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PROXIMATE EVALUATION OF A NUTRITIOUS SNACK FORMULATED FOR ADOLESCENTS USING BAMBARA NUTS, SOYBEANS, CHIA SEEDS AND DATES

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Abstract: Adolescence is a critical period of rapid growth with high nutritional demands, yet it is often marked by poor dietary habits, including the consumption of energy-dense, nutrient-poor snacks. This contributes to the burden of malnutrition. Leveraging snacking behaviour presents a strategic opportunity to improve adolescent nutrition through fortified, convenient food alternatives. This study aimed to develop and conduct a proximate evaluation of a nutritious snack formulated for adolescents using a blend of Bambara groundnuts, soybeans, chia seeds, and dates to enhance its nutritional profile. An experimental research design was employed. The raw ingredients were processed into flour (soybean, Bambara nut), syrup (dates), and a gel (chia seeds) and combined into three different snack formulations. The proximate composition (moisture, ash, crude lipid, crude protein, crude fibre, and carbohydrates) of the raw ingredients, processed ingredients, and final snack products was determined using standard AOAC methods and compared against a control cookie. The analysis revealed that the individual ingredients possessed distinct and complementary nutritional profiles. Soybean was a protein powerhouse (40.10%), chia seeds were rich in lipids (21.92%) and fibre (21.39%), and Bambara nut flour was high in carbohydrates (68.47%). The formulated snacks showed a significant nutritional enhancement over the control. Specifically, they exhibited a marked increase in protein (up to 24.84% in Sample C vs. 3.79% in control), dietary fibre (up to 2.59% vs. 0.89%), and ash (mineral) content (≈3.10% vs. 1.55%), alongside a reduction in carbohydrate content. Moisture and lipid levels remained comparable to the control, indicating no adverse effects on product stability and texture. The study successfully demonstrates that the strategic formulation of snacks using Bambara groundnut, soybean, chia seed, and date can yield a nutrient-dense product significantly superior to conventional options. This snack has high potential to address specific nutrient gaps and combat the triple burden of malnutrition among adolescents by providing a convenient source of high-quality protein, fibre, and essential minerals.

Keywords: *Adolescent Nutrition, Bambara Groundnut, Soybean, Chia Seeds, Dates, Proximate Evaluation.*

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Introduction

Adolescence is a period of rapid physiological and psychological development, second only to infancy in terms of growth velocity. This life stage is characterized by a significant increase in nutritional requirements to support bone mineralization, muscle development, and hormonal changes (Das et al., 2017). The global adolescent population is substantial, and their nutritional status is a critical determinant of their current health, cognitive performance, and long-term disease risk. Despite its importance, adolescent nutrition remains a frequently overlooked area in public health initiatives, leading the Lancet Commission on Adolescent Health and Wellbeing to label it a "hidden crisis" (Sawyer et al., 2019).

A primary concern in adolescent nutrition is the pervasive "triple burden of malnutrition"—the coexistence of undernutrition, micronutrient deficiencies, and overnutrition leading to overweight and obesity (Akseer et al., 2020). Micronutrient deficiencies, particularly of iron, are especially prevalent. Iron deficiency anemia (IDA) is one of the most common nutritional disorders among adolescents globally, leading to fatigue, impaired cognitive function, diminished learning capacity, and reduced school performance (Salam et al., 2021). The consequences extend beyond the individual, affecting societal productivity and economic development. Within the adolescent dietary pattern, snack foods play an influential and often detrimental role. Adolescents frequently consume a significant portion of their daily energy

intake from snacks, which are typically energy-dense, high in refined sugars and unhealthy fats, and poor in essential micronutrients and dietary fiber (Hess et al., 2016). This consumption pattern presents a dual challenge: it contributes to excessive calorie intake while failing to meet micronutrient needs. However, this habitual snacking behaviour also represents a strategic opportunity for public health nutrition. By developing and promoting nutrient-dense, culturally acceptable, and convenient snack alternatives, it is possible to leverage existing eating habits to improve overall dietary quality and address specific nutrient gaps in this population (Chacón et al., 2023).This study proposes a snack formulation that strategically combines four nutrient-rich, plant-based ingredients: Bambara groundnuts, soybeans, chia seeds, and dates. Each component was selected for its unique and complementary nutritional profile.

