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ORIGINAL ARTICLE

Development of an Extruded Snack Based on Sorghum, Pearl Millet and Biofortified beans

Arlene Rachael Andirigu/ Loveness Kuziwa Nyanga/ Prosper Chopera/

Authors' Affiliation

University of Zimbabwe, Faculty of Science, Department of Nutrition Dietetics and Food Science, Post Office Box, 167 Mount Pleasant, Harare, Zimbabwe

Corresponding author

Prosper Chopera

Email:

pchopera@gmail.com

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Abstract

The snacking prevalence especially among children has increased in recent decades. Snacks can contribute significantly to a child's dietary intake and therefore efforts must be made to make them wholesome and nutritious. The objective of this study was to develop acceptable multigrain snacks called puffs using white sorghum, pearl millet and nua45 beans with enhanced protein and mineral (zinc and iron) content. Three different formulations were produced and, for sensory analysis a commercially available alternative child snack was used for comparison. Nutrient analysis (macronutrients and micronutrients) was determined using standard Association of Official Analytical Collaboration (AOAC) international methods of analysis. Moisture content ranged from 6.22 to 9.70%, crude protein ranged between 5 to 16.41%, crude fat from 2.40 to 25%, crude fiber from 1.25 and 1.96%, ash between 0.02 and 4.22% and total carbohydrates between 66.68 and 73.48%. The most preferred formulation had the following mineral content: 7.60 mg/100 g Fe, 2.53 mg/100 g Zn, 260 mg/100 g Mg, 180 mg/100 g Na, 280 mg/100 g Ca and 360 mg/100 g P. The multigrain puffs produced are a good potential source of carbohydrates, proteins and micronutrients, such as iron, zinc, magnesium, calcium and phosphorus. Studies on nutrient absorption would be important to ascertain whether critical nutrients such as iron and zinc are absorbed from the gut and, if so, how much is being absorbed.

Key words: composite, extrusion, traditional grains, white sorghum, pearl millet, nutrition

1. Introduction

Snacks play a significant role in the daily calorie and nutritional intake of many children. They are typically prepared items consumed in between meals. Ready-to-eat snack foods are gaining popularity with caregivers due to their convenience, accessibility, texture, and look (Brennan *et al.,* 2013; Marangoni *et al.,* 2019). Cereals are the preferred and most common raw materials for manufacturing of snacks due to their practical qualities, low cost, and ready availability. Many technological and functional qualities are used to produce these snacks however the most recent and common is extrusion. Other ingredients can be added to improve texture and palatability during the extrusion process.

Pulses and oilseeds can be added to boost the nutritional value of cereal-based extruded snack meals due to their high nutrient content especially protein (Dayakar *et al.,* 2018). It has been demonstrated that extrusion cooking using composite flour is a revolutionary method for making food products that are nutritionally enhanced. In extrusion, grain that is soft and moist is put into an extruder while high temperatures and pressure are concurrently applied over a brief period of time. This causes alterations, such as the gelatinization of starch breakdown, protein denaturalization, lipid oxidation, taste creation, improved mineral bioavailability, and dietary fiber solubility, which increase nutrient bioavailability and digestibility of the end product (Devi *et al.,* 2013). Additionally, it lessens antinutritional factors, improving the product's organoleptic acceptance and safety. Typically, for product cooking, no external heat source is used. Instead, shear and friction in the extruder produce the required heat. Extrusion cooking is used to make expanded snack foods, modified starches for ready-to-eat cereals, infant foods, pasta, and pet foods all over the world (Dayakar *et al.,* 2018).

African and Asian diets from the past used to include traditional grains (millets), particularly white sorghum and pearl millet. A renewed interest has emerged in millets' nutritional and practical benefits. Sorghum and pearl millet have special nutritional qualities, they are devoid of gluten, have abundant amounts of carbohydrates, dietary fibre, phenolic components, and minerals (Taylor & Duodu, 2018). Many traditional dishes like *sadza* (thick porridge paste consumed in southern Africa), porridge, traditional beer, bread making employ sorghum and other millets (Pradeep, Dharmaraj, Sathyendra Rao *et al.,* 2013). Pearl millet has a protein content of 12–16% and about 5% fats, compared to sorghum's 10% and 3.5%, respectively. Nua45 beans consists of up to 34% protein, 95 and 38mg/kg iron and zinc respectively. Therefore, the nutritional makeup and other attributes of traditional grains present a variety of processing and value-adding opportunities. The quantity and quality of the protein and other nutrients in millet products would be improved by combining them with other high protein sources like pulses. Extrusion process can thus be used to create the millets-pulse composite flour resulting in the development of snacks and other products that are low in fat, high in protein, fibre and other nutritional components (Devi *et al.,* 2013).

