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DEVELOPMENT OF MULTIGRAIN SNACKS BAR: FUNCTIONAL AND NUTRITIONAL CONTENTS AS INFLUENCED BY MIXING RATIO AND EXTRUSION CONDITIONS

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The utilization of nutrient-dense, underutilized, gluten-free cereals and legumes could offer significant potential for innovation in the snack production industry. This study aimed to develop extruded multigrain (broken brown rice flour, maize flour, soybean flour, Bambara-nut flour, and date powder) snack bars and evaluate the mixing ratios and extrusion conditions, including screw speed (240 rpm and 480 rpm) and die temperature (130 °C and 150 °C), on the nutritional contents (proximate, vitamin B_1, B_2 and B_3) and functional (water absorption index and water solubility index). Regression modelling was used to analyse and optimize these parameters. The moisture content of the snack bars ranged from 5.57 to 12.59%, fat (6.42 to 14.73%), ash (2.09 to 4.68%), fibre (2.06 to 4.07%), protein (15.36 to 27.10%), and carbohydrate (36.53 to 61.43%). Vitamin content included B_1 (0.92 to 1.85 mg/100g), B_2 (0.40 – 0.72 mg/100g), B_3 (0.18 – 0.48mg/100g). The bulk density ranged from 0.51 to 0.76 g/cm^3, water absorption index (2.09 to 7.11), and the water solubility index (5.14 to 16.18). The optimized formulation consisted of 33.81% rice flour, 17.26% maize flour, 10% soybean flour, 20.81% Bambara-nut flour, and 18.08% date powder, processed at 150 °C and 240 rpm. This blend yielded a product with moisture content (9.16%), protein (19.53%), fibre (3.40%), ash (5.39%), and enhanced vitamin levels (B_1: 1.70 mg/100g, B_2: 0.76 mg/100g, B_3: 0.41 mg/100g). Conclusively, this study demonstrates the potential of these multigrain snack to bars provide high-quality and functional snack options from underutilized resources.

Keywords: Extrusion, vitamins, optimization, brown rice, soybean, date, bulk density.

INTRODUCTION

The global demand for nutrient-dense snacks is growing rapidly as consumers increasingly prioritize healthy eating. Snacks are frequently consumed, particularly by children, up to six times daily (1, 2). However, many conventional snacks are characterized by high calorie content, low protein, minerals, and functional nutrients, and they often contain gluten, limiting their appeal to health-conscious and gluten-intolerant consumers (3). Extruded snacks, which are created by compressing a blend of cereals, pulses, dried fruits, and nuts, presents an opportunity for developing functional foods with enhanced nutritional profiles (1, 4).

Broken brown rice, a whole grain rich in fibre, vitamins, and ferulic acid, is a promising base ingredient for functional snack bars. However, its vitamin content is limited and can be improved through complementary combinations with other nutrient-dense ingredients (5). Maize, known for its essential vitamins and minerals, and soybean, which are rich in

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high-quality protein, fibre, and bioactive compounds, enhance the nutritional quality of extruded snack bars (6, 7). Bambara-nut, an underutilized legume, is rich in protein, antioxidants, phytochemicals, and minerals, providing numerous health benefits, including antimicrobial and nutraceutical properties (8). Dates contribute further functional benefits due to their abundance of B-complex vitamins, phenolic compounds and dietary fibre (9).

Extrusion, a cost-effective and versatile processing method, is widely used to develop functional snacks. It enhances nutrient availability by facilitating transformations such as protein denaturation, starch gelatinization, and the inactivation of anti-nutrients (10). The success of extruded snacks depends on the optimal ingredient ratio and process conditions to achieve the desired taste, texture, and nutritional value (11). Studies highlights the critical influence of extrusion conditions on the properties of extruded snacks. Mugabi *et al*. (12) reported that barrel temperature and feed moisture significantly affect expansion ratio, water absorption, solubility, hardness, and colour in maize-soybean extrudates. Similarly, Sahu *et al*. (13) demonstrated that barrel temperature (100 -150 °C), screw speed (110 – 350 rpm), and feed moisture content (12 -20% wb) influence expansion, bulk density, hardness, and functional indices in maize-soy protein blends. Kaur *et al*. (14) explored screw speed (400 -550 rpm), barrel temperature (125 – 175 °C), and feed moisture (14 - 18%) on mechanical energy, water interaction properties, and bulk density of protein-enriched maize snacks. Osibanjo *et al*. (15) studied ingredient ratio and extrusion temperature on the physical and mechanical properties of maize-soybean extrudates, emphasizing their impact on acceptability. Sanusi *et al*. (16) investigated extrusion temperature, moisture content, and screw speed, demonstrating improvements in protein, phenolics, antioxidant activity, and vitamin C content in brown rice, pineapple peel, and Bambara-nut snacks. Although significant studies have been conducted on extruded snacks, limited studies have focused on the combined effects of blend ratios and extrusion conditions on the nutritional, and functional properties of multigrain snack bars (MGSB). This study aimed to develop MGSB using broken brown rice, maize, soybean, Bambara-nut, and dates and to model the effects of blend ratios and extrusion conditions on their nutritional and functional properties. This aligns with the United Nations Sustainable Development Goal 12, promoting responsible consumption and production through the use of nutrient-dense, gluten-free, and underutilized ingredients.

MATERIALS AND METHODS

MATERIALS

Broken brown rice was purchased from Onyx rice milling Ltd in Ilorin while maize, soybean, Bambara-nut and date used for the sturdy were purchased from a major market in Ilorin, Kwara State. Ten kilograms each of broken brown rice, maize, soybean, and Bambara-nut were milled into flour with a particle size of 0.30 mm mesh size using a Hammer mill (Nukor, Model; SG 30, South Africa) while the dates were deseeded and dehydrated with fluidized bed dryer at 70 °C for five (5 hours) before milling to a particle size of 0.30 mm.

EXPERIMENTAL DESIGN

Table 1 shows the interactive effect of a mixture of different raw materials (rice flour, maize flour, soybean flour, Bambara-nut flour and date powder), screw speed and die head temperature Minitab Statistical Software version 20.3 was used to generate 44 experimental test runs with D-Optimal Mixture Design. Different combinations of rice flour, maize flour, soybean flour, Bambara-nut flour, and date flour were used to prepare pre-extrusion feed mixtures according to the experimental design table. The constrained values of the of the independent variables were rice flour 10 - 60%, maize flour 10 - 60%, soybean flour 10 - 60% and Bambara-nut flour 10 - 60 %, and date flour 10 - 60%, screw speed die 240 rpm – 480 rpm and head temperature 130 °C – 150 °C.

