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Impact of Extrusion Cooking Variables on the Nutritional and Sensory Attributes of Rice-Defatted Sesame Breakfast Cereal

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ABSTRACT

Cereal-based foods are considered to lower risk to food safety compared to many other foods, which make them the good source of protein, B vitamins, energy and minerals for the general population. Blending rice and defatted sesame would provide a wide range of high protein, calories and micronutrients if properly processed. The retention of these essential nutrients was enhanced through the application of extrusion cooking processes such as barrel temperature, feed moisture content and feed blend composition. Extrusion cooking was carried out at different barrel temperature (80°C, 110°C and 140°C), different feed moisture content of (10%, 20% and 30%) and feed composition of sesame at (10%, 17.5% and 25%) to investigate the effect of extrusion conditions on nine samples with three control of extruded rice. The proximate composition revealed that the highest protein of the extruded breakfast cereals was 20.46% extruded at 110, 20% moisture and 25% feed blend composition of sesame. Functional properties revealed that the highest bulk density was 0.64g/cm^3 140°C barrel temperature, 30% moisture and 10% feed blend composition of sesame. Mineral content of the extrudate showed potassium was found to be high at 2.75mg/kg at a 110°C barrel temperature, 20% moisture and 17.5% feed blend composition of sesame and significant at ($P < 0.05$). Based on the findings, sample B ($R_{75}S_{25}T^{110}M_{10}$) exhibited best quality among the extrudates in terms of their nutritional qualities, functional properties and sensory attributes. These findings can be adopted in food industry where rice and sesame are their major ingredients for producing extruded breakfast cereal.

1. Introduction

Grains serve as valuable protein, B vitamin, energy, and mineral sources with relatively low food safety risks compared to other food categories. Rice, wheat, and maize dominate global consumption due to their high energy density. Nevertheless, cereal-based foods present nutritional challenges including

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post-heating swelling, limited mineral bioavailability, and anti-nutritional compounds that reduce nutrient absorption (Samtiya et al., 2020). Rice offers substantial energy plus essential nutrients including protein, minerals, and vitamins vital for growth and development (Tegegne et al., 2020). However, cereal-based diets require nutritional enhancement through diversification, biofortification, and optimization. Rice and rice products stand out among cereals for their digestible texture, hypoallergenic properties, low fat content, and white appearance—key attributes for weaning food formulation. The low fat content also makes rice suitable for baking applications. While rice contains sulfur-rich amino acids like cysteine and methionine, it lacks lysine (Koweiska et al., 2011). Digestion rates vary based on intrinsic factors (starch-protein interactions, starch properties, starch-lipid interactions) and extrinsic factors (hydrothermal processing, cooking methods) (Michelle et al., 2019). Rice, a semi-aquatic annual plant, thrives across diverse soil and water environments including flood-prone areas, uplands, lowlands, and rainfed regions. Current production and processing technologies inadequately meet grain demand. Extrusion cooking technology represents the latest advancement in starch-based food processing, valued for its reliability and thermal stability. This technique benefits high-protein legume processing (Skarma et al., 2020) and is increasingly utilized by food development industries for breakfast cereals, weaning foods, and modified cereal starches. The extrusion process generates heat through viscosity effects, rapidly cooking raw mixtures while altering material properties via biopolymer physicochemical changes (Pilli and Alessandrino, 2018). Sesame (Sesamun indicum L.), or benniseed, ranks among the oldest spices and oilseed crops, cultivated for seeds containing approximately 50% oil and 25% protein (Sani et al., 2014). Sesame oil demonstrates superior stability compared to other vegetable oils due to antioxidants including sesamum, sesamolin, and sesamol. Its extensive root system provides excellent drought tolerance, enabling cultivation where other crops struggle (Babagana et al., 2021). Therefore, fortifying lysine-deficient rice with sesame could produce nutritionally adequate breakfast cereals.

