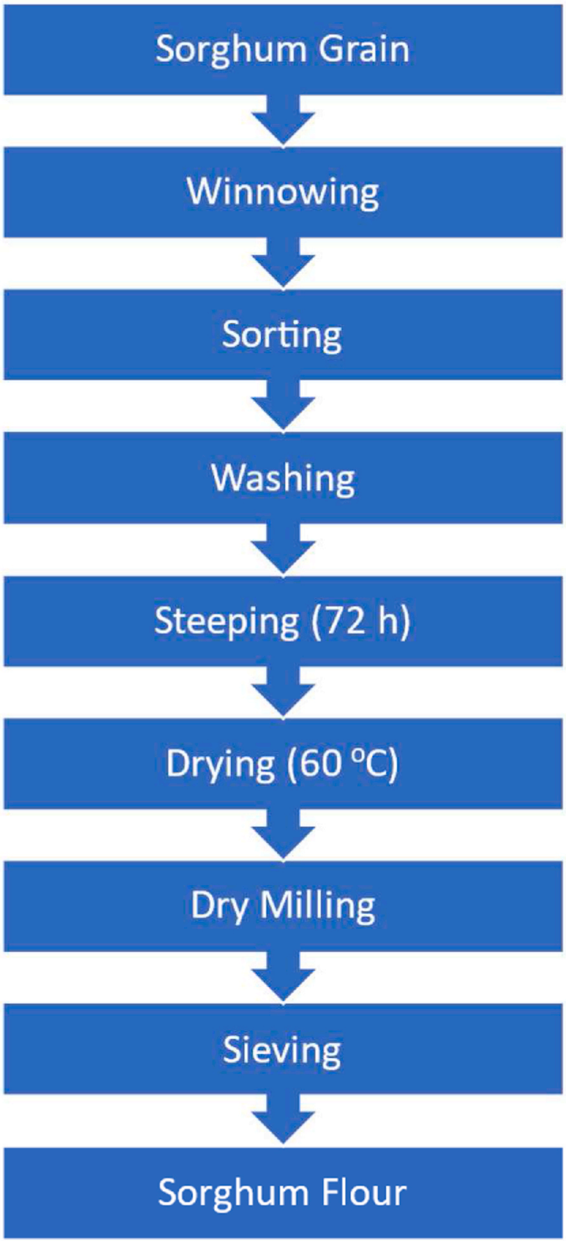

Fig. 2. Processing of sorghum flour.

2. Materials and methods

2.1. Source of material

Yellow maize and sorghum were obtained from International Institute of Tropical Agriculture, Ibadan while date palm fruits was obtained from Ikole local market, Ikole, Ekiti state. All other materials and reagents were of analytical grade.

2.2. Preparation of yellow maize

The process began with winnowing, sorting, and washing the yellow maize grains. Subsequently, these cleaned grains were soaked in water for a duration of 72 h with a continual draining of the steeping water. Following this, they underwent an oven-drying procedure at 60 °C for a span of 8 h. Afterward, the dried maize was milled to 15 % moisture content, sieved for breakfast preparation, and finally, packaged in polyethylene bags. These bags were then stored at room temperature (27 °C) until they were ready for use (refer to

Fig. 3. Processing of date flour.

Fig. 1).

2.3. Preparation of sorghum flour

The sorghum grains were sorted to remove stones, dirt and other extraneous materials. The cleaned grains were thoroughly washed and steeped in water for 12 h so as to attain a 42–46 % moisture level. The hydrated grains were spread on a moist jute bag which had been previously sterilized by boiling for 30 min and the grains were allowed to germinate for four days. Non germinated seeds were discarded and germinated seeds were dried at 60 °C in a cabinet dryer to a moisture content of 10–12 %. The withered rootless grains were gently brushed off and the malted grains were milled, sieved and packaged in an air tight container until ready for used as shown in Fig. 2.

2.4. Preparation of date palm

Date palm fruits were sorted to remove immature, overripe and damaged ones. The seeds were removed and the pulp was pulverized and dried (in a cabinet drier at 40 °C for 5 h) and sieved (0.5 mm screen size) (Fig. 3)

2.5. Formulation of composite flour blends

Seven flour blends were prepared from maize, sorghum and date palm flours according to the formulation shown in Table 1.

2.6. Production of extruded breakfast cereals

The flow chart for the production of extruded breakfast cereal is illustrated in Fig. 4. The composite flour was introduced into a twin-screw extruder with a capacity ranging from 100 to 1000 kg/h and operated at 220 V. The rotation of the screw served multiple functions: it blended and cut the raw materials, applied pressure to the product mixture, and propelled it along the length of the barrel to be extruded through a die in the desired shape. During this process, specific zones of the barrel were heated to cook the product mixture or cooled to adjust its texture. Additionally, water and/or solutions containing flavourings and colours could be precisely added to the product after extrusion, as the high pressure and temperature in the barrel might destroy them. The extruder featured a modular barrel design, allowing easy removal of heating and cooling segments (for altering product configuration). It also had a segmented agitator that accommodated a diverse range of screw configurations. Furthermore, the flexible die design permitted the production of a wide array of products with minimal parts needing adjustment.