Table 1. Interactive effect of mixture of different raw materials (rice flour, maize flour, soybean flour, Bambara-nut flour and date powder), screw speed and die head temperature

Run Order	Rice flour	Maize flour	Soybean flour	Bambara-nut flour	Date powder	Screw speed (rpm)	Die head temperature (°C)
1	10	10	10	10	60	240	130
2	60	10	10	10	10	240	130
3	10	60	10	10	10	240	130
4	10	10	60	10	10	240	130
5	10	10	10	60	10	240	130
6	20	20	20	20	20	240	130
7	15	15	15	15	40	240	130
8	40	15	15	15	15	240	130
9	15	40	15	15	15	240	130
10	15	15	40	15	15	240	130
11	15	15	15	40	15	240	130
12	10	10	10	10	60	480	130
13	60	10	10	10	10	480	130
14	10	60	10	10	10	480	130
15	10	10	60	10	10	480	130
16	10	10	10	60	10	480	130
17	20	20	20	20	20	480	130
18	15	15	15	15	40	480	130
19	40	15	15	15	15	480	130
20	15	40	15	15	15	480	130
21	15	15	40	15	15	480	130
22	15	15	15	40	15	480	130
23	10	10	10	10	60	240	150
24	60	10	10	10	10	240	150
25	10	60	10	10	10	240	150
26	10	10	60	10	10	240	150
27	10	10	10	60	10	240	150
28	20	20	20	20	20	240	150
29	15	15	15	15	40	240	150

Table 1. Continuation

Run Order	Rice flour	Maize flour	Soybean flour	Bambara-nut flour	Date powder	Screw speed (rpm)	Die head temperature (°C)
30	40	15	15	15	15	240	150
31	15	40	15	15	15	240	150
32	15	15	40	15	15	240	150
33	15	15	15	40	15	240	150
34	10	10	10	10	60	480	150
35	60	10	10	10	10	480	150
36	10	60	10	10	10	480	150
37	10	10	60	10	10	480	150
38	10	10	10	60	10	480	150
39	20	20	20	20	20	480	150
40	15	15	15	15	40	480	150
41	40	15	15	15	15	480	150
42	15	40	15	15	15	480	150
43	15	15	40	15	15	480	150
44	15	15	15	40	15	480	150

BLEND PREPARATION

Flours of broken brown rice, maize, soybean, Bambara-nut and date powder and water were added following the percentage proportion shown in Table 1. The blended samples were conditioned to 15% moisture by spraying with a calculated amount of water and blended using a mixer (Sokany Stand Mixer, Model: Cx 6612, China). One (1 kg) of each sample was packaged in air-tight zip packs and stored at 4 °C overnight. The feed material was allowed to stay for 3 hours to equilibrate at room temperature prior to extrusion.

PRODUCTION OF EXTRUDED MULTIGRAIN SNACK BARS

Fig 1. Shows the flow chart for the production of extruded multigrain snack bars. A co-rotating twin-screw extruder (Model: HN-65, Zhuoheng Product, Jinan City, Shandong Province, China) was used to extrude the mixture blend of broken brown rice flour, maize flour, soybean flour, Bambara-nut flour and date powder. The blends were mixed with potable water at 15% moisture content and a uniform mixture of mass (1 kg) was achieved using a mixer (Sokany Stand Mixer, Model: Cx-6612, China) per sample. The first and second heating bands of the extruder were set at a temperature of 80 °C and 100 °C, while the last heating band temperature was varied between 130 and 150 °C. The samples were fed through the hopper at a constant speed of 120 rpm which was conveyed into the barrel where the cooking takes place. From the barrel, the samples passed through the heating zones at barrel screw speeds that ranged between 240 and 480 rpm. The cooked sample within the barrel then passed through the orifice die designed in a square shape with a dimension of 40 by 40 mm and the extrudates were cut into bar shape. Extrudates were collected, dried using a forced-air dryer at 70 °C for 4 hours and it was packed in a zip-lock container, and stored properly at room temperature for further analysis.

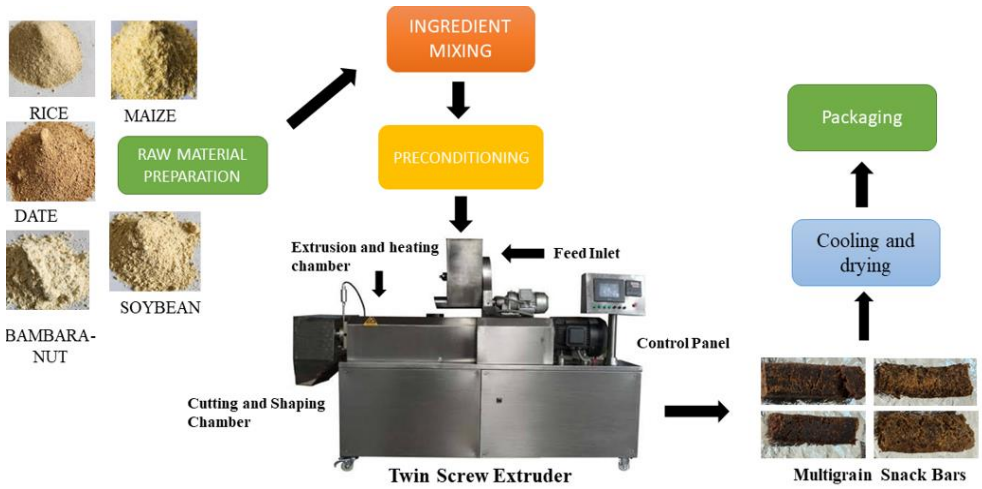

Figure 1. Flow chart for the production of multigrain snack bars

COMPOSITIONAL ANALYSIS

The composition (ash content, protein content, moisture content, crude fibre and crude fat) of the extruded snacks was carried out by the methods recommended by the Association of Analytical Chemists (17), while the total carbohydrates were calculated by difference.

VITAMIN ANALYSIS

Determination of thiamin (B_1)

One (1 g) of the samples was homogenized with ethanol solution of sodium hydroxide (50 ml). It was filtered into a 100 ml flask. Ten (10 ml) of the filtrates was pipetted and the colour developed by the addition of 10 ml of potassium dichromate and read at 360 nm. A blank sample was prepared, and the colour also developed and read at the same wavelength. The vitamin B_1 standard was also prepared in the same way at varying concentrations (20-100 µg/ml) and a standard curve was plotted.

Determination of riboflavin (B_2)

One (1 g) of the sample was extracted with 100 ml of 50% ethanol solution and shaken for 1 h. This was filtered into a 100 ml flask; 10 ml of the extract was pipetted into a 50 ml volumetric flask. Ten (10 ml) of 5% potassium permanganate and 10 ml of 30% H_2O_2 were added and allowed to stand over a hot water bath for about 30 min. Two (2 ml) of 40% sodium sulphate was added. This was made up to the 50 ml mark, and the absorbance was measured at 510 nm in a spectrophotometer. The vitamin B_2 standard was also prepared in the same way at varying concentrations (20-100 µg/ml) and a standard curve was plotted.

Determination of niacin (B_3)

One (1 g) of the sample was treated with 50 ml of 1 M sulphuric acid and shaken for 30 min. 3 drops of ammonia solution were added to the sample and filtered. Ten (10 ml) of the filtrates was pipette into a 50 ml volumetric flask and 5 ml potassium cyanide was added. This was acidified with five (5 ml) of 0.02 M H_2SO_4 and absorbance measured in the spectrophotometer at 470 nm wavelengths. The vitamin B_3 standard was also prepared in the same way at varying concentrations (20-100µg/ml) and a standard curve was plotted.

BULK DENSITY

Average length with and height of the of extrudates samples were measured and its volume was computed as:

$$\text{Vol } (cm^3) = LWH \quad [1]$$

where L= length of extrudates; W= width of extrudates and H = height of the extrudate.