In an effort to widen the applications of traditional grains, biofortified pulses and value addition, the current study was designed to develop and evaluate physicochemical and sensory aspects of a multi-millet based extruded ready-to-eat snack. The value-added traditional grains in this study were white sorghum and pearl millet. Nua45 beans was used as a protein, iron and zinc source.

2. Materials and Methods

2.1. Raw materials

Pearl millet *(Pennisetum glaucum (L.) R. Br.)*, white sorghum *(Sorghum bicolor. L)*, and nua45 beans were obtained on a single day just after harvesting period in July from farmers in Buhera (19.3211° S, 31.4399° E) in Zimbabwe.

2.2. Flour preparation from white sorghum, pearl millet and nua45 beans

White sorghum, pearl millet and nua45 beans were cleaned and sorted manually by sieving (mesh size 10) and winnowing (except nua45 beans) under moving air. Dehulling was done by pounding using a wooden pestle and mortar with the addition of 500 ml water per 5kg grains until the bran was separated from the endosperm. The pounding and winnowing processes were repeated several times before fully dehulled grains were obtained. The grains were then oven dried at 100°C for approximately 15 minutes. Grinding of the grains and beans was done using a ball mill from Ruzha brands to obtain course flour.

2.3. Formulation of multigrain puffs

Preliminary trials were undertaken to optimize the composite flour contemplating the product's sensory and nutritional qualities; mainly by instant sensory evaluation sessions, for example, some ratios produced burnt or unpuffed product. A final 3 composite flour sets were then developed by blending the flours from white sorghum, pearl millet, nua45 beans in various proportions 5:3:2, 5:2:3 and 5:1:4 respectively. The flour samples were blended, labeled, and stored in zip-lock bags at 25 °C for later examination and use.

2.4. Extrusion processing of multigrain puffs

The produced flour samples were extruded using a small laboratory single-screw extruder equipped with a die nozzle at constant extrusion conditions. The extruder was run using sorghum and bean flour until output product stabilized that is until it produced a clean and puffed product. The barrel was then fed with raw composite flour as it was being moved within by the screw. The feed continued to move down the barrel whilst the extrusion screw transformed the feed into a semi-solid, plasticized mass. The extrudates were pushed through the die at the barrel's discharge end. The resulting multigrain snacks were dried at 110°C for 5 minutes in an oven dryer before being allowed to equilibrate for 30 minutes at room temperature. Only for proximate and mineral analysis, a seasoned formulation (cheese seasoning F. Neil and Sons, Harare) made up sample 4, that is, formulation 2 with seasoning). This was added to see if there would be a significant difference in the proximate and mineral parameters.

2.4. Chemical analysis

2.4.1. Proximate composition of multigrain snacks

Composite flour samples of white sorghum, pearl millet, nua45 beans and snacks were analyzed for moisture content, ash, crude protein, crude fat, carbohydrate and total energy according to the Association of Official Analytical Collaboration (AOAC, 2000) international standard methods as follows:

2.4.1.1. Moisture content determination in multigrain snacks

Briefly, moisture content was determined by drying 10g of each sample in an evaporating dish in an oven at 105 °C until constant weight was achieved. Moisture content was calculated using the formula:

$$(\%)\ \text{moisture} = \left[\frac{w_1 - w_2}{w_1}\right] x100$$

Where: w_1 is the original sample's weight (g).

w_2 is the original sample's weight after drying (g).

2.4.1.2. Ash content in multigrain snacks

About 3 g of sample were weighed into a crucible followed by pre-ashing over a hot plate until fumes were no longer emitted. The samples were then placed in a muffle furnace at 550°C for 8hours. The formula to determine ash content was:

$$\text{Ash} = \left[\frac{\text{weight of ash}}{\text{original sample's weight}}\right] x100$$