2.7. Proximate analysis

Moisture content, crude protein, crude fat, crude fibre and ash were determined by standard methods of [9]. Carbohydrate were expressed as a percentage of the difference between the addition of other proximate chemical components and 100%.

2.8. Determination of techno- functional properties of the composite flour

2.8.1. Water absorption capacity (WAC)

To 1 g of the flour sample, 15 ml of distilled water was added in a 25 ml centrifuge tube and agitated on a vortex mixer for 2 min. It was centrifuged at 4000 revolutions per minutes (rpm) for 20 min. The supernatant was decanted and discarded. WAC parameters was calculated.

2.8.2. Oil absorption capacity (OAC)

The method of [10] was used. One gram of the sample was mixed with 10 ml refined corn oil in a centrifuge tube and allowed to stand at room temperature (30 ± 2 °C) for 1 h. It was centrifuged at 1600 rpm x *g* for 20 min. The volume of free oil was recorded. Fat absorption capacity was expressed as ml of oil bound by 100 g dried flour.

$$\times density\ of\ corn\ oil \times 100$$

Table 1
Formulation of the composite flour for the extruded breakfast cereals.

Sample	Maize Flour	Sorghum Flour	Date Palm Fruit
MA	90	0	10
MB	80	0	20
MC	70	0	30
SA	0	90	10
SB	0	80	20
SC	0	70	30
MSD	45	45	10

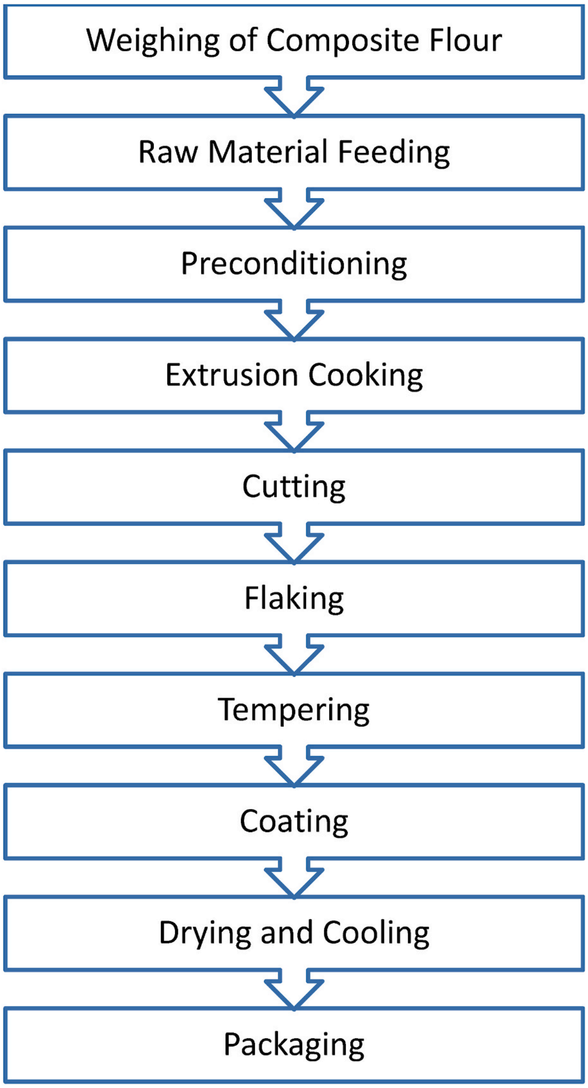

Fig. 4. Flow chart of extruded breakfast cereals.

2.8.3. *Determination of bulk density*

The determination of bulk density (both loose and packed) followed the procedure outlined by Ref. [11]. 10 ml graduated cylinder was delicately filled with the sample. The base of the cylinder was gently tapped on a laboratory bench multiple times until the sample level ceased to decrease after reaching the 10 ml mark. For loose bulk density, a clean and dried 100 ml measuring flask was weighed, and the flour sample was allowed to freely settle into it until it reached the designated mark. The flask was then reweighed along with the sample. Bulk density was computed as the weight of the sample divided by the volume of the sample (g/ml)

$$\text{Bulk density } (g / mL) = \frac{\textit{Weight of sample}}{\textit{Volume of sample aftapping}}$$

2.8.4. *Determination of swelling capacity*

The swelling capacity was assessed following the protocol outlined by Ref. [12] with slight adjustments. The sample was filled into a 100 ml graduated cylinder up to the 10 ml mark. Distilled water was then introduced to reach a total volume of 50 ml. The top of the cylinder was securely sealed and the content was mixed by turning the cylinder upside down. After 2 min, the suspension was inverted again and allowed to stand for 60 min. The swelling capacity of the sample was determined as a factor of the initial volume

$$\text{Swelling Capacity } (mL / g) = \frac{\textit{Volume Occupied by Sample}}{\textit{Original Sample Weight}}$$

2.8.5. Mineral analysis

Iron (Fe), Zinc (Zn) and Calcuim (Ca) were determined using atomic absorption spectrophotometer while potassium and sodium were determined using flour photometer on seven extruded sample flour according to the method described by Ref. [13]. Result was expressed on dry weight basis in mg/100g

2.8.6. Statistical analysis

Data collected were subjected to appropriate statistical analysis (ANOVA) using a statistical package for the social sciences, SPSS (version 20). Mean separation was done using Duncan multiple range test and significance difference was accepted at 5 % confidence level.