2. Literature Review

Rice's lysine deficiency necessitates supplementation with lysine-rich, high-protein foods to achieve proper essential nutrient balance, particularly since legumes typically provide abundant lysine (M.C. Temba et al., 2016). Globally, rice supplies approximately 13% of protein and 20% of carbohydrate consumption (Hoogenkamp et al., 2015). High-temperature, short-duration cooking of legume-cereal blends effectively eliminates antinutritional factors while preserving raw material nutritional value (Skarma et al., 2020; Bordoloi et al., 2014; Pawar et al., 2014). Sesame's composition includes 44-58% oil, 18-25% protein, 13.5% carbohydrates, and 5% ash (Adeniyan et al., 2013 and Tunde-Akintunde et al., 2012). Historically, sesame seeds were primarily processed for oil production, with the remaining cake used as livestock feed (Abimbola et al., 2021).

3. Research Methodology

Materials

Sample collection

The rice variety (FARO 52) and sesame variety (NCRIBEN-04E) were obtained from National cereals Research Institute Badeggi Niger State.

Sample processing

The paddy was cleaned manually to removed shaft before milling with (locally fabricated, NCRI) and milling with a rubber roll mill (Satake Corporation Ltd, Japan) and milled into rice flour.

Benniseed flour production

Benniseed grains were thoroughly cleaned to remove stones, sand and debris through a mesh, and then winnowed before washing. The washed benniseed was oven dry at 35°C for 1 hour in an oven before dry milling. Oil was extracted from the milled sesame cake decant; oven dried before getting the actual benniseed flour.

Figure 1. Flow diagram for the production of rice flour

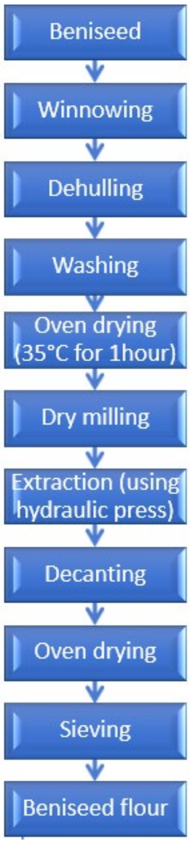

Figure 2. Flow diagram for the production of benniseed flour

Blend preparation and moisture adjustment

Rice and benniseed flour were mixed at different proportion with rice being the main ingredient using modified method of Danbaba *et al.,* (2016). The moisture content of flour was measured at different level using oven. After getting the initial moisture content of the blend which is (M1), the blended samples were conditioned to specific moisture content appropriate for the blend with calculated medium speed in a blender. The samples were sealed in containers and allowed to stay overnight. The amount of water to be added was calculated according to the method of Wimot BW., (1998).

Extrusion cooking experiment

The extrusion cooking experimental range using a small-scale laboratory single screw extruder (DUISBURG DCE-330 Models Germany) with components such as feeding, cooking and die zones couple with a screw feeder and 3mm die used to extrude the different samples. The samples were dried overnight after extrusion at 60°C in an oven and stored in a desiccator for analysis.

Experimental design

Table 1: Experimental Design of the mixed flour ratio associated with other extrusion variables using central composite design (CCD)

Sample	BRT (°C)	FMC (%)
C1($R_{100}S_0\,T^{80}M_{10}$)	80	10
C2($R_{100}S_0\,T^{110}M_{20}$)	110	20
C3($R_{100}S_0\,T^{140}M_{30}$)	140	30
A($R_{75}S_{25}T^{80}M_{10}$)	80	10
B($R_{75}S_{25}T^{110}M_{20}$)	110	20
C($R_{75}S_{25}T^{140}M_{30}$)	140	30
D($R_{82.5}S_{17.5}T^{80}M_{10}$)	80	10
E($R_{82.5}S_{17.5}T^{110}M_{20}$)	110	20
F($R_{82.5}S_{17.5}T^{140}M_{30}$)	140	30
G($R_{90}S_{10}T^{80}M_{10}$)	80	10
H($R_{90}S_{10}T^{110}M_{20}$)	110	20
I($R_{90}S_{10}T^{140}M_{30}$)	140	30

Source: Authors experimental design (2025).