2.4.13. Crude fat content determination in multigrain snacks

Accurately, 5 g of sample was weighed into a thimble and transferred into the Soxhlet extraction unit. The extraction unit was assembled over an electric heating mantle. Petroleum ether was heated in the flasks until it boiled; then adjusted to 30°C to achieve an average rate of 6 drops per second of the dripping solvent from the condenser into the sample chamber. The extraction was continued for 6 hours in a fume hood. The flasks and their contents were oven dried at 102°C for 1-2 hours until a constant weight was reached. Calculation was done using the formula:

$$(\%)\ \text{Crude Fat} = \left[\frac{W3-W2}{W3}\right] x100$$

Where: w_2 = Weight (g) of sample after drying

w_3 - Weight of original sample

2.4.1.5. Carbohydrate content determination

Carbohydrate content was determined by calculation method, that is,

100% - (crude fat + crude protein + ash + moisture) = % carbohydrate

2.4.1.6. Protein content determination

The micro Kjeldahl method according to Association of Official Analytical Collaboration (AOAC, 2000) international standard methods was used to determine the protein content, and 6.25 was multiplied over the nitrogen percentage to obtain the crude protein content.

2.4.2. Determination of Fe, Zn, Mg, P, Na, Ca

Mineral concentrations were determined by an Atomic Absorption Spectrophotometer AA-6701F Thermo Fischer Scientific with the results presented in mg/100g.

2.5. Sensory evaluation

Randomly selected untrained volunteer participants were chosen based on their desire to participate and frequency of similar snack product use. Participants were of diverse ages, genders, and professions. Sensory evaluation sessions were conducted in a well luminated room, with no communication among panelists during the test, using sensory booths according to the method described by Beinner *et al.* (2010) and Devi *et al.* (2013).

Each participant was served with 4 samples of the puffs (Figure 2) and an evaluation form. The samples had been seasoned using cheese seasoning bought from F. Neil and Sons, Harare. After tasting each sample, panelists were given a glass of water and told to rinse their mouths with it before swallowing it. Evaluation of all samples' acceptability was based on their general acceptability, appearance, taste, texture, and flavor. A 5 point hedonic scale with the extremes "extremely like" (5) and "extremely dislike" (1) was used.

2.6. Statistical analysis

Except for the sensory assessment, all the data were gathered in duplicate. All data was entered into SPSS v22 for analysis. To compare means, one way analysis of variance (ANOVA) was employed. Significance level was set at P<0.05.

3. Results and Discussion

The multigrain snacks were analysed for moisture content, ash, carbohydrate, crude protein, crude fat, fibre, and energy content and compared with a commercially available snacks. The proximate composition of the multigrain snacks is presented in figure 1.

The proximate composition of the samples showed significant differences (P<0.05) between the 3 formulations (multi grain-legume combinations - blending ratios for white sorghum to pearl millet to nua45 beans 5:3:2, 5:2:3, and 5:1:4 for formulations 1, 2 and 3 respectively) including seasoned formulation samples and commercial product. Moisture contents of the multigrain snacks and seasoned formulation was 8.74, 7.29, 9.7 and 6.22% while ash contents were 1.5, 2.09, 0.02 and 4.22% respectively. Comparable ash contents was also obtained by other researchers as stated by Sotunde (2021), with values ranging between 1.50 and 2.50% from corn, millet and soybean blend, although they were lower in comparison to the seasoned formulation. Ash content can range from 0-10%