3. Results and discussion

3.1. Proximate composition of the extruded breakfast cereal

The proximate composition results are detailed in Table 2. The control sample (commercial extruded cereal) exhibited significantly lower levels of moisture, ash, fat, protein, crude fiber, and carbohydrate content compared to the composite extruded breakfast cereals ($p \leq 0.05$). In general, there were no significant differences ($p > 0.05$) in almost all proximate parameters (protein, ash, fat, fiber, moisture content, and carbohydrate) except for sample CTRL. The moisture content values across all samples were low, indicating their extended shelf life [14].

Both ash and crude fiber increased with higher levels of date palm flour inclusion. Conversely, a decrease in fat and protein content was noted as the level of date palm flour inclusion increased. The values obtained for ash, fat, crude fiber, protein, and carbohydrate were all higher than those of the CTRL. The higher fiber content due to increased date palm inclusion offers various health benefits, facilitating digestion in the colon and potentially reducing instances of constipation [15].

3.2. Techno- functional properties of the samples

The results for the techno-functional properties of the extruded breakfast cereal samples are shown in Table 3. The result showed that the extruded breakfast cereal samples are not significantly different at $p < 0.05$.

3.2.1. Bulk density

Bulk density, a crucial parameter for flour expansion, provided insights into the porosity of food products [16]. It essentially quantified the weightiness of a flour sample, assuring that the relative volume of the composite flour in its packaging did not diminish excessively over time [17]. The importance of functional properties in assessing the usability of a material was highlighted by Omueti et al. [18], with bulk density playing a pivotal role in selecting suitable packaging materials and determining the quantity of powdery food products [19].

The measured bulk density of the extruded breakfast cereal samples ranged from 0.39 g/cm^3 to 0.50 g/cm^3. Notably, sample MB (80% maize and 20% date flour) exhibited the lowest value, while sample SA demonstrated the highest, in contrast to the control which had a value of 0.45 g/cm^3. Interestingly, samples MA, MC, SB, and SC all displayed the same value as the control sample (0.45 g/cm^3). The distinct processing methods employed in creating the flour blends, along with variations in flour ratios, likely contributed to these differing bulk density values [20]. This was evident in the notably higher and lower values observed in samples SA and MB, respectively, a finding consistent with [21]. Statistically, no significant difference ($p \leq 0.05$) was observed between the samples.

Bulk density played a pivotal role in packaging and material handling, as higher bulk density allowed for a greater amount of

Table 2
Proximate composition of the extruded samples (%).

Sample	Moisture content	Ash	Fat	Protein	Fibre	Carbohydrate
MA	$3.40^b \pm 0.50$	$2.73^a \pm 0.00$	$4.78^a \pm 0.06$	$4.28^a \pm 0.10$	$2.02^b \pm 0.60$	$82.79^a \pm 0.04$
MB	$3.25^b \pm 0.43$	$2.80^a \pm 0.60$	$4.55^a \pm 0.02$	$3.80^b \pm 0.11$	$2.22^b \pm 0.10$	$83.38^a \pm 0.54$
MC	$3.25^b \pm 0.32$	$2.99^a \pm 0.40$	$4.37^a \pm 0.01$	$3.35^b \pm 0.70$	$2.56^b \pm 0.20$	$83.48^a \pm 0.60$
SA	$3.63^b \pm 0.22$	$2.67^d \pm 0.14$	$4.32^a \pm 0.70$	$4.69^a \pm 0.37$	$2.07^b \pm 0.24$	$82.72^b \pm 0.46$
SB	$3.50^b \pm 0.01$	$2.72^a \pm 0.10$	$4.26^a \pm 0.45$	$4.43^a \pm 0.40$	$2.28^b \pm 0.11$	$82.81^a \pm 0.30$
SC	$3.45^b \pm 0.02$	$2.81^a \pm 0.11$	$4.13^a \pm 0.10$	$3.80^b \pm 0.23$	$2.67^b \pm 0.23$	$83.14^a \pm 0.05$
MSD	$5.20^a \pm 0.80$	$2.93^a \pm 0.10$	$2.36^b \pm 0.12$	$3.01^b \pm 0.50$	$3.60^a \pm 0.80$	$82.80^a \pm 0.62$
CTRL	$2.50^c \pm 0.01$	$2.34^b \pm 0.47$	$0.62^c \pm 0.30$	$2.85^c \pm 0.60$	$1.09^c \pm 0.I4$	$80.50^b \pm 0.24$

The values are mean standard deviations and those in the same column not sharing the same superscript letter were significantly different from each other ($p \leq 0.05$).
Key.
MA-90%Maize flour+10% Date palm flour; MB-80%Maize flour+20% Date palm flour.
MC-70%Maize flour+30% Date palm flour; SA-90%Sorghum flour +10% Date palm flour.
SB-80%Sorghum flour +20% Date palm flour; SC-70%Sorghum flour +30% Date palm flour.
CTRL- Commercial extruded cereal.

Table 3
Techno-functional properties of composite flour blends.