BRT=barrel temperature, FMC= Feed moisture content, FBC =feed blend composition

Sample C1 Control ($R_{100}S_0\,T^{80}M_{10}$)= 100% Rice:0% sesame:80°C Temperature:10% Moisture, Sample C2 Control ($R_{100}S_0\,T^{110}M_{20}$) = 100% Rice:0% sesame:Temperature:110°C:20% Moisture, Sample C3 Control ($R_{100}S_0\,T^{140}M_{30}$)= 100% Rice:0% Sesame: Temperature 140°C:30% Moisture, Sample A ($R_{75}S_{25}T^{80}M_{30}$)= 75% Rice: 25% Sesame: Temperature 80°C: Moisture 30%, Sample B ($R_{82.5}S_{17.5}T^{110}M_{20}$)= 82.5% Rice: 17.5% Sesame: 110°C Temperature: 20% Moisture, sample C ($R_{82.5}S_{17.5}T^{140}M_{20}$)=82.5% Rice: 17.5% Sesame:140°C Temperature :20% Moisture, Sample D ($R_{82.5}S_{17.5}T^{110}M_{30}$)=82.5% Rice: 17.5% sesame 110°C Temperature :30% Moisture, Sample E ($R_{90}S_{10}T^{140}M_{10}$)=90%Rice: 10% sesame: 140°C Temperature :10% Moisture, Sample F ($R_{90}S_{10}T^{80}M_{30}$)=90%Rice: 10% sesame :80°C Temperature :30%

Moisture, Sample G ($R_{90}S_{10}T^{110}M_{30}$)= 90% Rice:10%Sesame:110°C:30%Moisture,SampleH ($R_{90}S_{10}T^{80}M_{20}$) =90%Rice: 10% Sesame: 80°C: Temperature: 20% Moisture, Sample I ($R_{82.5}S_{17.5}T^{110}M_{10}$)=82.5% Rice: 17.5% Sesame:110°C: Temperature :10% Moisture.

Proximate composition

The proximate composition analysis was determined using the standard method of (AOAC 2000), while the total carbohydrate was obtained by difference.

Determination of functional properties

Bulk density (BD) the method of Arise *et al.*, (2019) was employed, Expansion index (EI) was determined using the method of Ranjit and Subha, (2014), Water absorption capacity (WAC) was determine using the method described by Adebowale *et al.*, (2012), Forming capacity (FC) and forming stability (FS) were determined by the method described by Chandra *et al*. (2015), swelling power (SP) and swelling capacity (SC) was determined by the method of AOAC (2011).

Mineral Analysis

Mineral composition (Calcium, Potassium, Sodium, Magnesium and Phosphorus) of the extrudate were determined using methods described by AOAC (2011).

Sensory Evaluation

Sensory evaluation of extrudate was determined using the method of Iwe, (2001).

Statistical analysis

The data collected were expressed as mean ± standard deviation. Analysis of variance (ANOVA) using duncan multiple range were carried out to determine the differences among the samples with significant differences accepted at $p^{<}0.05$.

4. Result and discussion

Proximate composition of the extruded breakfast cereal

The extruded breakfast cereal exhibited significant variations ($P < 0.05$) in moisture content (5.32–8.72%), with higher extrusion temperatures increasing moisture retention, independent of initial raw material moisture (Danbaba et al., 2016). This range aligns with Ndaliman et al. (2018), who reported 6.05% moisture in a millet-pigeon pea blend, and supports shelf-life stability, as levels above 10% may promote microbial or chemical spoilage (Danbaba et al., 2016).

