

Research Application Summary

Nutritional value and sensory properties of an extruded composite iron-rich bean-based snack targeting school children

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Abstract

Malnutrition is still a major challenge affecting a large group of the population in the world, and the problem has also been reported among school children. The major cause is insufficient nutrient intake and absorption from diet. The objective of the study therefore was to develop a composite puffed iron-rich bean-based snack for school-age children with acceptable, nutritive and highly palatable food properties. Extruded formulations with varied ingredient proportions were developed using Roba1 bean, maize, orange fleshed sweet potato (OFSP) and amaranth flours. The nutrient composition and sensory characteristics were determined. In order to obtain a nutritionally adequate and sensory desirable snack, the optimal snack formulation was determined by numerical optimization. The nutrient composition, taste and flavor characteristics varied significantly ($p < 0.05$) among formulations. An optimal formulation had protein, iron, dietary fibre and zinc content of 22.7g, 6.1 mg, 13.8 g and 3.4 mg per 100 g, with protein digestibility of 72.6 %. Organoleptic evaluation revealed that the formulations were moderately to highly acceptable by their appearance, taste, flavor, texture and overall acceptability with average scores of 6.000. Results showed that the developed formulations were adequate to meet at least 23 % of the protein, 21 % iron, and 15 % zinc recommended daily allowances for children aged 4 to 12 years. The study established that more nutritious extruded snacks can be developed based on dry beans as major ingredients, and the formulations contribute significantly to the recommended daily intake for school-age children. The optimal extruded bean-based snack can therefore be recommended for commercial production by industrialists.

Key words: bean-based, snack, extrusion, school-age children, optimization

Résumé

La malnutrition est toujours un problème majeur qui affecte un large groupe de la population dans le monde, et le problème a également été signalé parmi les écoliers. La cause majeure est un apport nutritionnel et une absorption insuffisants de l'alimentation. L'objectif de l'étude était donc de développer une collation à base de haricots riches en fer composite

pour les enfants d'âge scolaire avec des propriétés alimentaires acceptables, nutritives et très agréables au goût. Des formulations extrudées avec des proportions d'ingrédients variées ont été développées en utilisant du haricot Roba1, du maïs, de la patate douce à chair orange (OFSP) et des farines d'amarante. La composition nutritive et les caractéristiques sensorielles ont été déterminées. Afin d'obtenir une collation nutritionnellement adéquate et sensorielle souhaitable, la formulation optimale de collation a été déterminée par optimisation numérique. La composition nutritive, le goût et les caractéristiques de la saveur variaient considérablement ($p < 0,05$) entre les formulations. Une formulation optimale avait une teneur en protéines, en fer, en fibres alimentaires et en zinc de 22,7 g, 6,1 mg, 13,8 g et 3,4 mg pour 100 g, avec une digestibilité des protéines de 72,6%. L'évaluation organoleptique a révélé que les formulations étaient modérément à hautement acceptables par leur apparence, leur goût, leur saveur, leur texture et leur acceptabilité globale avec des scores moyens de 6 000. Les résultats ont montré que les formulations développées étaient suffisantes pour répondre à au moins 23% des protéines, 21% de fer et 15% de zinc indemnités journalières recommandées pour les enfants âgés de 4 à 12 ans. L'étude a établi que des collations extrudées plus nutritives peuvent être développées à base de haricots secs comme ingrédients majeurs, et les formulations contribuent de manière significative à l'apport quotidien recommandé pour les enfants d'âge scolaire. La collation optimale à base de haricots extrudés peut donc être recommandée pour la production commerciale par les industriels.

Mots clés: collation à base de haricots, collation, extrusion, enfants d'âge scolaire, optimisation

Background

Malnutrition continues to be a major problem in developing countries, and the cause is insufficient intake as well as absorption of nutrients especially protein, iron, vitamin A, iodine and zinc. Increasing levels of malnutrition have been observed among school children and this could be associated with the dependency on high-starch snack foods for a large part of the day (Bundy *et al.*, 2009). Beans are a rich protein source commonly consumed in diets of many individuals and could be used to enrich the starchy snack foods consumed by school children. However, though they are rich in macro- and micro-nutrients that are essential for growth and regular body function, beans also contain antinutritional substances (ANFs) which limit the digestion and absorption of nutrients. Previous works have shown that antinutritional substances can be removed from legumes and cereals by processing. Techniques such as soaking, fermentation, germination, milling and separation as well as heat processing (including extrusion) can be utilized to reduce ANFs in foods, and substantially improve the nutritional and sensory properties. Anton *et al.* (2008) and Martín-Cabrejas *et al.* (2009) in their studies, successfully reduced phytates, trypsin inhibitors and lectins by employing extrusion, germination, dehulling or soaking. Protein digestibility greatly improved for legume foods which were processed by extrusion (Alonso *et al.*, 2000).