Bambara groundnut (*Vigna subterranea*) is an underutilized, climate-resilient legume indigenous to Africa. It is a valuable source of protein (approximately 18-24%), complex carbohydrates, and essential minerals like iron, magnesium, and zinc (Oyeyinka & Oyeyinka, 2018). Its agronomic robustness and nutritional completeness make it a sustainable crop for improving food and nutrition security.

Soybeans (*Glycine max*) contribute a high-quality, complete protein containing all essential amino acids necessary for growth. Beyond protein, soy is a rich source of isoflavones, compounds associated with various health benefits, including potential positive effects on cognitive function and cardiovascular health (Messina et al., 2021). Recent research suggests that soy consumption in school-aged children may be linked to improved cognitive performance, including enhanced thinking and attention (Bristina et al., 2023).

Chia seeds (*Salvia hispanica* L.) offer a concentrated source of omega-3 alpha-linolenic acid (ALA), dietary fiber, and essential minerals. Notably, they are an exceptional plant-based source of calcium, which is crucial for achieving peak bone mass during adolescence (Ullah et al., 2016). The combination of healthy fats, fiber, and protein in chia seeds contributes to sustained energy release and satiety, which is beneficial for maintaining focus and preventing overconsumption of less healthy snacks.

Dates (*Phoenix dactylifera*) serve as a natural sweetener and binder, reducing or eliminating the need for added sugars. Dates are rich in dietary fiber, potassium, copper, and antioxidants (Rahmani et al., 2018). Importantly, evidence indicates that date consumption can effectively improve hematological indices. A study by Eshghi et al. (2020) demonstrated that date supplementation significantly increased hemoglobin levels in female adolescents with iron deficiency, positioning it as a functional food for combating anemia.

Therefore, this study aims to develop and conduct a proximate evaluation (moisture, ash, protein, fat, fiber, and carbohydrate content) of a nutritious snack formulated from Bambara groundnuts, soybeans, chia seeds, and dates.

Methodology

Research Design

This study employed an experimental research design to develop and evaluate a nutritious snack formulated from bambara nuts, soybean, chia seeds and dates. The study involved formulation and proximate analysis of the formulated snack.

The raw materials used in this study included bambara nuts, soybean, chia seeds and dates, which were sourced from a local market in Abuja, FCT, Nigeria. Equipment and reagents for laboratory analysis were obtained from the Sheda Science and Technology Complex, Chemistry Advanced Laboratory.

Sample Preparation and Formulation

The ingredients were sorted, cleaned, and processed separately. Bambara nuts were roasted at 150^0c to enhance flavour and reduce anti-nutritional factors. The roasted nuts were cooled to room temperature, dehulled and milled into flour using a food processor. The soybeans were soaked, fermented, boiled, sun-dried, roasted and milled into flour. Chia seeds were cleaned and soaked to form a gel-like structure, while dates were deseeded, blended into a paste, strained, boiled and cooled to form a syrup. All prepared ingredients were combined in varying proportions to produce three snack formulations (F1, F2, F3). The blends were mixed thoroughly, shaped into bite-size snacks, and baked at 150°C for 12-15 minutes. After cooling, samples were packaged in airtight containers for subsequent analysis.

Proximate Composition Analysis

The proximate composition of the snack samples was determined using standard AOAC (1990) methods. The parameters analyzed included:

Moisture content was determined by oven drying at 105°C, according to Udo and Oguwele's (1986) method. Ash content was determined by incineration in a muffle furnace at 550°C, according to James (1995). The Crude lipid content in the sample was extracted using soxhlet extraction procedure, described by Udo and Oguwele (1986). Crude fiber using the gravimetric method. The crude protein of the sample was determined using the micro-Kjeldahl method described by AOAC (1990). Carbohydrate was calculated by the method of James (1995) where the total proportion of carbohydrate in the leaves sample was obtained by calculation using the percentage dry method

Results and Discussion

Table 1: The proximate composition of pre-processing analysis of the ingredients used in the formulated snack in the study