After calculating the volume of extrudates, its bulk density was obtained as:

$$\text{BD } (kgcm^{-3}) = \frac{\text{mass of extrudates (kg)}}{\text{volume of extrudates } (cm^3)} \quad [2]$$

WATER ABSORPTION INDEX (WAI) AND WATER SOLUBILITY INDEX (WSI)

WAI and WSI were determined by method suggested by Muñoz-Pabon *et al*. (18) with slight modifications. The extruded snack was milled to mean particles size of 200-250 μm. A 2.5g sample was dispersed in 25g distilled water. A glass rod was used to break up any lumps and then stirred for 30 mins. The supernatant was decanted for determination of its solid content and the sediments were weighed. WAI and WSI were calculated as:

$$\text{WAI} = \frac{Weight\ of\ sediment}{Weight\ of\ dry\ solids} \quad [3]$$

$$\text{WSI} = \frac{Weight\ of\ dissolved\ solids\ in\ supernatant \times 100}{Weight\ of\ dry\ solids} \quad [4]$$

OPTIMIZATION VALIDATION

Response optimizer in Minitab software version 20.3 was used for the numerical optimization. The optimum validation error (OVE) was calculated to determine the fitness of the optimum condition using Equation [5] the performance of the predicted optimum conditions was validated by experiment in the laboratory (19).

$$\text{OVE} = \frac{V_e - V_p}{V_e} \times 100 \quad [5]$$

where V_e is the experimental value and V_p is the predicted value.

STATISTICAL ANALYSIS

Data obtained from the various experiments was subjected to statistical analysis using Statistical Package for Social Science (SPSS 20.0, SPSS Inc., and Chicago, IL, USA). The analysis was carried out in duplicate for all determinations and quantitative variables were analyzed by one-way ANOVA using the Duncan multiple tests with a confidence interval of 95% to determine significant differences between means.

RESULTS AND DISCUSSION

COMPOSITION OF MULTIGRAIN SNACK BARS OF EXTRUDED CEREAL BARS

Moisture content ranged from 5.57% to 12.59%. The highest levels were observed in blends with higher proportion of rice or Bambara-nut flour, combined with increased screw speed and die head temperature. This suggests that ingredient composition and extrusion conditions influence moisture retention, with brown rice and Bambara-nut contributing to higher moisture due to their water-binding properties. Fibre content ranges between 1.1% to 1.6% and 0.50% to 5% in brown rice and Bambara-nut respectively (20, 21). Products exceeding 10% moisture require additional processing to improve shelf life, as noted by Sanusi *et al.* (16). However, the results contradict studies suggesting that higher soybean proportions increase moisture content (22, 23), highlighting the complex interactions between ingredients and extrusion parameters. Furthermore, the linear regression coefficient for composition of the (MGSB) presented in the ANOVA Table 3 shows that the interaction of R (rice) and M (maize), R and S (soy bean), R and B (Bambara-nut), M and S, M and DH (die head temperature), B and DH; R, M, and DH; and R, B and DH, were all significant at $p < 0.05$. The positive coefficient of R and S, R and B, B and DH; and R, M, and DH indicates that the interactions positively influence the moisture content of the multigrain snack bar while the negative coefficient of R and M; M and S; M and DH; and R, B and DH indicates the interaction negatively influence the moisture content of the cereal bar. The generated regression model equation for moisture content is significant at *p*-value of 0.000 and F-value of 7.03. The coefficient of determination (R^2 and R^2_{adj}) of the model were 0.77 for R^2 and 0.67 for R^2_{adj}. Therefore, the model shows the adequacy to predict the effect of materials blends and extrusion conditions on the moisture content of cereal bar. This result corroborates with the findings of Sanusi and Akinoso (19) who stated that a model with a R^2 value above 0.7 is considered good and has a strong predictive capability.

Fat content varied from 6.42% to 14.73%, with higher values observed in blends enriched with soybean, which has naturally high fat content. The difference in fat content reflects not only the intrinsic composition of the ingredient but also the impact of extrusion on lipids migration and redistribution. The elevated fat levels in samples processed at higher screw speeds and temperatures suggest enhanced lipid extraction which corroborates the report of Alam *et al*. (24). The interaction of S and SS; R, M and SS (screw speed); and R, B and DH were significant at $p < 0.05$. Furthermore, the negative coefficient of R, B and DH shows that the interaction negatively affected the fat content of the MGSB. This means that the increase in the interaction will reduces the fat content of the snacks while increase in the interaction of S and SS and R, M and SS will increase fat content. The generated regression model equation for fat content was significant at *p*-value of 0.000 and *F*-value of 3.73.

Ash content values ranged between 2.09% and 4.68%. The highest ash content was found in balanced blends containing equal proportion of all ingredients, indicating that mineral content is optimized when ingredient distribution is uniform. Conversely, blends dominated by soybean, with relatively lower mineral content, exhibited reduced ash values. These findings contrast with the reports that soybean contributes significantly to ash content (25), possibly due to variation in soybean processing or formulation. The generated linear regression for the ash content was significant at $p < 0.05$ for several parameters. The positive coefficient of R and M; R and B; R and SS; B and SS; M, S and SS shows that the interaction positively affected the ash content of the MGSB. This indicate that the increase in the coefficient of the interaction will increases the ash content. The generated model for ash content was significant at *p*-value of 0.000 and *F*-value of 7.03. The coefficient of determination (R^2 and R^2_{adj}) of the model were 0.78 for R^2 and 0.66 for R^2_{adj}. Therefore, the model shows a very good adequacy to predict the effect of mixture ratio and extrusion conditions on the ash content.

Fibre content ranged from 2.06% to 4.07%, with highest levels observed in samples containing increased soybean proportions. This supports findings by Hein *et al*. (25) that legumes enhance the fibre in extruded products. The results also suggest that extrusion conditions, particularly screw speed, play secondary role in fibre retention. The observed deviation from studies reporting reduced fibre at higher temperatures (1) may be due to thermal and mechanical transformations during extrusion, which redistribute soluble and insoluble fibres. However, the generated linear regression model for the fibre showed that several parameters were not significant at $p < 0.05$. However, the interaction of R, S, and DH; the interaction of M, S and DH where significant with negative coefficient of R, S and DH depicting that increasing the interaction effect will lead to a decrease in fibre content, on the contrary, increasing the interaction effect of M, S and DH will increase the fibre content of the extruded snacks. The generated model equation for fibre content was significant at *p*-value of 0.011 and *F*-value of 2.03.

Carbohydrate content ranged from 36.53% to 61.43%. High levels were associated with blends containing rice and maize, where starch is gelatinized during extrusion, improving digestibility and textural quality. Conversely, the lowest carbohydrate values linked to the decomposition of starch at higher extrusion temperatures. These findings are consistent with reports by Moreno *et al*. (26) and Yi *et al*. (27), highlighting the dual role extrusion in enhancing carbohydrate quality while reducing starch content through thermal modification. The generated linear regression equation model for the carbohydrate content, shows that several parameters were significant at $p < 0.05$. The positive coefficients show that the interaction between R and M; M and SS; M and S; R and DH; M and DH and three-way interaction R, B and DH increases the carbohydrate content. However, M and S have the highest impact. On the contrary, the negative coefficients of R and B; B and DH suggested reduction in carbohydrate content due to these interactions. Furthermore, R and B caused the strongest reduction in carbohydrate. The generated linear regression model equation for carbohydrate content was significant at *p*-value of 0.000 and *F*-value of 3.82. The coefficient of determination (R^2 and R^2_{adj}) of the model were 0.67 for R^2 and 0.50 for R^2_{adj}. Therefore, the model shows adequacy to predict the effect of materials blends and extrusion conditions on the carbohydrate content of the MGSB.