Additionally, micronutrient content of selected cereal, legume and root foods have been improved through breeding, with the aim of increasing nutrient intake for vulnerable

groups, especially those who cannot afford food supplements (Blair, 2013). In this respect, selected varieties of sweet potato, maize and cassava have been enriched with pro-vitamin A, while the common bean varieties were enriched with iron and zinc through conventional breeding. Reports show that consumption of biofortified beans can improve the nutritional status of individuals. A study conducted in Rwanda (Haas *et al.*, 2014) established that consumption of biofortified common beans increased iron levels in the blood for women of adolescent and child-bearing age.

The objective of the present study was to develop composite nutritive iron-rich bean-based snack targeting school children, and determine its nutritional quality and acceptability. Secondly the study aimed to determine the nutrition benefit derived from consuming the optimal bean-enriched composite snack product.

Study description

Formulations. The study was conducted at Makerere University Uganda, in partnership with Peak Value Industries Ltd, a commercial food processing company. Formulations containing Roba1 (iron-rich) bean, maize, orange flesh sweet potato (NASPOT 10 – a pro-vitamin A rich food), and amaranth flours were developed using the mixture design of Design Expert software (version 11, Stat Ease, Tufts, USA). The formulations were developed to significantly contribute to the protein, iron and zinc recommended daily intake for children aged 4 to 12 years (whose RDI is 19 – 34 g protein, 10 – 8 mg iron, and 5 – 8 mg zinc per day). Roba 1 iron-rich bean variety was selected for its richness in protein, iron and zinc, i.e., 26 g, 66.7 mg and 27.6 mg per 100 g, respectively) (Natabirwa *et al.*, 2018). The amaranth grain, a pseudo cereal, was selected since it is rich in protein, iron, zinc and carbohydrate (14 g, 17.4 mg, 3.4 mg, and 67.9 g per 100 g, respectively (Muyonga *et al.*, 2008). Maize is a starchy food commonly used in puffed snacks on the market in Uganda. Starch is very important in extrusion for the functional properties including expansion and texture which it imparts on extrudates.

Extrusion processing, nutritional and acceptability analysis. The formulations were processed in a Twin screw extruder (Model DP 70-III, Jinan, China) at feed moisture of 15%, barrel temperatures (60/110/142 °C), screw speed (40 Hz) and cutter speed 12 Hz. The nutrient composition was estimated using Nutrisurvey 2007 programme. The protein digestibility was determined using a multi-enzyme method (Krupa-Kozak and Soral-Śmietana, 2010). The sensory properties including appearance, taste, flavor, texture (hardness and crunchiness) and overall acceptability of the snack extrudates were determined by hedonic rating on 9 – point scale (where 1 = dislike extremely and 9 = like extremely) using a 52 – member panel. Panelists were food science and technology students of Makerere university who were sensitized about the product.

Results and discussion

Nutrient composition. The nutrient composition varied among formulations ranging from 16.6 – 20.9 g/100g for protein, 4.1 – 5.7 mg/100 g iron, and 2.7 – 3.4 mg/100 g for zinc (Table 1). The energy content ranged from 368.5 to 388.8 kcal. In general, the

formulations provided reasonable amounts of iron, zinc, protein and dietary fibre. The results showed that a serving size of 40 g (Fig.1) to a child aged 4 – 8 years would provide 50 % of protein, 21 % iron and 8 % energy of the recommended dietary intake (Whitney and Rolfes, 2011). The formulations had considerably high protein digestibility (> 71%).