SAMPLE	Bulk Density (g/cm^3)	Water absorption Capacity (g/ml)	Oil absorption Capacity (g/ml)	Swelling power (g/g)	Dispersability (%)
CTRL	$0.45^b \pm 0.00$	$4.43^a \pm 0.03$	$2.14^a \pm 0.03$	$3.67^b \pm 0.05$	$60.05^a \pm 0.05$
MA	$0.45^b \pm 0.00$	$4.42^a \pm 0.03$	$1.92^b \pm 0.03$	$4.27^a \pm 0.02$	$56.63^b \pm 0.04$
MB	$0.39^c \pm 0.00$	$3.17^b \pm 0.02$	$1.69^c \pm 0.03$	$2.83^c \pm 0.03$	$46.69^c \pm 0.25$
MC	$0.45^b \pm 0.00$	$2.86^c \pm 0.04$	$1.56^c \pm 0.02$	$2.82^c \pm 0.01$	$44.75^d \pm 0.04$
SA	$0.50^a \pm 0.00$	$1.69^d \pm 0.02$	$1.48^c \pm 0.01$	$1.43^e \pm 0.03$	$23.37^g \pm 0.04$
SB	$0.45^b \pm 0.00$	$1.98^d \pm 0.01$	$1.99^b \pm 0.02$	$1.82^d \pm 0.02$	$30.05^e \pm 0.05$
SC	$0.45^b \pm 0.00$	$1.72^d \pm 0.02$	$1.85^b \pm 0.01$	$1.59^d \pm 0.01$	$26.68^f \pm 0.01$

Values are meanc± S.D. Means with same superscript across a column are not significantly different at $p < 0.05$.
Key.
MA-90%Maize flour+10% Date palm flour; MB-80%Maize flour+20% Date palm flour.
MC-70%Maize flour+30% Date palm flour; SA-90%Sorghum flour +10% Date palm flour.
SB-80%Sorghum flour +20% Date palm flour; SC-70%Sorghum flour +30% Date palm flour.
CTRL- Commercial extruded cereal.

material to occupy a smaller volume [22]. It also held significance in determining packaging requirements, facilitating material handling, and guiding processing applications within the food industry [23]. In food formulation, particularly for products with low retrogradation tendencies, a low bulk density was desirable [24]. However, in assessing the mixing quality of a particular substance, a higher bulk density was considered a favorable physical attribute [18].

3.2.2. Water absorption capacity (WAC)

The water absorption capacity (WAC) of the extruded breakfast cereal samples varied from 1.69 g/ml to 4.43 g/ml. Sample SA displayed the lowest WAC, while the control sample had the highest value. Among the maize-based extruded breakfast cereal samples, sample MA recorded the highest value (4.42 g/ml), whereas sample MC had the lowest (2.86 g/ml) compared to the control sample (4.43 g/ml). Within the sorghum-based extruded breakfast cereal samples, sample SB demonstrated the highest WAC (1.98 g/ml), and sample SA showed the lowest (1.69 g/ml) compared to the control sample (4.43 g/ml).

The water absorption capacity of the maize-based extruded breakfast cereal samples decreased as the concentration of maize flour decreased and the content of date palm flour increased. Conversely, the water absorption capacity of the sorghum-based extruded breakfast cereal samples increased with a decrease in sorghum flour concentration and an increase in date palm flour concentration. This suggested that the level of substitution had an impact on the WAC of the extruded breakfast cereal samples. These findings aligned with the results obtained by Ref. [25] when substituting ogi with bambara groundnut flour. In their study, the WAC values of a blend of bambara nut flour with ogi decreased with an increase in bambara nut concentration.

The maize-based extruded breakfast cereal samples exhibited higher water absorption than the sorghum-based ones, possibly due to the elevated fiber content of date fruits. Water absorption contributes to the bulking and consistency of products, and an increased capacity in food systems allows end-users to modify the functional properties of the dough in bakery products [26].

As stated by Ref. [21], WAC is the product's ability to interact with water when water is limited. Therefore, the differences in WAC between the samples could be attributed to their respective hydrophilic components, such as carbohydrates, which retain more water than proteins or lipids (30). Extruded breakfast cereal samples with high water absorption capacities may also contain high-hydrophilic elements like starches and polar amino acid residues, which influence their gelation and hydrophilic abilities [27]. Extruded breakfast cereal samples with low water absorption produced thinner meals, which are desirable for infant formulations [28].

3.2.3. Oil absorption capacity (OAC)

The oil absorption capacity of cereal flour played a crucial role in shaping the texture and flavor profile of food products. Elements such as particle size, starch and protein content, as well as the type of protein and lipids, were influential factors in determining the Oil Absorption Capacity of flour [29]. The oil absorption capacity of the extruded breakfast cereal samples ranged from 1.56 g/ml to 2.14 g/ml, with sample MC demonstrating the lowest value and the control sample showing the highest. In the case of maize-based extruded breakfast cereal samples, sample MC had the lowest value (1.56 g/ml), while sample MA displayed the highest (1.92 g/ml) compared to the control sample (2.14 g/ml). Among the sorghum-based extruded breakfast cereal samples, sample SA exhibited the lowest value (1.48 g/ml), whereas sample SB registered the highest (1.99 g/ml) against the control sample (2.14 g/ml).