Table 2. Effect of materials blends and extrusion conditions on composition of multigrain snack bars

S/n	Moisture content (%)	Fat (%)	Ash (%)	Fibre (%)	Protein (%)	Carbohydrate (%)
A1	9.24±0.01^{g}	10.93±0.16^{d}	3.19±0.04^{mlk}	2.14±0.01^{ts}	22.35±0.49^{fed}	52.16±0.69^{ut}
A2	6.49±0.03^{t}	9.16±0.05^{nml}	3.36±0.03^{kj}	2.06±0.02^{t}	18.69±0.01^{ponm}	60.23±0.02^{dc}
A3	7.00±0.02^{rq}	7.88±0.66^{ts}	3.63±0.03^{i}	3.12±0.00^{e}	20.84±0.06^{kjih}	57.51±0.22^{i}
A4	5.57±0.03^{w}	7.17±0.19^{w}	4.29±0.07^{fed}	4.07±0.01^{a}	19.50±0.69^{ml}	59.39±0.39^{fed}
A5	6.70±0.15^{s}	7.82±0.23^{uts}	2.79±0.25^{po}	3.26±0.01^{d}	18.6±0.05^{pon}	60.80±0.46^{cb}
A6	7.24±0.01^{on}	10.99±0.09^{dc}	4.17±0.02^{gfe}	2.84±0.08^{hg}	18.37±0.01^{qpon}	56.39±0.20^{k}
A7	6.51±0.09^{t}	9.56±0.01^{kj}	3.60±0.02^{i}	2.73±0.00^{i}	23.10±0.04^{dc}	54.51±0.00^{rqpo}
A8	6.24±0.00^{u}	9.19±0.03^{nml}	4.46±0.00^{dc}	3.93±0.03^{b}	25.24±0.02^{b}	50.94±0.08^{xwv}
A9	5.76±0.02^{v}	9.57±0.05^{vu}	2.34±0.65^{q}	2.68±0.00^{ji}	23.16±0.23^{dc}	58.49±0.31^{hgf}
A10	6.42±0.05^{t}	9.53±0.00^{v}	2.09±0.01^{r}	3.93±0.00^{c}	19.13±0.02^{onm}	61.43±0.05^{b}
A11	6.47±0.04^{t}	7.88±0.07^{ts}	2.31±0.15^{fed}	2.43±0.04^{lk}	17.91±0.01^{srqp}	61.00±0.31^{cb}
A12	7.08±0.06^{qp}	9.02±0.08^{on}	3.09±0.03^{nml}	2.75±0.02^{ih}	20.12±0.06^{lk}	57.95±0.04^{ihg}
A13	7.74±0.02^{k}	10.09±0.09^{gfe}	3.23±0.10^{mlk}	3.16±0.05^{ed}	17.18±0.02^{uts}	58.61±0.11^{gfe}
A14	10.20±0.07^{e}	11.10±0.23^{dc}	3.03±0.02^{nml}	2.26±0.15^{qpon}	18.69±0.00^{ponm}	54.73±0.47^{qpon}
A15	9.84±0.00^{f}	8.95±0.05^{on}	3.15±0.00^{mlk}	2.62±0.00^{j}	20.07±0.01^{lk}	55.38±0.07^{onml}
A16	9.82±0.01^{f}	9.32±0.10^{mlk}	2.80±0.10^{po}	2.37±0.00^{nml}	25.61±0.01^{b}	50.08±0.18^{yx}
A17	10.60±0.02^{d}	9.38±0.01^{lk}	4.23±0.00^{fed}	2.31±0.01^{onm}	23.14±0.01^{dc}	50.32±0.02^{yxw}
A18	7.45±0.02^{ml}	8.83±0.01^{o}	3.24±0.02^{lk}	2.62±0.02^{j}	22.35±0.050^{fed}	55.51±0.46^{nmlk}
A19	8.48±0.06^{i}	7.74±0.06^{vuts}	3.23±0.50^{mlk}	2.27±0.00^{qpon}	22.15±0.00^{gfe}	56.13±0.19^{lk}
A20	7.31±0.03^{onm}	9.40±0.02^{lk}	3.49±0.01^{ji}	2.09±0.01^{ts}	21.31±0.00^{hg}	56.40±0.02^{k}
A21	7.69±0.01^{k}	11.05±0.02^{dc}	3.01±0.01^{nm}	2.27±0.00^{qpon}	18.49±0.41^{qpon}	57.49±0.43^{i}
A22	8.72±0.02^{h}	9.98±0.05^{hgf}	2.89±0.03^{on}	2.87±0.01^{gf}	21.53±0.31^{hjf}	54.01±0.35^{rq}
A23	10.26±0.00^{e}	9.69±0.02^{ji}	3.83±0.02^{h}	2.28±0.01^{qpon}	18.81±1.20^{onm}	55.12±1.25^{ponm}
A24	9.86±0.01^{f}	9.90±0.16^{ihg}	2.60±0.00^{p}	3.26±0.00^{d}	21.52±0.63^{hjf}	52.87±0.49^{ts}
A25	7.69±0.02^{k}	8.17±0.00^{rq}	4.16±0.08^{gfe}	2.14±0.01^{tsr}	20.45±0.16^{kji}	57.39±0.12^{ji}
A26	6.87±0.04^{r}	8.42±0.02^{qp}	3.98±0.08^{hg}	2.28±0.02^{pon}	20.08±0.14^{gfe}	56.36±0.23^{lk}
A27	7.52±0.07^{l}	10.95±0.34^{d}	3.14±0.03^{ml}	1.88±0.02^{u}	24.82±0.04^{b}	51.69±0.11^{vu}
A28	8.22±0.02^{j}	10.30±0.07^{e}	4.68±0.08^{b}	2.13±0.02^{ts}	18.92±0.07	55.75±0.06^{mlk}
A29	10.83±0.07^{c}	9.98±0.07^{hgf}	4.46±0.11^{dc}	3.25±0.01^{d}	21.20±0.02^{ih}	50.27±0.25^{yxw}
A30	10.46±0.00^{d}	9.07±0.05^{pon}	4.29±0.06^{fed}	2.41±0.02^{mlk}	23.28±0.01^{c}	50.48±0.13^{yxw}
A31	10.61±0.01^{d}	7.97±0.05^{sr}	2.16±0.06^{r}	2.28±0.01^{qpon}	27.10±0.07^{a}	49.87±0.04^{y}
A32	5.83±0.02^{v}	12.62±0.08^{b}	4.36±0.08^{edc}	2.50±0.01^{k}	21.02±0.02^{jih}	53.66±0.02^{sr}
A33	5.83±0.02^{v}	10.13±0.08^{gfe}	4.32±0.01^{fed}	3.09±0.01^{e}	20.22±0.01^{lkj}	56.39±0.09^{k}
A34	7.20±0.06^{po}	10.92±0.00^{d}	4.34±0.01^{fedc}	2.28±0.01^{qpon}	19.23±0.05^{nm}	56.03±0.00^{mlk}
A35	12.59±0.04^{b}	6.42±0.09^{y}	4.55±0.01^{cb}	2.24±0.02^{rqpo}	15.36±0.01^{v}	58.83±0.12^{gfe}
A36	9.80±0.05^{f}	9.73±0.20^{jih}	3.84±0.03^{h}	2.31±0.01^{onm}	19.67±0.01^{ut}	57.64±0.10^{ih}
A37	10.12±0.06^{e}	14.70±0.06^{a}	4.14±0.05^{gf}	2.40±0.01^{ml}	17.45±0.00^{tsr}	51.20±0.18^{wv}
A38	12.59±0.04^{b}	11.26±0.07^{c}	3.52±0.08^{ji}	2.33±0.01^{onml}	23.28±0.07^{c}	47.03±0.11^{z}
A39	12.08±0.06^{a}	6.81±0.04^{x}	4.37±0.03^{edc}	2.19±0.08^{srqp}	20.16±0.06^{lk}	54.39±0.09^{rqp}
A40	7.52±0.01^{l}	7.67±0.08^{vut}	5.11±0.01^{a}	2.75±0.03^{ih}	22.87±0.07^{edc}	54.08±0.16^{rq}
A41	8.73±0.09^{h}	6.71±0.16^{x}	4.42±0.02^{dc}	2.94±0.02^{g}	17.64±0.02^{srq}	59.56±0.22^{ed}
A42	9.85±0.00^{f}	10.18±0.15^{fe}	4.39±0.11^{edc}	2.61±0.02^{j}	16.44±0.03^{u}	36.53±0.27^{kj}
A43	7.39±0.15^{nml}	8.54±0.04^{p}	4.12±0.05^{gf}	2.17±0.02^{srq}	18.25±0.02^{rqpo}	59.54±0.18^{ed}
A44	6.92±0.06^{r}	6.73±0.11^{x}	4.67±0.03^{b}	2.27±0.00^{qpon}	15.45±0.02^{v}	55.64±0.39^{a}

Values within columns with dissimilar superscript letters are significantly ($p \leq 0.05$) different from each other.