Table 1. Ingredient proportions and estimated nutrient composition per 100 g

Exp. run	Ingredient proportion (%)				Nutrient composition per 100 g						
	Beans (%)	Maize (%)	OFSP (%)	Amaranth (%)	Protein (g)	Energy (kcal)	Carb. (g)	Dietary fibre (g)	Fat (g)	Fe (mg)	Zinc (mg)
1	50	34.3	10.7	5.0	16.6	388.8	66.9	11.3	2.6	4.7	2.7
2	59.3	35.8	5.0	0.0	18.3	385.1	69.5	12.4	2.5	5.0	2.9
3	52.1	22.9	15.0	10.0	17.0	385.4	62.5	11.1	2.5	5.0	2.7
4	55.7	29.4	15.0	0.0	17.2	387.9	63.8	11.6	2.2	4.6	2.7
5	72.4	10.0	13.9	3.7	20.3	375.6	58.8	12.7	1.8	5.5	3.0
6	60.9	24.1	5.0	10.0	19.2	378.7	66.4	12.3	2.7	5.5	3.0
7	85.0	10.0	5.0	0.0	23.0	368.5	61.9	14.2	1.7	6.0	3.4
8	66.0	25.2	8.8	0.0	19.3	381.0	64.8	12.6	2.1	5.2	3.0
9	68.0	22.6	5.0	4.3	20.2	377.3	65.8	12.9	2.3	5.5	3.1
10	65.6	17.7	15.0	1.8	18.9	381.2	60.7	12.2	1.9	5.1	2.9
11	71.9	10.0	8.6	9.5	20.9	372.6	60.8	12.9	2.2	5.8	3.2
12	54.0	30.6	5.4	10.0	18.0	383.2	68.4	11.8	2.9	5.3	2.9
13	50.0	45.0	5.0	0.0	16.7	390.8	72.1	11.7	2.8	4.6	2.8
14	60.7	14.3	15.0	10.0	18.6	379.7	59.8	11.8	2.3	5.3	2.9
15	76.4	16.8	5.8	1.0	21.4	373.8	63.6	13.5	2.0	5.7	3.2

Where, Carb. = carbohydrate, OFSP=Orange freshed sweet potato

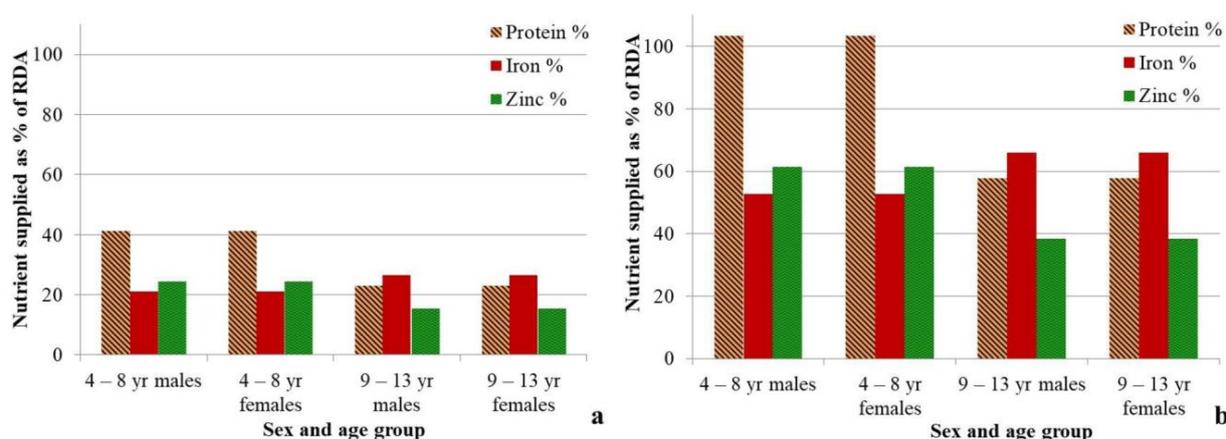


Figure 1. Nutrient benefit as percent of RDA derived from consuming (a) 40 snack serving (b) 100 g snack serving