Ash content differed significantly ($P < 0.05$), ranging from 0.49–1.21% in controls and 0.82–2.02% in sesame-fortified samples, decreasing at higher temperatures and moisture levels, consistent with findings from rice-cactus pear blends (El-Samahy et al., 2007). Fat content varied from 0.99–2.13% (controls) to 3.23–5.58% (fortified), likely due to Maillard reactions and caramelization (El-Samahy et al., 2007). Fats are vital for nutrient absorption and physiological functions (Gbenyi *et al.,* 2016).

Protein content was higher in fortified samples (13.14–20.46%) than controls (1.97–2.28%), attributed to sesame enrichment and extrusion-induced protein denaturation, enhancing digestibility (Cauhtemoc *et al.,* 2018). Similar increases were noted in millet-cowpea extrudates (Filli *et al.,* 2011) and sorghum-wheat blends (Yoo et al., 2013). The rise in protein also improved water absorption capacity (Arise *et al.,* 2020).

Crude fiber was higher in controls (0.33–0.79%) than fortified samples (0.05–0.12%), with extrusion parameters negatively affecting fiber content, contrary to Filli et al. (2011). Extrusion may convert insoluble to soluble fiber (Naumann et al., 2021). Carbohydrates were significantly lower in fortified samples (65.51–73.71%) than controls (90.68–93.37%), due to sesame inclusion, aligning with rice-soybean extrudates (Danbaba *et al.,* 2017). These results highlight the nutritional benefits of rice-sesame extrusion for breakfast cereals (Jisha *et al.,* 2010).

Table 2. Proximate composition of the extruded breakfast cereal

Sample	Moisture (%)	Ash (%)	Crude Fat (%)	Protein (%)	Crude fibre (%)	CHO (%)	Energy value
C1($R_{100}S_0T^{80}M_{10}$)	$2.55^f±0.01$	$1.21^e±0.01$	$1.12^j±0.01$	$1.97^k±0.01$	$0.79^a±0.00$	$92.37^b±0.01$	$387^d±0.04$
C2($R_{100}S_0T^{110}M_{20}$)	$1.72^g±0.35$	$0.99^f±0.01$	$0.99^k±0.00$	$2.28^j±0.00$	$0.65^b±0.01$	$93.37^a±0.36$	$392^c±1.47$
C3($R_{100}S_0T^{140}M_{30}$)	$4.18^e±0.36$	$0.49^h±0.00$	$2.13^i±0.00$	$2.19^j±0.00$	$0.33^c±0.00$	$90.68^c±0.36$	$391^c±1.45$
A($R_{75}S_{25}T^{80}M_{10}$)	$6.57^c±0.06$	$2.02^a±0.00$	$4.42^d±0.04$	$20.12^b±0.01$	$0.12^i±0.00$	$66.75^g±0.04$	$387^d±0.31$
B($R_{75}S_{25}T^{110}M_{20}$)	$5.32^d±0.01$	$1.94^b±0.01$	$4.06^h±0.00$	$20.46^a±0.02$	$0.12^i±0.00$	$66.34^g±0.13$	$391^d±0.33$
C($R_{75}S_{25}T^{140}M_{30}$)	$8.34^b±0.07$	$1.56^b±0.00$	$3.23^h±0.01$	$14.37^g±0.00$	$0.09^e±0.00$	$72.09^e±0.09$	$376^g±0.33$
D($R_{82.5}S_{17.5}T^{80}M_{10}$)	$6.41^c±0.06$	$1.49^d±0.05$	$5.20^b±0.05$	$19.86^d±0.02$	$0.09^e±0.00$	$66.94^g±0.05$	$394^b±0.70$
E($R_{82.5}S_{17.5}T^{110}M_{20}$)	$8.72^a±0.00$	$1.47^{cd}±0.01$	$4.30^e±0.06$	$19.92^c±0.01$	$0.08^{ef}±0.00$	$65.51^h±0.12$	$380^f±0.10$
F($R_{82.5}S_{17.5}T^{140}M_{30}$)	$6.54^c±0.01$	$1.43^d±0.01$	$4.83^c±0.00$	$13.28^h±0.00$	$0.09^e±0.00$	$73.84^d±0.00$	$392^c±0.02$
G($R_{90}S_{10}T^{80}M_{10}$)	$5.59^d±0.06$	$1.02^f±0.01$	$5.58^a±0.05$	$17.66^f±0.01$	$0.06^g±0.00$	$70.08^f±0.14$	$401^a±0.09$
H($R_{90}S_{10}T^{110}M_{20}$)	$5.61^d±0.08$	$1.57^b±0.00$	$4.21^f±0.00$	$18.41^e±0.01$	$0.09^e±0.00$	$70.09^f±0.09$	$392^c±0.33$
I($R_{90}S_{10}T^{140}M_{30}$)	$8.16^b±0.06$	$0.82^g±0.06$	$4.13^g±0.01$	$13.14^i±0.01$	$0.05^h±0.00$	$73.71^d±0.05$	$385^e±0.30$