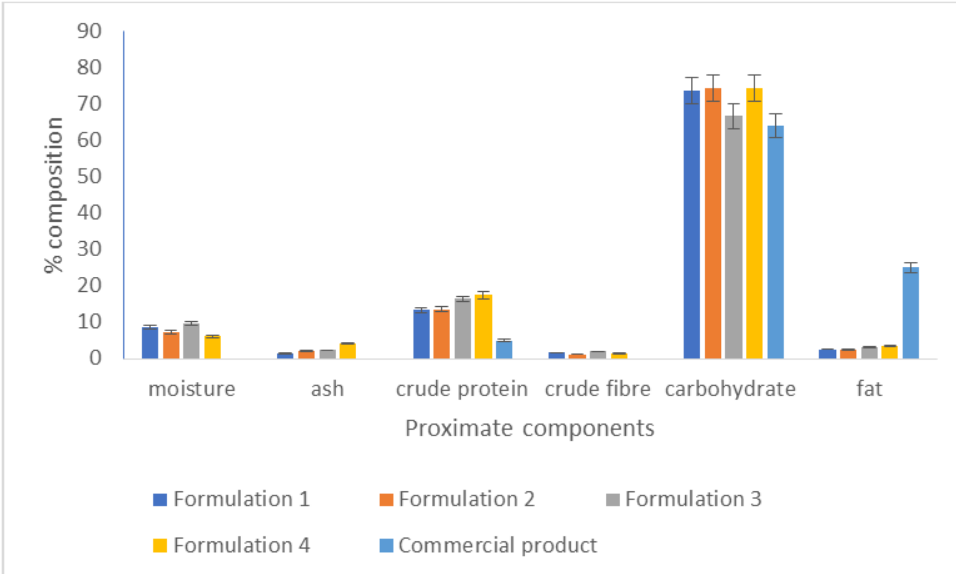

Figure 1: Nutrient composition of extruded multigrain snacks

Figure 2: Product formulations produced and the commercial product used for sensory evaluation
NB: blending ratios for white sorghum to pearl millet to nua45 beans 5:3:2, 5:2:3, and 5:1:4 for formulations 1, 2 and 3 respectively.

and should be lower than 5% for complementary foods, recommended by the WHO as stated by Laryea *et al.* (2018). This ensures safety of the food and absence of toxic minerals. Moisture content of the seasoned formulation was comparable to that obtained by Omwamba & Mahungu (2014), that is, 6.72%. This is because of the further drying process involved before addition of the seasoning.

Other samples had moisture content which ranged between 7.2 and 8.27% as obtained by Korkerd *et al.* (2016). However, for product 1 and 3, values were higher although they were also acceptable based on those obtained by Awofadeju *et al.* (2021) that is, 10.05; 8.36; 9.78 and 10.06%. Moisture content should be below 18% to deter mould and bacterial growth as this affects the shelf life of the product (Sotunde, 2021). The multigrain puffs formed generally were a good source of protein with values of 13.34, 13.34, 16.41, and 17.5 g/100g for the 3 different formulations and the seasoned formulation respectively. Protein content was highest in formulation 3 and lowest in the commercial product which was 5%. This might be because of the different proportions of legume used, in this case, nua45 beans. Furthermore, the ingredients of the commercial product did not include legumes but maize grains which are in general a poor source of protein. Pulses have high protein content (17-34%), their use especially in combination with cereals proteins would deliver balanced nutrition in a sustainable way Nesli Sozer (2016). The solubility and functioning of proteins are improved by extrusion processing (Omwamba & Mahungu, 2014). Cereal-legume blends have high protein content and this has also been reported by other researchers for example Nkama & Filli (2007) who reported protein content between 14.5 and 21.1% in pearl millet and legume extruded products (cowpea, soybean, and groundnut).

Fat content obtained were 2.60, 2.40, 3.29, 3.39 and 25% for samples 1, 2, 3, seasoned formulations and commercial product respectively. It was highest in the commercial product due to the addition of vegetable oil during the seasoning process. The fat variations obtained were lower compared to those obtained in a study by Devi *et al.* (2013) which ranged between 1.31 and 2.36% who made multigrain sorghum based snacks except for the commercial product.

Minerals are needed in the human body for a variety of reasons, including the regulation and maintenance of the body's metabolism and homeostasis.

Table 1 shows results for mineral analysis. Minerals were not detected in the commercial product. This might be because no legume or traditional grains were used which have high mineral content or the levels were below the detection limit of our instrument. A deficiency in these nutrient components can lead to a high prevalence of common ailments and disease symptoms. The rate of absorption and bioavailability of minerals can be considerably increased by food fortification and pre-processing processes such as germination and fermentation (Gharibzahedi & Jafari, 2017). The iron content obtained was 6.57, 7.60, 7.63, 7.43 mg/100 g for the 3 different formulations and the seasoned formulation respectively. Due to the prevalence of iron deficiency in infants and young children in developing countries, it is important that their diets contain enough amounts of iron. Iron is essential for children's physical and mental development, good health as well as synthesis of adequate haemoglobin. For children from 6 months and older, the recommended nutritional consumption range for iron is 1.7 to 11 mg/day. Therefore, 100 grams of the multigrain puffs are sufficient to satisfy an infant's Recommended Daily Intake (RDI) (Laryea *et al.,* 2018; RDI, 1997).

Magnesium contents of all samples were significantly different ($p < 0.05$), that is, 240, 260, 310 and 250mg/100g for the 3 different formulations (W5:P3:N2) (W5:P2:N3), (W5:P1:N4) and the seasoned formulation respectively. Magnesium is especially useful for healthy bones, proper nervous system functioning and energy metabolism. Magnesium content obtained was lower compared to values obtained in a study by Awolu & Akintade (2021) in the development of rice-kidney beans composite flours incorporated with fermented and unfermented sorghum flours for the production of ready-to-eat extruded snacks. They ranged between 428 and 511 mg/100 g.