Ingredients	Moisture (%)	Ash (%)	Crude Lipid (%)	Crude Protein (%)	Crude fibre (%)	Carbohydrates (%)
Date Seed(D)	6.69±0.01[a]	2.24±0.01[a]	1.40±0.02[a]	6.95±0.05[a]	3.45±0.01[a]	79.27±0.0[a]
Soya Beans Seed(S)	3.11±0.01[b]	4.70±0.02[b]	18.55±0.05[b]	42.14±0.02[b]	7.51±0.02[b]	26.49±2.51[b]
Bambara Nuts(B)	6.12±0.02[a]	2.88±0.04[a]	6.85±0.04[c]	18.13±0.03[c]	5.18±0.02[c]	60.84±0.01[c]
Chia Seeds(C)	4.72±0.04[ab]	4.49±0.01[b]	24.46±0.02[d]	19.76±0.06[c]	22.450.03[d]	24.12±0.05[b]
F value	45.000	71.955	963.020	354.865	453.967	460.727
p value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Values are mean±standard error of the mean of the proximate content of the pre-processing analysis. Values with the same superscript are not significantly different at $p<0.05$ at 95 % confidence interval.

Table 2: The proximate composition of post-processing analysis of the ingredients used in the formulated snack in the study

Ingredients	Moisture (%)	Ash (%)	Crude Lipid (%)	Crude Protein (%)	Crude fibre (%)	Carbohydrates (%)
Date syrup(DS)	77.12±0.01[a]	1.06±0.03[a]	1.11±0.01[a]	4.55±0.02[a]	0.12±0.01[a]	16.04±0.01[a]
Soya Beans Flour(SY)	5.27±0.01[b]	1.96±0.01[b]	19.23±0.01[b]	40.10±0.02[b]	0.52±0.01[b]	32.92±0.02[b]
Bambara Nut flour(BN)	7.03±0.02[c]	1.52±0.04[ab]	5.87±0.02[c]	16.92±0.01[c]	0.19±0.01[a]	68.47±0.07[c]
Chia Seed Soaked in water(CH)	5.38±0.02[b]	3.87±0.05[c]	21.92±0.03[b]	19.23±0.01[d]	21.39±0.03[c]	28.21±0.04[b]
F value	423.431	60.131	88.635	306.165	270.105	45.205
p value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Values are mean±standard error of the mean of the proximate content of the post-processing analysis. Values with the same superscript are not significantly different at $p<0.05$ at 95 % confidence interval.

Table 3: The proximate composition of post formulation analysis of the cookies formulated in the study

Ingredients	Moisture (%)	Ash (%)	Crude Lipid (%)	Crude Protein (%)	Crude fibre (%)	Carbohydrates (%)
Sample A (Cookies)	9.46±0.05	3.10±0.03[a]	15.17±0.04	19.28±0.01[a]	1.01±0.01[ad]	51.98±0.07[a]
Sample B (Cookies)	8.65±0.05	3.05±0.01[a]	13.49±0.01	12.39±0.01[b]	1.49±0.01[b]	60.92±0.05[b]
Sample C (Cookies)	9.09±0.02	3.11±0.01[a]	13.29±0.01	24.84±0.03[c]	2.59±0.04c	47.087±0.03[a]
Sample D (Standard)	9.82±0.04	1.55±0.05[b]	14.27±0.22	3.79±0.01[d]	0.89±0.01[d]	69.68±0.06[c]
F value	1.901	75.343	2.138	43.431	46.559	32.030
p value	0.0872	<0.001	0.0639	<0.001	<0.001	<0.001

Values are mean±standard error of the mean of the proximate content of the samples. Values with the same superscript are not significantly different at $p<0.05$ at 95 % confidence interval.

The proximate Composition of the raw ingredients

The proximate analysis of the raw ingredients reveals significant nutritional diversity, highlighting their unique and complementary potential in food formulation. The distinct profiles of date seed (D), soya bean (S), Bambara nut (B), and chia seed (C) suggest that their carefully planned combination could be employed to develop snack products with targeted nutritional benefits. The low moisture content observed across all ingredients is a positive indicator for shelf stability. The significantly lower moisture content in soya bean and chia seeds, compared to date seed and Bambara nut, suggests an inherently lower water activity, which can inhibit microbial growth and extend the storage life of

the derived flours (Adejuyitan *et al.,* 2020). This is a critical factor for the viability and food safety of any product developed from these ingredients.