A1 (rice(R)-10%, maize (M)-10%, soybean(S)-10%, Bambara-nut (B)-10%, date powder (DP)-60%, screw speed (SS)-240 rpm and die head temperature (DH)-130 ℃), A2 (R-60%, M-10%, S-10%, B-10%, DP-10%, SS-240rpm and DH-130 ℃), A3 (R-10%, M-60%, S-10%, B-10%, DP-10%, SS-240rpm and DH-130 ℃), A4 (R-10%, M-10%, S-60%, B-10%, DP-10%, SS-240rpm and DH-130 ℃), A5 (R-10%, M-10%, S-10%, B-60%, DP-10%, SS-240rpm and DH-130 ℃), A6 (R-20%, M-20%, S-20%, B-20%, DP-20%, SS-240rpm and DH-130 ℃), A7 (R-15%, M-15%, S-15%, B-15%, DP-40%, SS-240 rpm and DH-130℃), A8 (R-40%, M-15%, S-15%, B-15%, DP-15%, SS-240rpm and DH-130 ℃), A9 (R-15%, M-40%, S-15%, B-15%, DP-15%, SS-240rpm and DH-130 ℃), A10 (R-15%, M-15%, S-40%, B-15%, DP-15%, SS-240rpm and DH-130 ℃), A11 (R-15%, M-15%, S-15%, B-40%, DP-15%, SS-

240rpm and DH-130 ℃), A12 (R-10%, M-10%, S-10%, B-10%, DP-60%, SS-480rpm and DH-130℃), A13 (R-60%, M-10%, S-10%, B-10%, DP-10%, SS-480rpm and DH-130 ℃), A14 (R-10%, M-60%, S-10%, B-10%, DP-10%, SS-480rpm and DH-130 ℃), A15 (R-10%, M-10%, S-60%, B-10%, DP-10%, SS-480rpm and DH-130 ℃), A16 (R-10%, M-10%, S-10%, B-60%, DP-10%, SS-480rpm and DH-130 ℃), A17 (R-20%, M-20%, S-20%, B-20%, DP-10%, SS-480rpm and DH-130 ℃), A18 (R-15%, M-15%, S-15%, B-15%, DP-40%, SS-480rpm and DH-130 ℃), A19 (R-40%, M-15%, S-15%, B-15%, DP-15%, SS-480rpm and DH-130 ℃), A20 (R-15%, M-40%, S-15%, B-15%, DP-15%, SS-480rpm and DH-130 ℃), A21 (R-15%, M-15%, S-40%, B-15%, DP-15%, SS-480rpm and DH-130 ℃), A22 (R-15%, M-15%, S-15%, B-40%, DP-15%, SS-480rpm and DH-130 ℃), A23 (R-10%, M-10%, S-10%, B-10%, DP-60%, SS-240rpm and DH-150 ℃), A24 (R-60%, M-10%, S-10%, B-10%, DP-10%, SS-240rpm and DH-150 ℃), A25 (R-10%, M-60%, S-10%, B-10%, DP-10%, SS-240rpm and DH-150 ℃), A26 (R-10%, M-60%, S-10%, B-10%, DP-10%, SS-240rpm and DH-150 ℃), A27 (R-10%, M-10%, S-10%, B-60%, DP-10%, SS-240rpm and DH-150 ℃), A28 (R-20%, M-20%, S-20%, B-20%, DP-20%, SS-240rpm and DH-150 ℃), A29 (R-15%, M-15%, S-15%, B-15%, DP-15%, SS-240rpm and DH-150 ℃), A30 (R-40%, M-15%, S-15%, B-15%, DP-15%, SS-240rpm and DH-150 ℃), A31 (R-15%, M-40%, S-15%, B-15%, DP-15%, SS-240rpm and DH-150 ℃), A32 (R-15%, M-15%, S-40%, B-15%, DP-15%, SS-240rpm and DH-150 ℃), A33 (R-15%, M-15%, S-15%, B-40%, DP-15%, SS-240rpm and DH-150 ℃), A34 (R-10%, M-10%, S-10%, B-10%, DP-60%, SS-480rpm and DH-150 ℃), A35 (R-60%, M-10%, S-610%, B-10%, DP-10%, SS-480rpm and DH-150 ℃), A36 (R-10%, M-60%, S-10%, B-10%, DP-10%, SS-480rpm and DH-150 ℃), A37 (R-10%, M-10%, S-60%, B-10%, DP-10%, SS-480rpm and DH-150 ℃), A38 (R-10%, M-10%, S-10%, B-60%, DP-10%, SS-480rpm and 150 ℃), A39 (R-20%, M-20%, S-20%, B-20%, DP-20%, SS-480rpm and DH-150 ℃), A40 (R-15%, M-15%, S-15%, B-15%, DP-40%, SS-480rpm and DH-150 ℃), A41 (R-40%, M-15%, S-15%, B-15%, DP-15%, SS-480rpm and DH-150 ℃), A42 (R-15%, M-40%, S-15%, B-15%, DP-15%, SS-480rpm and DH-150 ℃), A43 (R-15%, M-15%, S-40%, B-15%, DP-15%, SS-480rpm and DH-150 ℃), A44 (R-15%, M-15%, S-15%, B-40%, DP-15%, SS-480rpm and DH-150 ℃).

Table 3. Linear regression coefficients, mixture ratio and extrusion parameters for the composition of multigrain snack bars