Table 1: Mineral content of multigrain extrudes and commercial product

Formulation	Fe	Zn	Mg	Na	Ca	P
1 (W5:P3:N2)	$6.57^{a}\pm0.15$	$2.60^{a}\pm0.12$	$240^{a}\pm11.53$	$140^{a}\pm8.82$	$190^{a}\pm5.77$	$350^{a}\pm5.77$
2 (W5:P2:N3)	$7.60^{b}\pm0.12$	$2.53^{b}\pm0.12$	$260^{b}\pm11.53$	$180^{b}\pm5.77$	$280^{b}\pm5.77$	$360^{b}\pm11.55$
3 (W5:P1:N4)	$7.63\ ^{b}\pm0.18$	$2.87^{c}\pm0.33$	$310^{c}\pm8.82$	$170^{c}\pm5.77$	$290^{c}\pm5.77$	$370^{c}\pm6.67$
Seasoned formulation	$7.43^{b}\pm0.13$	$3.40^{d}\pm0.28$	$250^{d}\pm11.55$	$220^{d}\pm5.11$	$360^{d}\pm6.43$	$280^{d}\pm5.77$
P value	<.001	<.001	<.001	<.001	<.001	<.001

NB: Means with by the different superscript letters within columns are significantly different at p<0.05.

Zinc and sodium content obtained varied significantly among all samples, that is, 2.60, 2.53, 2.50, 3.40 mg/100 g and for sodium values were 140, 180, 170 and 220 mg/100g respectively for the 3 different formulations (W5:P3:N2) (W5:P2:N3), (W5:P1:N4) and the seasoned formulation respectively. The zinc and sodium content were highest in seasoned formulation because the minerals may have been present in the seasoning used. Zinc obtained was higher compared to that obtained by Awolu & Akintade (2021) in their rice-kidney bean-sorghum composite flour which ranged between 1.34 and 2.10mg/100g while sodium was lower with values ranging between 2.10 and 2.79 mg/100 g. Zinc is essential for human health because it has critical structural and functional roles in systems that are involved in gene expression, cell division and growth and immunologic and reproductive functions therefore high but adequate levels are required as per life cycle stage. However, low sodium levels are desirable as high intakes are associated with disorders of the circulatory system. The calcium content was 190, 280, 290, 360 mg/100 g. A similar study by Awolu & Akintade (2021) found calcium values ranging between 212 and 280 mg/100 g. In another study to develop a ready-to-eat snack mix from traditional grains and legumes by Pradeep, Dharmaraj & Rao (2013), their mean calcium content was 219 mg/100 g. Calcium is necessary for bone health (Singh *et al.,* 2007).

Phosphorus contents were 350, 360, 370 and 280 mg/100 g respectively for the 3 different formulations and the seasoned formulation respectively. This was higher than the RDI for children from 6 months of 275 mg/100 g (RDI, 1997) and lower than that obtained in a study by Kindiki (2017) of 1050 mg/100 g. Options to increase phosphorus content for older children in the developed products may include fortification. Phosphorus is important for all tissues and cells for their growth, maintenance and repair, as well as for the synthesis of genetic material. Additionally, other vitamins and minerals like