The oil absorption capacity of the maize-based extruded breakfast cereal samples decreased as the proportion of maize flour decreased and the proportion of date palm flour increased in the extruded breakfast cereal. Conversely, the oil absorption capacity of the sorghum-based extruded breakfast cereal samples increased with a decrease in sorghum flour concentration and an increase in date palm flour concentration. The higher oil absorption capacities exhibited by the control sample (2.14 g/ml), sample MA (1.92 g/ml), and sample SB (1.99 g/ml) may be attributed to their elevated protein content and low water absorption of the composite flour. The retention of lipids is indicative of the protein's capacity to absorb and retain oil. A higher oil absorption capacity in food materials enhances mouthfeel and aids in flavor retention [30]. According to Ref. [31], the increase in oil absorption capacity could be attributed to the solubilization and dissociation of proteins, leading to the exposure of the non-polar components contained within the protein molecules.

3.2.4. Swelling power

Swelling power, which refers to a product's ability to expand upon contact with water [26], was assessed in terms of the strength of bonds in the crystalline section of starch granules, indicating how easily the starch or flour cooked. It served as a crucial metric for gauging both the amount of water food samples absorbed and the extent of their expansion within a specific timeframe [19]. The swelling power of the extruded breakfast cereal samples ranged from 1.43 g/g to 4.27 g/g. Sample SA showed the lowest value, while sample MA demonstrated the highest, surpassing even the control sample, which registered 3.67 g/g, making it the second-highest after sample MA. This suggested that sample MA and the control sample, both exhibiting high swelling power compared to the other extruded samples, would yield a thick and viscous cereal or gruel. Among the maize-based extruded breakfast cereals, sample MC displayed the lowest value (2.82 g/g), while sample MA showcased the highest (4.27 g/g) compared to the control sample (3.67 g/g). Among the sorghum-based extruded breakfast cereals, sample SA had the lowest value (1.43 g/g), while sample SB recorded the highest (1.82 g/g) against the control sample (3.67 g/g).

Notably, the swelling power of maize-based extruded breakfast cereal samples was significantly higher than that of sorghum-based ones. Moreover, the control sample exhibited a much higher value compared to the maize and sorghum extruded breakfast cereal samples, except for sample MA, which recorded the highest value. This disparity could be attributed to differences in processing methods, the percentage of flour proportions incorporated into each sample, and potentially variations in the molecular organization within the starch granules of the samples [32].

The swelling power of the extruded samples somewhat aligned with the findings of [26], who reported values ranging from 4.57 to 5.89 g/g in a previous study on granola. Additionally, the results indicated that the swelling power of maize-based extruded breakfast cereal samples decreased with a decrease in the percentage of maize flour and an increase in the percentage of date palm added to the extruded breakfast blend. Conversely, the swelling power of sorghum-based extruded breakfast cereal samples increased with a decrease in the percentage of sorghum flour and an increase in the percentage of date palm flour added to the extruded breakfast blend.

3.2.5. Dispersibility

Dispersibility, referring to how individual components from flour spread and integrate within a medium of dispersion [33], indicated how readily the sample mass separated, allowing particles to sink below the surface and disperse quickly in a liquid medium [34]. The dispersibility percentage of the extruded breakfast cereal samples ranged from 23.37 % to 60.05 %. The control sample exhibited the highest value, while sample SA showed the lowest. Among the maize-based extruded breakfast cereal samples, sample MC had the lowest value (44.75%), while sample MA demonstrated the highest (56.63 %) compared to the control sample (60.05%). Among the sorghum-based extruded breakfast cereal samples, sample SA had the lowest value (23.37%), while sample SB registered the highest (30.05%) against the control sample with a value of 60.05%. Higher dispersibility in flour indicated a greater ability to reconstitute in water [34]. However, it was observed that, except for the control samples with the highest value (60.05%), the maize-based extruded breakfast cereal samples had high dispersibility, whereas the sorghum-based extruded breakfast cereal samples exhibited lower dispersibility. Consequently, the control sample and the maize-based extruded breakfast cereal samples would likely reconstitute more effectively in water compared to the sorghum-based extruded breakfast cereal samples.

In general, the dispersibility of maize-based extruded breakfast cereal samples decreased as the percentage of maize flour decreased and the percentage of date palm flour increased in the blend, while the dispersibility of sorghum-based extruded breakfast cereal samples increased with a decreasing percentage of sorghum flour and an increasing percentage of date palm flour in the blend.

3.2.6. Mineral composition of the extruded breakfast cereal

The result for the mineral composition of the extruded breakfast cereal samples are presented in Table 4. Sodium, potassium, calcium, zinc and iron were analyzed for all the samples. The result showed a significant difference at ($p < 0.05$) in the mineral

Table 4
Mineral composition of extruded breakfast cereals.