The ash content, which reflect total mineral content, was significantly higher in soya bean and chia seeds. This finding positions these two ingredients as potent mineral sources for food fortification. The high ash content in chia seeds is consistent with its reputation as a nutrient dense food (Ullah *et al*., 2016), while the robust mineral profile of soya bean is well documented in the literature (Adebowale *et al*., 2022). Conversely, the lower ash content in date seed and Bambara nut indicates that while they may provide energy and other macronutrients, they would be less significant contributors to the mineral density of a composite blend.

The crude lipid analysis showed a clear gradient, with chia seeds containing the highest level, followed by soya bean. This establishes chia seeds as a higher lipid source in formulations, which is significant given its high content of beneficial omega-3 fatty acids (Melgar *et al.,* 2021). Soya bean's substantial lipid content further reinforces its status as a major oilseed crop. In contrast, the low lipid content of Bambara nut and the very low level in date seed mark them as low-fat ingredients, which would be advantageous in creating snacks with reduced fat content.

The protein content showed variability, with soya bean exhibiting a markedly superior concentration. This result underscores soya bean's value as a plant-based protein source for combating protein-energy malnutrition in developing regions (Mune, 2022). The moderate and statistically similar protein levels in Bambara nut and chia seeds are notable; Bambara nut, an indigenous African legume, demonstrates a protein content comparable to the chia, highlighting the potential of underutilized local crops (Oyeyinka *et al.*, 2021). Date seed, with its low protein content, would function primarily as a source of carbohydrates rather than protein in a composite formulation.

The crude fibre results position chia seeds as an exceptional source of dietary fibre, containing significantly more than the other ingredients. This high fibre content is beneficial for gastrointestinal health and satiety, a key attribute for healthy snacking (Slavin, 2020). The intermediate fibre content of soya bean and Bambara nut adds to their nutritional portfolio, while date seed's low fibre content suggests its primary nutritional role lies elsewhere. The carbohydrate content revealed that, Date seed and Bambara nut were identified as high-carbohydrate ingredients, making them suitable as base ingredients or primary sources of energy in snack formulations. The significantly lower and similar carbohydrate content of soya bean and chia seeds is a direct consequence of their high levels of other components—protein and lipids in soya bean, and lipids and fibre in chia seeds. This inverse relationship is expected in proximate composition and confirms the distinct macronutrient specialization of each ingredient.

Proximate Composition of Processed Ingredients

In the current study, raw ingredients were processed into more functional forms including date syrup, soya bean flour, Bambara nut flour, and soaked chia seeds.

The exceptionally high moisture content of date syrup is characteristic of its syrupy, concentrated form and aligns with its primary function as a natural sweetener and humectant in food products. This high water activity necessitates careful consideration in product formulation to ensure shelf stability, potentially requiring low moisture in other components or the use of preservatives. In contrast, the low and statistically similar moisture contents of soya bean flour and soaked chia seeds are ideal for powder-based formulations, ensuring microbial stability and a longer shelf life (Adejuyitan *et al.,* 2020). The slightly higher moisture in Bambara nut flour, though still low, may require monitoring during storage to prevent clumping or spoilage.

There was significant reduction in the ash content of soya bean and Bambara nut following processing into flour, compared to their raw seed values. This suggests that certain mineral-rich components, such as the seed coat or hull, may have been lost during processing in flour production (Oyeyinka *et al.,* 2021). Soaked chia seeds, however, retained a significantly higher ash content than the other processed ingredients, reinforcing its status as a mineral-dense component even after hydration, making it a valuable ingredient for boosting the mineral content of the final product.