Source	Moisture	Fat	Ash	Fibre	Protein	Carbohydrates
X_1	-0.75526	0.26849	-0.295599	-0.361801	-1.71257	3.85654
X_2	1.66516	0.64666	-0.060969	0.276414	0.31637	-1.84316
X_3	-0.81341	-1.14777	0.655996	0.156264	1.26730	0.88219
X_4	-1.61641	-1.39834	-0.137684	0.325384	-1.14940	4.97675
X_5	0.94137	-0.40131	0.058071	0.177274	1.26363	-1.03912
X_1X_2	-0.13809*	-0.14677	0.049231*	0.027313	0.13363*	0.07471*
X_1X_3	0.09616*	-0.02759	-0.017254	0.048615	0.02045	-0.12035
X_1X_4	0.14970*	0.13290	0.010256*	-0.024862	0.011042*	-0.37846*
X_1X_5	-0.07027	0.06828	-0.014029*	-0.019560	-0.06731*	0.10289*
X_2X_3	-0.01384*	0.11241	-0.045388	-0.050387	-0.11607	0.11321*
X_1X_6	0.00026	0.00026	0.000460*	0.000134	-0.00011	-0.00101
X_2X_6	0.00038	-0.00014	-0.00629*	-0.000112	0.00074	-0.00025
X_3X_6	0.00032	0.00104*	-0.000186	0.000010	-0.00055	-0.00064
X_4 X_6	0.00032	0.00038	0.000277*	-0.000057	0.00028	-0.00120
X_5X_6	-0.00041	0.00036	0.000052	0.000111	-0.00098	0.00087
$X_1X_2X_6$	-0.00002	0.00008*	0.000018	0.000003	-0.00013*	0.00004
$X_1X_3X_6$	-0.00000	-0.00003	-0.000027*	-0.000012	0.00001	0.00006
$X_1X_4X_6$	-0.00001	-0.00005	-0.000026*	0.000004	0.00000	0.00008
$X_1X_5X_6$	0.00001	-0.00005	-0.000003	-0.000009	0.00010	-0.00004
$X_2X_3X_6$	-0.00001	0.00006	0.000041*	0.000005	0.00003	-0.00001
X_1X_7	0.00525	-0.00163	0.000835	0.002347	0.01230	-0.01910*
X_2X_7	-0.01251*	-0.00352	0.002637	-0.001406	-0.00392	0.01872*
X_3X_7	0.00600	0.00586	-0.003705*	-0.000793	-0.00554	-0.00182

Table 3. Continuation

Source	Moisture	Fat	Ash	Fibre	Protein	Carbohydrates
X_4X_7	0.01210*	0.01008	0.000051	-0.002038	0.01125	-0.03146*
X_5X_7	-0.00523	0.00295	-0.000564	-0.001556	-0.00604	0.01045
$X_1X_2X_7$	0.00110*	0.00084	-0.000422*	-0.000208	-0.00043	-0.00088
$X_1X_3X_7$	-0.00068	0.00031	0.000178	-0.000323*	-0.00015	0.00067
$X_1X_4X_7$	-0.00112*	-0.00087*	0.000037	0.000171	-0.00098	0.00276*
$X_1X_5X_7$	0.00049	-0.00038	0.000140	0.000178	0.00034	-0.00077
$X_2X_3X_7$	0.00007	-0.00066	0.000215	0.000341*	0.00066	-0.00063
R^2	0.77	0.65	0.78	0.50	0.67	0.66
R^2_{adj}	0.67	0.48	0.66	0.25	0.50	0.48
R^2_{pred}	0.58	0.18	0.50	0.00	0.26	0.26
F-value	7.03	3.73	6.93	2.03	3.97	3.82
P-value	0.000	0.000	0.000	0.011	0.000	0.000

**Significant at 95% level*

Rice flour=X_1, Maize flour=X_2, Soybean flour=X_3, Bambara-nut flour=X_4, Date powder= X_5, Screw speed= X_6, Die head temperature= X_7

VITAMINS

The ternary plot in Fig. 1a illustrates the influence of varying proportions of rice, maize, and soybean flours on vitamin B_1 (thiamine) content in extruded snacks, with higher soybean flour proportions leading to increased thiamine level and higher rice flour proportions leading to decreased levels, under constant processing conditions. Similarly, in Fig. 1b, higher vitamin B_2 (VB_2) concentrations were observed in regions closer to soybean flour (bottom-right vertex), suggesting that soybean flour contributes significantly to the VB_2 content. Lower VB_2 values appear in regions dominated by maize or rice flour. Screw speed, die head temperature Bambara-nut flour, and date powder quantities were held constant at 240 rpm, 130 °C, 10%, and 10%, respectively, suggesting that the observed effects are primarily due to the flour proportions. This finding is in corroboration with the findings of Itagi and Singh (28); Mostafa *et al*. (29) and Osibanjo *et al*. (15) who reported an increase in VB_2 with an increase in soybean content.

Vitamin B_3 (niacin), offers several health benefits, especially in neuroprotection, metabolic regulation, and cellular health. Its multifaceted roles include promoting remyelination, reducing apoptosis in stressed cells, and enhancing mitochondrial function, making it a vital nutrient for various physiological processes and playing a significant role in energy metabolism (30). The ternary plot in Fig. 1c, illustrates the effect of varying proportions of material blend (maize flour, rice flour, and soybean flour) on the VB_3 of content of extruded snack bars. The darkest region indicates the highest Vitamin B_3 (VB_3) content which is influenced by increase in soybean flour and decreases with increase in maize flour. This emphasizes that soybean flour significantly contributes to VB_3.

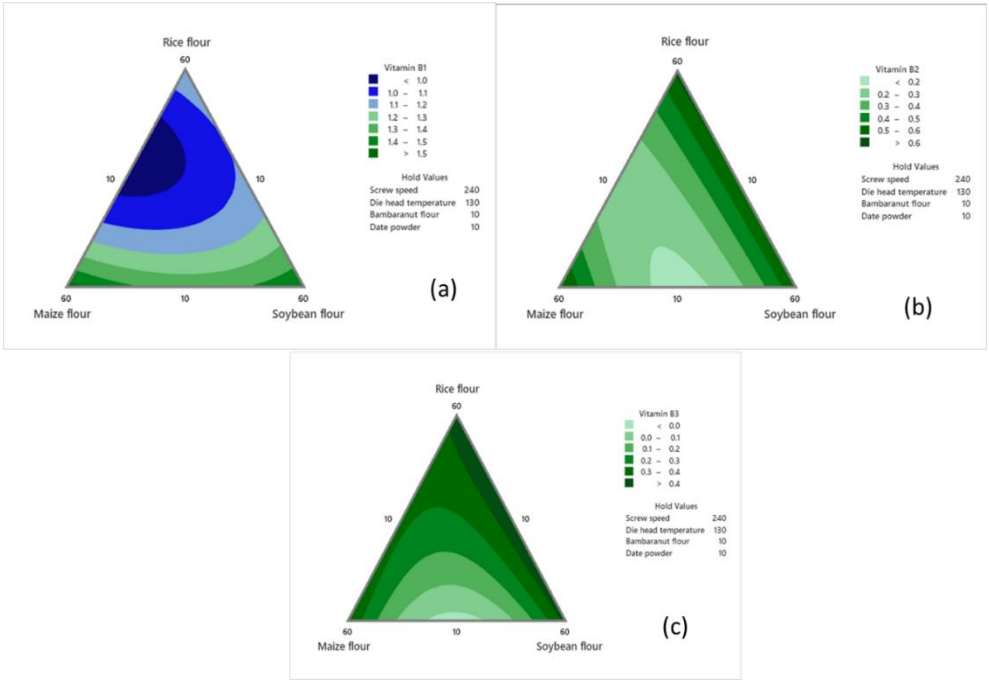

Figure 1. Effects of material blends and extrusion conditions on the Vitamin B_1 (a), Vitamin B_2 (b) and Vitamin B_3 (c) of the extruded multigrain snack bars

FUNCTIONAL PROPERTIES

The bulk density of the MGSB ranged between 0.51 and 0.76, the water absorption index (WAI) was (2.09 - 7.11) and water solubility index (WSI) was (5.14 - 16.18) had a considerable significant difference at $p < 0.05$. Fig. 2a illustrates the ternary plot of bulk density for extruded snack bars under constant extrusion conditions (screw speed: 240 rpm; die head temperature: 130 °C and fixed mixture ratios of (Bambara-nut flour: 10%; and date powder: 10%). Bulk density was influenced by the proportion of rice, maize, and soybean flours. Low bulk density was associated with high rice flour content (blue region), while higher bulk density resulted from a combination of maize and soybean flour (dark region). Blends with all three flours at specific proportions optimized bulk density, evident in the dark green zones in the central region. High bulk density indicates firmer, more compact bars, whereas low density produces lighter, aerated snack bars. WAI reflects the properties of extruded snacks, influenced by starch gelatinization during extrusion, which enhances WAI. Fig 2b shows the impact of blends ratio on WAI. Higher rice content significantly increased WAI (dark green region near rice apex), while soybean contributed moderately (light green region), and maize reduced WAI (blue region). High WAI improves texture and mouthfeel, critical for functional and sensory quality. WSI indicates molecular degradation and solubility of starch and protein during extrusion. Fig 2c demonstrates the effects of blend ratio at fixed conditions. Higher rice flour content increased the WSI (dark green region near the rice apex) due to its denser structure and lower starch gelatinization. Soybean contributed an intermediate WSI (light region), attributed to its protein composition. Blends of rice and soybean enhanced solubility compared to maize-heavy

blends. High WSI is desirable for improved digestibility, hydration, and dispersibility in food products.