Sample	Sodium	Potassium	Calcium	Zinc	Iron
	mg/100g	mg/100g	mg/100g	mg/100g	mg/100g
MA	$18.67^{a}\pm0.43$	$291.50^{b}\pm0.90$	$421.40^{a}\pm0.20$	$4.11^{b}\pm0.03$	$15.10^{a}\pm0.02$
MB	$16.39^{b}\pm0.01$	$287.35^{b}\pm0.85$	$409.35^{a}\pm0.85$	$5.21^{a}\pm0.01$	$15.22^{a}\pm0.02$
MC	$16.04^{b}\pm0.02$	$273.00^{b}\pm0.60$	$394.55^{a}\pm0.05$	$5.36^{a}\pm0.02$	$15.07^{a}\pm0.06$
SA	$12.49^{c}\pm0.09$	$321.60^{a}\pm1.10$	$363.65^{c}\pm2.75$	$4.43^{ab}\pm0.03$	$9.84^{c}\pm0.04$
SB	$12.33^{c}\pm0.03$	$292.70^{b}\pm1.90$	$345.45^{c}\pm0.75$	$4.66^{ab}\pm0.02$	$9.22^{c}\pm0.02$
SC	$12.05^{c}\pm0.03$	$253.00^{c}\pm2.20$	$341.88^{c}\pm3.99$	$4.83^{ab}\pm0.03$	$9.47^{c}\pm0.05$
CTRL	$10.88^{d}\pm0.03$	$351.65^{a}\pm0.75$	$321.50^{d}\pm0.70$	$4.64^{b}\pm0.03$	$12.88^{b}\pm0.03$

Values are means of triplicate ± standard deviation. Values with different superscript along the same column are significantly difference ($p \leq 0.05$).
Key.
MA-90%Maize flour+10% Date palm flour; MB-80%Maize flour+20% Date palm flour.
MC-70%Maize flour+30% Date palm flour; SA-90%Sorghum flour +10% Date palm flour.
SB-80%Sorghum flour +20% Date palm flour; SC-70%Sorghum flour +30% Date palm flour.
CTRL- Commercial extruded cereal.

composition of all samples. The sodium and calcium content of all samples increased greatly compared to the control samples.

3.2.7. Sodium

The sodium content in the extruded breakfast cereal samples ranged from 10.88 mg/100 g to 18.67 mg/100g. The control sample had the lowest value, while sample MA exhibited the highest. Among the maize-based extruded breakfast cereal samples, sample MC had the lowest sodium content (16.04 mg/100g), whereas sample MA showed the highest (18.67 mg/100g) in contrast to the control sample (10.88 mg/100g). Among the sorghum-based extruded breakfast cereal samples, sample SC had the lowest sodium content (12.05 mg/100g), while sample SA demonstrated the highest (12.49 mg/100g) compared to the control sample (10.88 mg/100g). These values fell below the recommended daily allowance set by the US (500 mg/100g) [26]. They were also lower than the values reported by Ref. [35] ranging from 97.5 to 187.3 mg/100g. This variation in results may be attributed to differences in processing methods and the sodium composition of the maize, sorghum, and date palm flours used.

Additionally, it was observed that the control sample had the lowest sodium content, and the maize-based extruded breakfast cereal samples had higher sodium content compared to the sorghum-based ones. The study also revealed that the sodium content in both the maize and sorghum extruded breakfast cereal samples decreased with a reduction in the proportion of maize and sorghum flour, respectively, and an increase in the addition of date palm flour in the blend. Sodium is the primary cation found in the body's extracellular fluid and is essential for maintaining plasma volume, regulating acid-base balance, normal cellular function, and transmitting nerve impulses [36].

Monitoring sodium intake is crucial, especially in cases where high blood pressure is a concern [37,38].

3.2.8. Potassium

The potassium content in the extruded breakfast cereal samples ranged from 253 mg/100g to 351.65 mg/100g, with sample SC showing the lowest value and the control sample displaying the highest. Among the maize-based extruded breakfast cereal samples, sample MC had the lowest value (273 mg/100g), while sample MA demonstrated the highest (291.50 mg/100g) in contrast to the control sample (351.65 mg/100g). Among the sorghum-based extruded breakfast cereal samples, sample SC had the lowest value (253 mg/100g), while sample SA exhibited the highest (321.60 mg/100g) compared to the control sample (351.65 mg/100g). It's worth noting that the potassium content in the control samples was higher than that in both the maize and sorghum extruded breakfast cereal samples. These ranges of values were above the US Recommended Daily Allowances for both men and women (3.5 mg) [17] and lower than the results recorded by Ref. [35] with potassium values ranging from 107.0 to 238.0 mg/100g. The observed decrease in the potassium content of the maize and sorghum extruded breakfast cereal samples compared to the high content in the control sample suggests that date palm fruits are not as rich a source of potassium as sorghum and maize [39]. Potassium is a crucial nutrient for regulating total body fluid volume and maintaining acid-base balance [40].

Potassium is essential for blood clotting and muscle contraction. It predominantly exists as an intracellular cation, and a significant portion of this cation is bound to protein. This has an impact on osmotic pressure and contributes to maintaining normal pH levels [37,38]. Potassium is also vital for counterbalancing the adverse effects of sodium on blood pressure, nerve and muscle function, and the regulation of electrolytes, which are minerals in the body that can carry an elect rical charge [41]. An increased level of potassium could be a valuable asset in product formulation, especially in breakfast cereals, where potassium holds importance as a key macronutrient among other minerals [35].