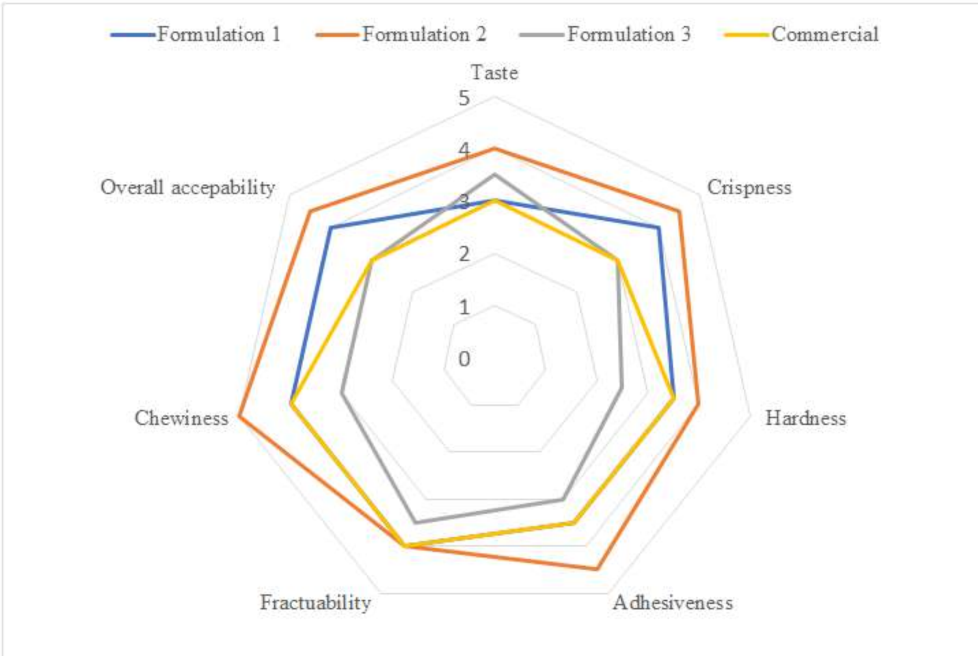

Figure 3: Sensory evaluation of multigrain snacks and commercial product
NB: blending ratios for white sorghum to pearl millet to nua45 beans 5:3:2, 5:2:3, and 5:1:4 for formulations 1, 2 and 3 respectively.

vitamin D, iodine, magnesium, and zinc need phosphorus in order for them to be metabolised (Gonzalez Ballesteros *et al.,* 2017).

The formulated products had a low amount of dietary fibre, that is, 1.48, 1.25, 1.66 and 1.96 g/100g dietary fibre as compared to that obtained by Kharat *et al.* (2019) in the research conducted to standardize extrusion process using foxtail millet, peas and rice of 7.44 g/100g. This low amount could be due to the fact that all the grains were de husked before use. Although low fibre content is inversely related to mineral bioavailability, fibre is important as it contributes to healthy bowel movement; it increases bulk weight and reduces intestinal transit time. Fibre also increases viscosity and decreases glycemic index. Therefore, further studies must determine the correct balance or optimum level of dehulling that will produce a product with adequate fibre and highly bioavailable nutrients (Csatári & Kovács, 2022).

The carbohydrate contents obtained were 73.48, 72.31, 66.63 and 68.79%. The fairly high nutrient values of protein and fat in sample 3 and 4 contributes to the decreased carbohydrate content in the named samples. More so, the differences in the carbohydrate content are also as a result of total amount of grains put in the different formulations. That is, 80, 70 and 60% of the 3 formulations and approximately 100% for the commercial. Grains have carbohydrate content ranging between 67 and 83% (Hassan *et al.,* 2021). The obtained values were higher compared to values of 56.19 to 59.61% obtained by Sotunde (2021) with increasing substitution of pearl millet. Sample 2 had the highest carbohydrate content. The puffs' carbohydrate content indicates that they are a good source of energy for the body's normal metabolism.

Figure 3 displays the average ratings for various sensory characteristics of the extruded snacks. Formulation 2 had the highest scores for all attributes except for fractuability which was highest for formulation 1, hence it was the most accepted. The 3rd formulation had the lowest mean scores, followed by the commercial and lastly formulation 1. This result could be related to high nua45 bean ratio in formulation 3 compared to the other formulations. The resultant product from Formulation 3 realised less expansion (Figure 2). Legumes have very low expansion ratio, as such they affect the overall texture of extruded products. This was also evidenced by Devi *et al.* (2013) whereby expansion of resultant extrudates decreased with the addition of a mixed legume flour. Snacks from formulation 2 were chosen for use in the consumer acceptance test because they received the highest mean score (4.33) for overall acceptability. Formulation 3 was however comparable to the commercial product for most sensory attributes.

4. Conclusion

The most preferred formulation for the multigrain puffs was the blend with 50% white sorghum, 20% pearl millet and 30% nua45 beans flours. It included considerably high protein (16.63%), zinc (2.53 mg/100 g) and iron (7.6 mg/100g) compared to other formulations ($p<0.05$). Multigrain composite flour from white sorghum, pearl millet and nua45 beans can be used to develop a ready to eat snack food with improved nutrient properties which can promote nutrient intake when consumed in between meals. The multigrain puffs are a commendable option due to their nutritional composition than the already available commercial puffs. It is recommended that physical properties of the most preferred output be studied as well as bioavailability of nutrients.

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Conflict of interest

The authors declare that there are no conflicts of interest.

Ethics

This Study does not involve Human or Animal Testing.

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