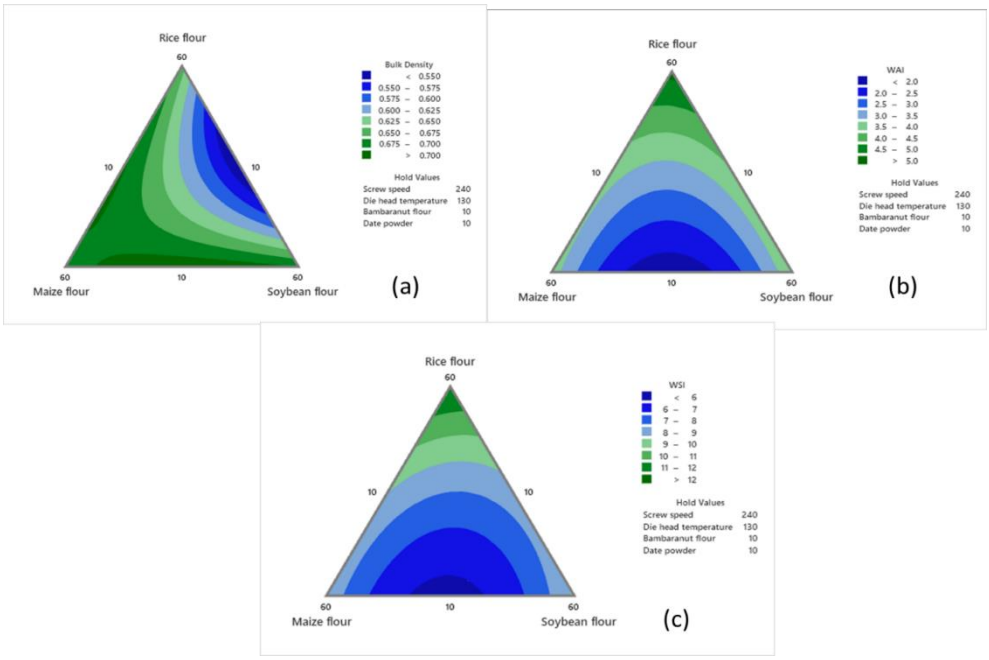

Figure 2. Effects material blends and extrusion conditions on the Bulk density (a), Water absorption index (b) and Water solubility index (c) of the extruded multigrain snack bars

OPTIMIZATION OF THE MATERIAL BLENDS AND EXTRUSION CONDITIONS OF THE MULTIGRAIN SNACK BARS

The numerical optimization blends and extrusion condition which produced the best quality multigrain snack bars was based on the following criteria: minimum moisture content: minimum, fat: maximum, ash: maximum: fibre: maximize, protein: maximum, carbohydrate: maximum. The optimum blends contained 33.81% rice flour, 17.26% maize flour, 10% soybean flour, 20.81% Bambara-nut and 18.08% date powder extruded at 150 °C with screw speed of 240 rpm. Table 5 summarizes the predicted responses of the optimum blends and extrusion condition with maximum global desirability value. The optimum blend and extrusion condition were established when the desirability values of the predicted responses and global desirability value were closer to unity (GD = 0.73). The optimum predicted blend and extrusion condition were experimented to confirm the result. The result validates that the predicted and experimented values for the responses closely matches with relative error which ranged between 8.7 and 10.9%. Hence, the optimum blends and extrusion condition can be used to formulate cereal bars with the best nutritional composition.

Table 4. Optimum mixture ratio and extrusion condition variables with maximum global desirability value

Parameter	Predicted value (%)	Experimental value (%)	Relative error (%)	Desirability	Global desirability
Moisture content	9.16	10.19	10.12	0.49	0.73
Ash	5.39	6.08	11.11	1.00	
Fibre	3.40	3.75	9.31	0.67	
Protein	19.53	21.87	10.69	0.36	
Vitamin B_1	1.70	1.88	9.66	0.83	
Vitamin B_2	0.76	0.86	10.95	1.00	
Vitamin B_3	0.41	0.45	9.40	0.77	

CONCLUSIONS

This study involved formulation of multigrain snack bars from broken brown rice, maize, soybean, Bambara-nut and date. The material blends, screw speed and die head temperature significantly affected the composition, vitamins and functional properties of the multigrain snack bars. The regression model developed for the composition and vitamins were significant with R^2 and R^2_{adj} ranged between 0.39 and 0.95. The optimum blends of 33.81% rice flour, 17.26% maize flour, 10% soybean flour, 20.81% Bambara-nut and 18.08% date powder and extrusion temperature of 150 °C and screw speed of 240 rpm was established for the best quality multigrain snack bar of moisture content (9.16%), ash (5.39%), fibre (3.40%), protein (19.53%), vitamin B_1(1.70 mg/100g), vitamin B_2 (0.76 mg/100g) and vitamin B_3 (0.41 mg/100g). This study has demonstrated that extruded multigrain snack bars can be produced from nutrient dense, underutilized, gluten free and functional cereals, legumes and fruits which can reduce cost of production and potentially increase income generation.

REFERENCE

1. Sanusi, M. S.; Sunmonu, M. O.; Alasi, S. O.; Adebiyi, A. A.; Tajudeen, A. A. Composition, bioactive constituents and glycemic index of brown rice-watermelon seeds extruded snacks as stimulated by extrusion conditions. *Applied Food Research*, **2023**, *3*(1), 100287.
2. Kowalska, H.; Masiarz, E.; Ignaczak, A.; Marzec, A.; Hać-Szymańczuk, E.; Salamon, A.; Galus, S. Advances in multigrain snack bar technology and consumer expectations: A review. *Food Reviews International*, **2023**, *39*(1), 93-118.
3. Neder-Suárez, D.; Quintero-Ramos, A.; Meléndez-Pizarro, C. O.; de Jesús Zazueta-Morales, J.; Paraguay-Delgado, F.; Ruiz-Gutiérrez, M. G. Evaluation of the physicochemical properties of third-generation snacks made from blue corn, black beans, and sweet chard produced by extrusion. *Lebensmittel-Wissenschaft & Technologie*, **2021**, *146*, 111414.
4. Boukid, F.; Klerks, M.; Pellegrini, N.; Fogliano, V.; Sanchez-Siles, L.; Roman, S.; Vittadini, E. Current and emerging trends in cereal snack bars: implications for new product development. *International Journal of Food Sciences and Nutrition*, **2022**, *73*(5), 610-629.