Source: Laboratory experiment 2025

Mean ± SD Mean with different superscript in each column are significantly different p<0.05

Mineral composition of the extruded breakfast cereal

Minerals, though present in small amounts, play vital roles in food chemistry and nutrition. However, few studies have explored mineral changes during extrusion cooking, likely due to their general stability during processing (Jideani et al., 2011; Singh et al., 2007). Key minerals in extruded products include sodium, potassium, calcium, magnesium, and phosphorus. Sodium intake should be moderated due to its link with hypertension (Kadan et al., 2003). Fortification increased mineral content, with sodium levels significantly higher (P<0.05) in fortified samples (0.40–0.94 mg/100g) than in controls (0.27–0.36 mg/100g), possibly due to lower barrel temperatures enhancing phytic enzyme activity (Kanu et al., 2009). Potassium, crucial for pH balance (Swaminathan, 2003), has daily requirements of 3000mg (ages 1–3) and 4500mg (ages 9–13) (WHO, 2012). Phosphorus levels were significantly higher (P<0.05) in fortified samples (0.79–2.31 mg/100g vs. 0.13–0.26 mg/100g in controls), likely due to sesame addition and enzymatic activity during gelatinization (Ndaliman et al., 2018). Calcium showed minimal variation except in one sample (2.75 mg/100g), aligning with studies on extruded grits (Jideani et al., 2021). Deficiency can cause bone disorders (Danbaba et al., 2018). Magnesium increased with sesame fortification (2.06–4.79 mg/100g vs. 0.95–1.22 mg/100g in controls) but decreased at higher barrel temperatures, consistent with findings on rice-cowpea blends (Danbaba et al., 2015). Overall, fortification enhanced mineral content, benefiting nutritional quality, particularly in breakfast cereals.