Acceptability. Mean scores for sensory attributes were above the average score of 5 indicating that the appearance, taste, flavor and overall acceptability attributes were moderately liked by panelists. The taste and flavor scores were significantly different ($p < 0.05$). Sensory characteristics are key determinants of the palatability and acceptability of food among consumers. The relatively low scores for texture may be attributed to the protein-starch interactions which tends to limit expansion of extrudates (Siddiq *et al.*, 2013). The moderately high flavor scores were possibly due to the browning reactions during extrusion cooking which produces nice nutty smells (Mohsen *et al.*, 2009) and have been described as desirable to consumers. Alternatively, the moderate flavor values were possibly associated with the beany flavor (Nyombaire *et al.*, 2013), which is not desired by consumers. However, it is reported that extrusion removes the beany flavor from legumes. Results from this study therefore showed that the bean-based snack product would be moderately acceptable to consumers.

Optimal formulation. Optimization of selected nutritional, sensory and textural attributes yielded products with optimal desirability above 0.7 (0.86 - 0.94), which were considerably highly desirable based on the global desirability index as specified (Derringer, 1980). The optimal formulation provided 389 kcal energy, 22.7 g protein, 6.1 mg Fe and 3.4 mg Zn in every 100 g of product. This translate into 8 % kcal of daily energy, 23 % protein, 15 % of zinc and 21 % of iron of RDA from a 40 g serving to children aged 4 - 8 years. In general, the results showed a processing possibility of bean-based snack formulation containing 66 – 67 kg Robal beans in every 100 kg of total ingredients.

Table 2. Mean scores of sensory attributes for the bean-based composite snack formulations

Exp. run	Ingredient proportions (%)				Acceptability scores				
	Beans	Maize	OFSP	Amaranth	Hardness	Crunchiness	Taste	Flavour	OA
1	50	34.3	10.7	5.0	6.5 ^a	7.0 ^a	6.5 ^{abcd}	6.5 ^{abcd}	6.7 ^{abcde}
2	59.3	35.8	5.0	0.0	6.9 ^a	6.9 ^a	6.3 ^{abcd}	6.5 ^{abcd}	6.7 ^{abcde}
3	52.1	22.9	15.0	10.0	6.6 ^a	6.5 ^a	3.6 ^{bd}	5.4 ^{bd}	6.2 ^{de}
4	55.7	29.4	15.0	0.0	7.4 ^a	7.2 ^a	6.3 ^{abcd}	6.3 ^{abcd}	6.8 ^{abcde}
5	72.4	10.0	13.9	3.7	6.7 ^a	6.8 ^a	6.1 ^{abcd}	6.1 ^{abcd}	6.5 ^{abcde}
6	60.9	24.1	5.0	10.0	6.6 ^a	7.0 ^a	6.4 ^{abcd}	6.0 ^{abcd}	6.4 ^{abcde}
7	85.0	10.0	5.0	0.0	7.1 ^a	7.3 ^a	6.8 ^{ac}	6.9 ^a	7.1 ^{abcde}
8	66.0	25.2	8.8	0.0	7.0 ^a	7.2 ^a	6.4 ^{abcd}	6.6 ^{ac}	6.8 ^{abcde}
9	68.0	22.6	5.0	4.3	6.9 ^a	7.1 ^a	6.9 ^a	6.4 ^{abcd}	6.7 ^{abcde}
10	65.6	17.7	15.0	1.8	6.7 ^a	7.1 ^a	6.3 ^{abcd}	6.3 ^{abcd}	6.2 ^{cde}
11	71.9	10.0	8.6	9.5	7.0 ^a	7.1 ^a	6.6 ^{abcd}	6.6 ^{ac}	7.7 ^a
12	54.0	30.6	5.4	10.0	6.5 ^a	6.7 ^a	6.8 ^{ac}	6.5 ^{abcd}	7.0 ^{abcde}
13	50.0	45.0	5.0	0.0	7.1 ^a	7.2 ^a	6.8 ^a	6.4 ^{abcd}	6.8 ^{abcde}
14	60.7	14.3	15.0	10.0	7.0 ^a	7.2 ^a	6.1 ^{abcd}	6.0 ^{abcd}	6.3 ^e
15	76.4	16.8	5.8	1.0	6.8 ^a	7.1 ^a	6.3 ^{abcd}	6.3 ^{abcd}	6.8 ^{abcde}

OA = overall acceptability, OFSP=Orange freshed sweet potato

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