5. Dalbhagat, C. G.; Mahato, D. K.; Mishra, H. N. Effect of extrusion processing on physicochemical, functional and nutritional characteristics of rice and rice-based products: A review. *Trends in Food Science & Technology*, **2019**, *85*, 226-240.
6. Simić, M.; Nikolić, V.; Sarić, B.; Milovanović, D.; Kostadinović, M.; Žilić, S. Changes in Nutritional and Techno-Functional Properties of Whole Grain Maize Flours Induced by Dry-Heat Treatment. *Foods*, **2024**, *13*(20), 3314.
7. Agyenim-Boateng, K. G.; Zhang, S.; Zhang, S.; Khattak, A. N.; Shaibu, A.; Abdelghany, A. M.; Feng, Y. The nutritional composition of the vegetable soybean (Maodou) and its potential in combatting malnutrition. *Frontiers in Nutrition*, **2023**, *9*, 1034115.
8. Ramatsetse, K. E.; Ramashia, S. E.; Mashau, M. E. Effect of partial mutton meat substitution with Bambara groundnut (*Vigna subterranea* L. Verdc.) flour on physicochemical properties, lipid oxidation, and sensory acceptability of low-fat patties. *Food Science & Nutrition*, **2024**, *12*(6), 4019-4037.
9. Fernández-López, J.; Viuda-Martos, M.; Sayas-Barberá, E.; Navarro-Rodríguez de Vera, C.; Pérez-Álvarez, J. Á. Biological, nutritive, functional and healthy potential of date palm fruit (*Phoenix dactylifera* L.): Current research and future prospects. *Agronomy*, **2022**, *12*(4), 876.
10. Huang, X.; Liu, H.; Ma, Y.; Mai, S.; & Li, C. Effects of extrusion on starch molecular degradation, order–disorder structural transition and digestibility - A review. *Foods*, **2022**, *11*(16), 2538.
11. Jain, R.; Goomer, S. Understanding extrusion technology for cereal–pulse blends: A review. *Cogent Food & Agriculture*, **2023**, *9*(1), 2253714.
12. Mugabi, R.; Byakika, S.; Mukisa, I. M. Effects of feed moisture content, soybean ratio and barrel temperature on physical and functional properties of extruded maize-soybean flour blends. *Tanzania Journal of Science*, *48*(2), **2022**, 447-459.
13. Sahu, C.; Patel, S.; Tripathi, A. Effect of extrusion parameters on physical and functional quality of soy protein enriched maize based extruded snack. *Applied Food Research*, **2022**, *2*(1), 100072.
14. Kaur, N.; Kumar, R.; Singh, A.; Shobha, D.; Das, A. K.; Chaudhary, D.; Singh, B. Improvement in nutritional quality of traditional unleavened flat bread using Quality Protein Maize. *Frontiers in Nutrition*, **2022**, *9*, 963368.
15. Osibanjo, A.; Sowbhagya, C.; Olatunji, O. Evaluation of Maize/Soybean Blends for Snack Production by Extrusion Cooking. *European Journal of Agriculture and Food Sciences*, **2022**, *4*(2), 7-10.
16. Sanusi, M. S.; Sunmonu, M. O.; Alasi, S. O.; Adebowale, A. A.; Esho, I. T.; Tajudeen, A. A. *Modification of Some Quality Attributes of Brown Rice-Bambara-nuts-Pineapple Peels Extruded Snacks Through Extrusion Conditions*. Conference Proceedings, 1st Faculty of Engineering and Technology Conference (FETiCON 2023), Jun. 5-7, 2023.
17. Tobaruela, E. D. C.; Santos, A. D. O.; de Almeida-Muradian, L. B.; Araujo, E. D. S.; Lajolo, F. M.; Menezes, E. W. Application of dietary fiber method AOAC 2011.25 in fruit and comparison with AOAC 991.43 method. *Food chemistry*, **2018**, *238*, 87-93.
18. Muñoz-Pabon, K. S.; Parra-Polanco, A. S.; Roa-Acosta, D. F.; Hoyos-Concha, J. L.; Bravo-Gomez, J. E. Physical and paste properties comparison of four snacks produced by high protein quinoa flour extrusion cooking. *Frontiers in Sustainable Food Systems*, **2022**, *6*, 852224.
19. Sanusi, M. S.; Akinoso, R. Modelling and optimising the impact of process variables on brown rice quality and overall energy consumption. *International Journal of Postharvest Technology and Innovation*, **2021**, *8*(1), 70-88.
20. Danbaba, N.; Nkama, I.; Badau, M. H.; Ndindeng, A. S. Development, nutritional evaluation and optimization of instant weaning porridge from broken rice fractions and bambara groundnut (*Vigna subterranea* L. Verdc) blends. *Nigerian Food Journal*, **2016**, *34*(1), 116–132. https://doi.org/10.4314/NIFOJ.V34I1.
21. Danbaba, N.; Nkama, I.; Badau, M. H.; Idakwo, P. Y. Influence of extrusion conditions on nutritional composition of rice-bamabara groundnut complementary foods. *Arid Zone Journal of Engineering, Technology*, **2019**, 559-582.
22. Basediya, A. L.; Pandey, S.; Shrivastava, S. P.; Khan, K. A.; Nema, A. Effect of process and machine parameters on physical properties of extrudate during extrusion cooking of sorghum,

horse gram and defatted soy flour blends. *Journal of Food Science and Technology*, **2013**, *50*(1), 44-52.
23. Sharifi, S.; Majzoobi, M.; Farahnaky, A. Development of healthy extruded maize snacks; Effects of soybean flour and feed moisture content. *International Journal of Food Science & Technology*, **2021**, *56*(7), 3179-3187.
24. Alam, M. S.; Kaur, J.; Khaira, H.; Gupta, K. Extrusion and extruded products: changes in quality attributes as affected by extrusion process parameters: a review. *Critical Reviews in Food Science and Nutrition*, **2016**, *56*(3), 445-473.
25. Hein, K.; Lin, M.; Zar, T.; Kyaw, P. Development of cereal-based nutri bar combining with different levels of partially sprouted chickpeas flour. *Agpe the Royal Gondwana Research Journal of History, Science, Economic, Political and Social Science*, **2023**, *4*(7), 27-37.
26. Moreno, C. R.; Fernández, P. C. R.; Rodríguez, E. O. C.; Carrillo, J. M.; Rochín, S. M. Changes in nutritional properties and bioactive compounds in cereals during extrusion cooking. *Extrusion of Metals, Polymers and Food Products*, **2018**, 104-124.
27. Yi, C.; Qiang, N.; Zhu, H.; Xiao, Q.; Li, Z. Extrusion processing: A strategy for improving the functional components, physicochemical properties, and health benefits of whole grains. *Food Research International*, **2022**, *160*, 111681.
28. Itagi, H. B. N.; Singh, V. Preparation, nutritional composition, functional properties and antioxidant activities of multigrain composite mixes. *Journal of Food Science and Technology*, **2012**, *49*, 74-81.
29. Mostafa, R.; Haleem, A.-E.; Gabal, S. Formulation and evaluation of some novel breakfast blends made from cereals and legumes. *Alexandria Journal of Food Science and Technology*, **2017**, *14*(2), 25-34.
30. Petrović, K.; Stojanović, D.; Štrbac, F.; Hristovska, T. Physiological role, pharmacokinetics and pharmacodynamics of niacin in cows. *Zbornik radova, 26. međunarodni kongres Mediteranske federacije za zdravlje i produkciju preživara – FeMeSPRum* (Radovi), 2024, 24-24.