Table 3. Mineral composition of the extruded breakfast cereal

Sample	Na(mg/10g)	K(mg/1g)	P(mg/1g)	Ca(mg/100)	Mg(mg/100g)
C1($R_{100}S_0T^{80}M_{10}$)	$0.27^{h}\pm0.00$	$0.36^{ef}\pm0.00$	0.26 ± 0.00	$1.72^{b}\pm0.01$	$0.95^{f}\pm0.01$
C2($R_{100}S_0T^{110}M_{20}$)	$0.32^{i}\pm0.01$	$0.35^{ef}\pm0.00$	$0.14^{1}\pm0.00$	$0.81^{e}\pm0.01$	$1.22^{e}\pm0.01$
C3($R_{100}S_0T^{140}M_{30}$)	$0.36^{i}\pm0.00$	$0.30^{f}\pm0.00$	$0.13^{i}\pm0.01$	$1.65^{c}\pm0.01$	$1.01^{f}\pm0.01$
A($R_{75}S_{25}T^{80}M_{10}$)	$0.54^{d}\pm0.01$	$0.51^{c}\pm0.08$	$0.79^{h}\pm0.02$	$0.43^{h}\pm0.07$	$2.07^{d}\pm0.04$
B($R_{75}S_{25}T^{110}M_{20}$)	$0.42^{g}\pm0.03$	$0.38^{de}\pm0.01$	$2.31^{a}\pm0.03$	$0.45^{h}\pm0.02$	$2.51^{c}\pm0.08$
C($R_{75}S_{25}T^{140}M_{30}$)	$0.94^{a}\pm0.00$	$0.71^{ab}\pm0.02$	$1.21^{d}\pm0.01$	$0.66^{f}\pm0.02$	$2.15^{d}\pm0.07$
D($R_{82.5}S_{17.5}T^{80}M_{10}$)	$0.58^{c}\pm0.00$	$0.65^{b}\pm0.05$	$1.34^{c}\pm0.05$	$0.65^{f}\pm0.03$	$2.06^{d}\pm0.06$
E($R_{82.5}S_{17.5}T^{110}M_{20}$)	$0.51^{e}\pm0.00$	$0.66^{b}\pm0.03$	$1.54^{b}\pm0.01$	$2.75^{a}\pm0.01$	$2.55^{c}\pm0.07$
F($R_{82.5}S_{17.5}T^{140}M_{30}$)	$0.47^{f}\pm0.01$	$0.78^{a}\pm0.01$	$0.83^{g}\pm0.01$	$0.91^{d}\pm0.01$	$2.95^{b}\pm0.02$
G($R_{90}S_{10}T^{80}M_{10}$)	$0.84^{b}\pm0.01$	$0.73^{ab}\pm0.00$	$0.87^{g}\pm0.01$	$0.66^{f}\pm0.01$	$4.79^{a}\pm0.06$
H($R_{90}S_{10}T^{110}M_{20}$)	$0.48^{f}\pm0.00$	$0.36^{ef}\pm0.04$	$0.91^{f}\pm0.02$	$0.57^{g}\pm0.01$	$2.94^{b}\pm0.02$
I($R_{90}S_{10}T^{140}M_{30}$)	$0.40^{h}\pm0.14$	0.46 ± 0.03	$1.10^{e}\pm0.02$	$0.68^{f}\pm0.01$	$2.45^{c}\pm0.02$

Source: Laboratory experiment 2025

Mean ± SD Mean with different superscript in each column are significantly different $p<0.05$

Functional properties of the breakfast cereal

The functional properties of extruded breakfast cereal were influenced by sesame enrichment. Compared to control samples (C1-C3), sesame-fortified samples exhibited lower bulk density (0.49–0.64 g/cm³ vs. 2.75–3.35 g/cm³), aligning with findings by Keawpeng et al. (2014) and Ndaliman et al. (2018), who noted similar decreases with lower barrel temperatures and higher moisture content. Water absorption capacity (WAC) ranged from 3.56% to 4.93%, peaking at 110°C, 20% moisture, and 17.5% sesame blend. Higher temperatures and moisture reduced WAC, consistent with Bhattacharya (1990) and Altan et al. (2008). Swelling capacity improved in fortified samples (5.49–7.63) versus controls (3.73–4.82), attributed to increased sesame content, though high temperatures and moisture diminished swelling. The solubility index was lower in fortified samples (0.24–6.98%) than in controls (5.09–9.37%), supported by Danbaba et al. (2017), linking higher moisture to reduced protein denaturation and solubility. Expansion index (6.75–8.15) was affected by die diameter, contrasting with Ndaliman *et al.* (2018) but agreeing with Ajita & Jha (2017), who found protein content inversely related to expansion. Low screw speed and high feed composition also impacted expansion (Filli *et al.,* 2013).