3.2.9. Calcium

The calcium content in the extruded breakfast cereal samples ranged from 321.50 mg/100g to 421.40 mg/100g. The control sample had the lowest value, while sample MA had the highest. Among the maize-based extruded breakfast cereal samples, sample MC displayed the lowest value (394.55 mg/100g), whereas sample MA showcased the highest (421.40 mg/100g) compared to the control sample (321.50 mg/100g). Among the sorghum-based extruded breakfast cereal samples, sample SC registered the lowest value (341.88 mg/100g), while sample SA recorded the highest (363.65 mg/100g) against the control sample (321.50 mg/100g). The results also indicated a decline in the calcium content of both the maize and sorghum extruded breakfast cereals as the percentage of maize and sorghum flour, respectively, decreased, and the percentage of date palm flour increased in the blend. The maize-based extruded breakfast cereal samples had higher calcium content (ranging from 394.55 mg/100g to 421.40 mg/100g) than the control sample (321.50 mg/100g) and the sorghum extruded breakfast cereal samples. However, the calcium content of the sorghum-based extruded breakfast cereal samples was higher (ranging from 341.88 to 363.65 mg/100g) than the control samples (321.50 mg/100g). The increase in calcium content in the maize and sorghum extruded breakfast cereal samples compared to the control sample could be attributed to the higher inclusion of date palm flour in the extruded blend samples, as well as the different cereals and processing methods used in production [42].

Calcium is one of the most crucial minerals required by the body, playing a vital role in most metabolic processes and providing rigidity to the skeleton. It is necessary for growth, the maintenance of strong teeth and bones, nerve signaling, muscle contraction, and the secretion of certain hormones and enzymes [43]. A deficiency in calcium can lead to numbness in fingers, toes, osteoporosis, rickets, muscle cramps, convulsions, and lethargy [44].

3.2.10. Iron

The iron content in the extruded breakfast cereal samples varied from 9.22 mg/100g to 15.2 mg/100g, with sample SB displaying the lowest value and sample MB exhibiting the highest, in contrast to the control sample which had a value of 12.88 mg/100g. Among the maize-based extruded breakfast cereal samples, sample MB showcased the highest value (15.22 mg/100g), followed by sample MA

(15.10 mg/100g), while sample MC demonstrated the lowest value (15.07 mg/100g) compared to the control sample (12.88 mg/100g). Among the sorghum-based extruded breakfast cereal samples, sample SA registered the highest value (9.84 mg/100g), followed by sample SC (9.47 mg/100g), and sample SB had the lowest value (9.22 mg/100g) in contrast to the control sample (12.88 mg/100g).

The findings also revealed that the iron content in the maize extruded breakfast cereal samples was higher (ranging from 15.07 mg/100g to 15.22 mg/100g) than that of the control sample (12.88 mg/100g). However, the control sample's iron content (12.88 mg/100g) was higher than that of the sorghum extruded breakfast cereal samples (ranging from 9.22 mg/100g to 9.84 mg/100g). The values obtained in this study closely align with those reported by Ref. [22] for breakfast cereals made from African yam bean, maize, and defatted coconut, which ranged from 9.81 mg/100g to 14.10 mg/100g.

Iron is a component of myoglobin, a protein that facilitates oxygen delivery to muscles and supports metabolism in humans. Regular consumption of iron-rich foods has the potential to prevent anemia in infants and young children [45]. Iron is also crucial for hemoglobin formation, oxygen transportation, and electron transport in the human body [40]. The iron content observed in this study falls below the maximum iron concentration limit in food set by FAO [46], which is 42.5 mg/100g. Additionally, the iron content aligns with the Recommended Daily Allowance (RDA) of iron, which is 15 mg/day for females aged 14–18 years and 11 mg/day for males aged 14–18 years [47].

3.2.11. Zinc

The zinc content in the extruded breakfast cereal samples ranged from 4.11 mg/100g to 5.36 mg/100g. Sample MA displayed the lowest value, while sample MC exhibited the highest, in contrast to the control sample with a value of 4.64 mg/100g. Among the maize-based extruded breakfast cereal samples, sample MA had the lowest value (4.11 mg/100g), and sample MC had the highest value (5.36 mg/100g) compared to the control sample (4.64 mg/100g). Among the sorghum-based extruded breakfast cereal samples, sample SA registered the lowest value (4.43 mg/100g), and sample SC recorded the highest (4.83 mg/100g) against the control sample (4.64 mg/100g).

Furthermore, the maize-based extruded breakfast cereal samples had higher zinc values (ranging from 4.11 mg/100g to 5.36 mg/100g) compared to the values of the sorghum extruded breakfast cereal samples (ranging from 4.43 mg/100g to 4.83 mg/100g). It was also noted that the values of sample MA and sample SA were lower than the value of the control sample (4.64 mg/100g). Additionally, the results demonstrated an increase in zinc values in the maize and sorghum extruded breakfast cereal samples with a decrease in the percentage of maize and sorghum flour added, respectively, and an increase in the percentage of date palm flour added to the extruded blends. Zinc played a pivotal role in supporting normal growth and development during pregnancy, childhood, and adolescence [48].

3.3. Colour properties of the extruded breakfast cereal

Colour played a crucial role in consumers' food choices and directly influenced product marketing. The color of food products was influenced by the ingredients used in their formulations. Table 5 presented the colour characteristics, including brightness, redness, and yellowness, of the extruded breakfast cereal samples. The results indicated significant differences in brightness, redness, and yellowness among the extruded breakfast cereal samples.