The lipid profile remained largely consistent with the raw ingredients, with soaked chia seeds and soya bean flour containing the highest and statistically similar levels. This confirms that the processing methods employed did not lead to substantial oil extraction or loss, preserving these ingredients as excellent sources of dietary lipids. The high lipid content in chia seeds contributes to its energy density and functional properties, while soya bean flour's lipid content adds to its overall nutritional value. The low lipid content in date syrup and Bambara nut flour further defines their roles as low-fat carbohydrate and protein sources, respectively. The protein content solidifies the distinct roles of each ingredient. Soya bean flour is the protein powerhouse, with a concentration significantly higher than all others, underscoring its role as a primary protein fortificants in plant-based products (Mune, 2022). Soaked chia seeds and Bambara nut flour provided moderate and distinct levels of protein, making them excellent complementary protein sources. Date syrup, with its low protein content, functions primarily as a carbohydrate-based sweetener rather than a protein contributor. Soaked chia seeds retained an exceptionally high fibre content, establishing it as the premier ingredient for enhancing the dietary fibre and associated health benefits. This is similar to the report of Adebowale *et al*., (2022). The carbohydrate content in Bambara nut flour emerged as the primary high-carbohydrate ingredient, making it a suitable base for providing energy density. Soya bean flour and soaked chia seeds, with their moderate and similar carbohydrate levels, reflect their balanced macronutrient profiles, where significant portions of their mass are comprised of protein and lipids/fibre, respectively. Date syrup's surprisingly low carbohydrate content, given its nature as a syrup, is likely because its composition is dominated by its high moisture content; on a dry weight basis, its carbohydrate level would be substantially higher (Adebowale *et al.,* 2022).

Proximate Composition of Formulated Cookies

The proximate composition of the formulated cookie samples reveals a successful nutritional transformation, with the composite flour blends significantly enhancing the dietary quality of the snacks compared to the conventional control. The results demonstrate that strategic formulation can effectively modulate the macronutrient profile to create a more balanced and nutrient-dense product.

The non-significant differences in moisture and lipid content between the experimental samples and the control are favourable findings from a product development perspective. This indicates that the incorporation of date syrup, soya bean flour, Bambara nut flour, and chia seeds did not adversely alter fundamental physical attributes related to shelf-stability and texture that are critical for consumer acceptance (Adebowale *et al.,* 2022). For the ash, protein, fibre, and carbohydrate profiles, there is significant finding. The significantly higher ash content in all three formulated samples (A, B, and C) compared to the control is a direct indicator of a superior mineral content. This finding aligns with the initial analysis of the raw ingredients, which identified soya bean and chia seeds as rich mineral sources. The elevated ash content confirms that these fortified cookies can serve as a more effective vehicle for delivering essential dietary minerals such as calcium, phosphorus, and zinc than the conventional refined flour-based cookie, addressing a key aspect of micronutrient deficiency (Oyeyinka *et al.,* 2021). The protein content in the formulated samples showed increase, with Sample C achieving a level approximately 6.5 times that of the control. This profound enhancement can be directly attributed to the high-quality protein from soya bean flour, an ingredient well-established for its role in combating protein-energy malnutrition. This finding is similar to that of Mune, (2022). The graded levels of protein across Samples A, B, and C are likely a function of the varying inclusion rates of the protein-dense ingredients, particularly soya bean flour, within their respective composite blends. This demonstrates the potential for precise nutritional tailoring in product formulation. A similar, though more varied, trend was observed for crude fibre. Sample C demonstrated a significantly higher fibre content, which can be linked to the inclusion of chia seeds, previously identified as an exceptional source of dietary fibre. The moderate increase in Sample B and the non-significant difference between Sample A and the control suggest differing proportions of fibre-rich components in their formulations. The enhanced fibre content contributes to improved satiety and digestive health, offering a functional benefit over conventional snack options (Slavin, 2020). The significant reduction in carbohydrate content in the formulated samples, particularly in Samples A and C, is a direct and expected consequence of nutrient dilution. As the proportions of non-carbohydrate components specifically protein, fibre, and ash (minerals) increased in the composite flours, the relative percentage of carbohydrates necessarily decreased.

Conclusion

The proximate evaluation successfully demonstrates that the strategic formulation of snacks using Bambara nut, soybean, chia seed, and date ingredients represents a significant nutritional improvement over conventional refined flour-based products. The composite flour blends effectively enhanced the dietary quality of the final cookies, markedly increasing their protein, dietary fiber, and ash content while reducing the relative proportion of simple carbohydrates. This nutritional transformation was achieved without compromising key product attributes like moisture and lipid content, which are critical for shelf-stability and consumer acceptance. The distinct yet complementary profiles of the individual ingredients were instrumental in this success: soybeans served as a protein powerhouse, chia seeds contributed exceptional fiber and mineral density, while Bambara nuts and dates provided a solid energy base and natural sweetness, respectively. Therefore, this study validates the potential of leveraging underutilized crops and functional foods to develop nutrient-dense snacks tailored to address the specific nutritional requirements and combat the triple burden of malnutrition among the adolescent population.

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