Table 4. Functional properties of the extruded breakfast cereal

Sample	Bulk Density(g/cm)	Water absorption capacity (%)	Swelling capacity (%)	Swelling power (%)	Solubility Index (%)	Expansion Index
C1($R_{100}S_0T^{80}M_{10}$)	$3.34^{a}\pm0.01$	$4.93^{a}\pm0.00$	$4.82^{i}\pm0.70$	$205.32^{a}\pm0.01$	$5.50^{b}\pm0.40$	$6.75^{d}\pm0.07$
C2($R_{100}S_0T^{110}M_{20}$)	$3.10^{b}\pm0.19$	$4.84^{a}\pm1.05$	$4.77^{i}\pm0.76$	$200.98^{b}\pm0.01$	$5.09^{c}\pm0.01$	$7.50^{c}\pm0.00$
C3($R_{100}S_0T^{140}M_{30}$)	$2.75^{c}\pm0.02$	$3.56^{bc}\pm3.80$	$3.73^{j}\pm0.01$	$134.25^{c}\pm1.06$	$9.37^{a}\pm0.40$	$8.15^{a}\pm0.07$

Sample	Bulk Density(g/cm)	Water absorption capacity (%)	Swelling capacity (%)	Swelling power (%)	Solubility Index (%)	Expansion Index
A($R_{75}S_{25}T^{80}M_{10}$)	0.55^{d}±0.01	3.71^{b}±4.74	6.74^{e}±0.71	87.55^{e}±0.69	3.48^{h}±0.07	7.55^{c}±0.10
B($R_{75}S_{25}T^{110}M_{20}$)	0.57^{d}±0.00	3.61^{bc}±0.69	6.97^{d}±1.46	87.22^{e}±0.01	4.27^{g}±0.05	6.70^{d}±0.28
C($R_{75}S_{25}T^{140}M_{30}$)	0.53^{d}±0.02	2.65^{d}±0.00	5.49^{h}±2.90	74.89^{h}±0.70	0.24^{i}±0.01	8.15^{a}±0.07
D($R_{82.5}S_{17.5}T^{80}M_{10}$)	0.52^{d}±0.02	3.88^{b}±4.57	6.80^{e}±4.95	77.19^{g}±0.71	4.46^{e}±0.72	7.65^{bc}±0.21
E($R_{82.5}S_{17.5}T^{110}M_{20}$)	0.54^{d}±0.05	3.92^{b}±3.70	7.63^{a}±9.19	83.68^{f}±0.70	6.40^{f}±0.71	7.75^{bc}±0.21
F($R_{82.5}S_{17.5}T^{140}M_{30}$)	0.54^{d}±0.00	3.54^{bc}±0.00	6.34^{f}±0.07	91.76^{d}±0.69	0.72^{i}±0.04	8.05^{ab}±0.07
G($R_{90}S_{10}T^{80}M_{10}$)	0.59^{d}±0.01	3.30^{bc}±5.47	7.28^{b}±5.66	87.04^{e}±1.42	4.35^{g}±0.07	7.90^{bc}±0.14
H($R_{90}S_{10}T^{110}M_{20}$)	0.49^{d}±0.00	3.34^{bc}±1.39	5.70^{g}±7.03	75.46^{h}±0.70	6.98^{d}±0.09	6.75^{d}±0.35
I($R_{90}S_{10}T^{140}M_{30}$)	0.64^{d}±0.07	3.03^{cd}±0.00	7.17^{c}±0.72	91.63^{d}±0.71	3.15^{h}±0.01	8.05^{ab}±0.07

Source: Laboratory experiment 2025

Mean ± SD Mean with different superscript in each column are significantly different p<0.05.

Sensory evaluation of the extruded breakfast cereal

Table 5 presents the sensory attributes of extruded breakfast cereal made from rice and defatted sesame flour. A significant taste difference ($P^{<}0.05$) was observed between fortified (D, F: 5.10–7.45) and control samples (C1, C2: 5.20–6.35). Sample B scored highest in taste (7.70) and flavor (7.25), likely due to higher moisture content. Sample I showed superior texture (7.50 vs. C2's 5.55, $P^{<}0.05$), possibly from lower barrel temperature and feed moisture. This aligns with 1we (2001), who noted that cereal-legume blends improve texture and that consumer preferences influence flavor. Color scores varied: C1 and C2 (5.45–6.15) vs. fortified samples D and B (4.80–7.35). Higher feed moisture and barrel temperature enhanced color, consistent with Rampersad *et al.* (2003), who reported similar sensory trends. Fortified samples A, B, C, F, and H were most acceptable in taste, color, texture, and flavor, while C2 (control) scored lower.