The brightness of the extruded breakfast cereal samples ranged from 55.31 to 64.48. Sample MB had the lowest brightness value, while sample MA had the highest brightness value, surpassing the control sample with a brightness value of 57.99. Within the extruded breakfast cereal samples, sample MA boasted the highest brightness value (64.48), followed by sample MC (58.14), while sample MB displayed the lowest brightness value (55.31) compared to the control sample with a brightness value of 57.99. Among the sorghum-based extruded breakfast cereal samples, sample SB recorded the highest brightness value (59.79), followed by sample SC (57.56), and sample SA had the least brightness value (57.01) compared to the control sample's brightness value of 57.99. These observations suggested that maize and sorghum possessed inherent genetic attributes that resulted in varying brightness indices in food products. The higher brightness value in sample MA could be attributed to the presence of β-carotene compounds found in maize [49].

The redness of the extruded samples ranged from 0.63 to 2.73. Sample MB had the lowest redness value, whereas sample MA

Table 5
Colour properties of extruded breakfast cereals.

SAMPLE	Brightness	Redness	Yellowness
MA	$64.48^{a} \pm 1.71$	$2.73^{a} \pm 0.23$	$17.37^{a} \pm 0.99$
MB	$55.31^{ab} \pm 0.55$	$0.63^{d} \pm 0.22$	$10.00^{c} \pm 0.10$
MC	$58.14^{ab} \pm 3.32$	$1.02^{c} \pm 1.01$	$12.27^{b} \pm 2.50$
SA	$57.01^{ab} \pm 0.42$	$0.97^{d} \pm 0.14$	$11.00^{bc} \pm 0.28$
SB	$59.79^{b} \pm 0.43$	$2.47^{a} \pm 0.17$	$12.77^{b} \pm 0.12$
SC	$57.56^{ab} \pm 0.69$	$0.89^{d} \pm 0.29$	$11.23^{bc} \pm 0.45$
CTRL	$57.99^{ab} \pm 1.42$	$1.48^{b} \pm 1.05$	$12.27^{b} \pm 1.31$

Values are mean ± S.D. Means with same superscript across a column are not significantly different at $p < 0.05$.
Key.
MA-90%Maize flour+10% Date palm flour; MB-80%Maize flour+20% Date palm flour.
MC-70%Maize flour+30% Date palm flour; SA-90%Sorghum flour +10% Date palm flour.
SB-80%Sorghum flour +20% Date palm flour; SC-70%Sorghum flour +30% Date palm flour.
CTRL- Commercial extruded cereal.

exhibited the highest redness value compared to the control sample with a redness value of 1.48. Among the sorghum samples, sample SB had the highest redness value (2.47), followed by sample SA (0.97), while sample SC displayed the lowest redness value (0.89) compared to the control sample's redness value of 2.73. Within the maize-based extruded breakfast cereal samples, sample MA recorded the highest redness value (2.73), followed by sample MC (1.02), and sample MB had the lowest redness value (0.63).

The increase in redness value for sample MA and sample SB, as well as the decrease in redness value for sample MB, MC, SA, and sample SC, may be attributed to variations in carotenoid levels based on the percentage of sorghum and maize flour added [50,43].

The yellowness of the extruded samples ranged from 10 to 17.37. Sample MB had the lowest yellowness value, while sample MA exhibited the highest yellowness value compared to the control sample with a yellowness value of 12.27. Among the sorghum-based extruded breakfast cereal samples, sample SB displayed the highest yellowness value (12.77), followed by sample SC (11.23), while sample SA had the lowest yellowness value (11.00) compared to the control sample's value of 12.27.

These variations in the colour of the extruded breakfast cereal samples can be attributed to the presence of color pigments, such as carotenoids, in the maize and sorghum extruded samples [26].

4. Conclusion

The study's findings demonstrated that extruded breakfast cereals made from various cereals (including maize and sorghum) along with date palm fruit may meet accepted quality standards in terms of nutritional evaluation. Additionally, incorporating date palm flour into both maize and sorghum-based samples of complementary cereals improved their functional properties, including bulk density, water absorption capacity, oil absorption capacity, swelling power, and dispersibility. Moreover, it positively influenced the mineral content, such as sodium, potassium, calcium, iron, and zinc, in the extruded breakfast cereal samples, therefore creating a novel use for date palm fruits. Based on the results and discussions obtained, Storage stability studies should be carried out to be able to establish shelf life of the extruded breakfast cereal for mass production.

Author's contribution

ADEPEJU A.B conceived and designed the experiments; ALUKO, D.M analyzed and interpreted the data, OLUGBUYI, A O co-supervised the research, effected corrections on the write up and contributed reagents., OYINLOYE, A.M proof read the manuscript while ADENIRAN, O. O performed the experiments and wrote the first draft.

Data Availability

Data will be made available on request.

CRediT authorship contribution statement

A.B. Adepeju: Conceptualization. **D.M. Aluko:** Writing – original draft. **A.O. Olugbuyi:** Investigation, Conceptualization. **A.M. Oyinloye:** Writing – review & editing. **O.O. Adeniran:** Supervision, Ajibola Mitchell.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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