Table 5. Sensory evaluation of the extruded breakfast cereal

Sample	Taste	Colour	Flavor	Texture	General acceptability
C1 ($R_{100}S_0$ $T^{80}M_{10}$)	5.20^{f}±0.13	5.40^{f}±0.13	6.05^{cd}±0.14	5.55^{e}±0.11	6.35^{c}±0.15
C2($R_{100}S_0$ $T^{110}M_{20}$)	6.35^{c}±0.11	6.15^{d}±0.15	6.55^{b}±0.15	6.60^{b}±0.13	6.90^{b}±0.14
C3($R_{100}S_0$ $T^{140}M_{30}$)	5.25^{ef}±0.12	5.45^{f}±1.15	5.80^{de}±0.16	5.80^{de}±0.17	5.60^{d}±0.15
A($R_{75}S_{25}T^{80}M_{10}$)	6.95^{b} ±0.17	7.15^{ab}±0.17	7.30^{a}±0.18	7.45^{a}±0.14	7.10^{b}±0.15
B($R_{75}S_{25}T^{110}M_{20}$)	7.45^{a}±0.14	7.35^{a}±0.20	7.25^{a}±0.18	7.50^{a}±0.14	7.70^{a}±0.15
C($R_{75}S_{25}T^{140}M_{30}$)	6.35^{c}±0.11	6.40^{cd}±0.13	6.75^{b}±0.09	6.65^{b}±0.11	7.15^{b}±0.15
D($R_{82.5}S_{17.5}T^{80}M_{10}$)	5.90^{d} ±0.12	4.80^{g} ±0.14	5.40^{e}±0.11	6.10^{cd}±0.17	6.25^{c}±0.14
E($R_{82.5}S_{17.5}T^{110}M_{20}$)	5.30^{ef}±0.15	5.60^{ef}±0.16	5.85^{d}±0.13	5.70^{de}±0.15	6.20^{c}±0.13
F($R_{82.5}S_{17.5}T^{140}M_{30}$)	6.95^{b}±0.15	6.80^{bc}±0.18	7.20^{a}±0.14	7.30^{a}±0.13	7.20^{b}±0.18
G($R_{90}S_{10}T^{80}M_{10}$)	5.65^{de}±0.20	6.05^{de}±0.11	6.40^{bc}±0.15	5.85^{de}±0.15	6.10^{c}±0.14
H($R_{90}S_{10}T^{110}M_{20}$)	7.05^{ab}±0.15	7.15^{ab}±0.15	7.30^{a}±0.16	7.45^{a}±0.61	7.30^{ab}±0.13
I($R_{90}S_{10}T^{140}M_{30}$)	5.10^{f}±0.19	4.05^{h}±0.28	6.10^{cd}±0.16	6.45^{bc}±0.17	5.95^{cd}±0.11

Source: Laboratory experiment 2025

Mean ± SD Mean with different superscript in each column are significantly different p<0.05.

5. Conclusions

In this study, different formulation of rice-defatted sesame seed flour blends were used to produced breakfast cereal. The sesame was added to improve its nutritional quality. Based on the findings, sample B ($R_{75}S_{25}T^{110}M_{10}$) extruded at 110°C barrel temperature, 20% moisture and 25% sesame blend composition among the extrudates exhibited better nutritional qualities, functional properties and sensory evaluation. The optimum values of feed moisture content, barrel temperature and feed blend composition favors the production of breakfast cereal with high protein, energy value and appreciable lysine level was achieved. These findings can be adopted in food industry where rice and sesame are their major ingredients for producing extruded products.

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