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Effect of Gum Arabic from *Acacia senegal* var. *kerensis* and Texturized Soy Protein on Pysico-Chemical Properties of Protein-Rich Snack Stick

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Abstract

Protein-energy malnutrition (PEM) as a result of poor nutrition, especially for deprived resourced households, is a big health concern in the world. According to the World Health Organisation, PEM accounts for 49% of the 10.4 million deaths of children under five that take place in developing countries. The aim of this study was to evaluate the influence of gum Arabic (GA) and texturized soy protein (TSP) and their interactive effect on proximate, functional, and textural properties of the protein-rich snack stick produced from ground green maize, GA powder, and ground TSP. GA varied at 0%, 4%, 8%, and 12%, while TSP varied at 0%, 12%, 24% and 36%. The 5 cm long protein-rich snack sticks were made using a sausage stuffer and baked in an oven at 110˚C for 1 hr 30 minutes. The snack sticks were subjected to proximate, functional and textural analysis using the standard methods. Increasing GA resulted in a significant ($p < 0.05$) increase in moisture content (13.64%) and fibre (2.85%). Increasing TSP had a significant increase in protein content (29.58%), moisture content (13.09%), and water holding capacity (2.35%). The incorporation of GA and TSP significantly ($p < 0.05$) increased the protein content (32.46%), Ash content (3.6%), fat (11.96%), and moisture content (16.25%) of protein-rich snack sticks. The interactive effect between GA and TSP led to a decrease in fibre and carbohydrates. Results from this study show GA and TSP significantly enhanced the physico-chemical properties of protein-rich snack sticks. A sample with 4% GA and 36% TSP is recommended for the best physico-chemical attributes of the protein-rich snack stick.

Keywords

Gum Arabic, Protein, Snack, Hydrocolloids, Nutrition

1. Introduction

It is estimated the world population will reach 9 billion by the year 2050, which will additionally worsen protein-energy malnutrition [1]. This will increase food insecurity, especially protein-energy malnutrition in developing countries [2]. In the last six decades, the world population has increased by 250%, reaching the 7 billion mark [3]. Nearly 1 billion people cannot afford quality foods with enough energy and protein [4]. PEM can be mitigated using readily available maize together with legumes [5].

Maize (*Zea mays*) accounts for nearly 40% of all cereal production in Sub-Saharan Africa, where more than 80% is used as food. Maize is consumed as stable food in most African countries. It grows in diverse ecological zones and is available in abundance. It's consumed in various forms: green maize roasted or boiled, snack, porridge, steamed products, bread or beverages. Various maize varieties are known to provide health benefits since they contain phytochemicals such phenolics, carotenoids (yellow maize), anthocyanins (blue maize), phlobaphenes (red maize), insoluble and soluble dietary fibre, and polar and nonpolar lipids [5]. The utilization of maize to make snacks with protein-rich legumes like soybean flour is on the rise [6].

Various reports are available on the preparation of nutritious snack bars. Cereals, fruits, nuts, and sugar are just a few of the raw materials that are used to prepare nutritious snack bars [7]. There are several varieties of cereal bars, such as bars with high protein, high fibre, and high calories [8]. Maize has low protein quality due to a deficiency in some essential amino acids (lysine and tryptophan) [9]. It has been suggested that these maize-based food products can be improved by incorporating protein-rich pulses like beans [10].

Despite the knowledge of the benefits drawn from maize and legume combinations, there is limited uptake by commercial entities to produce snacks with combinations of whole grain maize and legumes. Plant-based systems require more sustainable compared to meat-based systems [11]. The use of plant-based proteins to make snacks and meat analogues has gained popularity. This has been fuelled by the shift of preference by consumers who prefer plant or lab-grown proteins [12]. The introduction of protein-rich snack sticks will be essential in alleviating this menace as well as improving protein malnutrition among consumers [13]. There are a number of traditionally made snacks that can be improved nutritionally to alleviate malnutrition. Examples of typical African snacks include boiled or roasted plantains, roasted or boiled roots and tubers (cassava, yams, and potatoes), boiled or roasted green maize, roasted ground nuts or oilseeds, fried fish, termites or locusts, and fruits (bananas, oranges, mangoes, or sugarcane) [14]. *Mundu* remains a largely unexplored traditional ground green maize snack in Kenya.

Mundu is one of the few snacks traditionally made from ground green maize at the doughy stage with 8% crude protein content. The ground green maize is wrapped using the cob leaves and boiled in salted water for about 15 minutes until maize gelation occurs, as shown in **Figure 1**. *Mundu* is commonly prepared and consumed during green maize's doughy stage prior to harvesting by Mbeere people in Embu County, Kenya. However, *Mundu* doesn't provide adequate nutritional requirements for the wholesome growth and development of an individual, especially children above the age of 2 years. *Mundu* is only available for a short period since no preservation intervention has been deployed.

Gum Arabic is one of the gums that have gained wide application within the food industry [15]. They have been used as extenders, binders or stabilizers in most foods [16]. They are hydrocolloids with numerous applications as functional ingredients and were preferred for their excellent water and protein-binding properties. They are majorly polysaccharides with glycoprotein fraction accounting for less than 3%. In the innovative formulation of unique products that meet consumer demands, various ingredients, such as gums, have been utilized. For example, GA has been used in the preparation of extended beef rounds [17], improvement of goat cheese [18], improvement of wheat-plantain composite flour bread [19], and improvement of wheat dough functionalities [20]. Gum Arabic has been used as an ingredient in foods like yogurts, meatballs, and snack bars, among others, to improve textural properties as well as sensory properties [21]. This study promotes the utilization of readily available maize and improves the nutrition quality of *Mundu* to come up with a novel protein-rich snack stick by incorporating gum Arabic as an emulsifier and texturized soy protein to raise crude protein.

2. Materials and Methods

2.1. Materials and Study Site

Fresh green maize Embu Poa (EMB226) was purchased from Maguna stores in Embu, Kenya. The spices were obtained from Naivas Westside Mall, Nakuru City. Texturized Soy protein was acquired from Archer Daniels Midland (ADM) Company through Chemicals & Solvents E.A. LTD. Gum Arabic (*Acacia senegal* var. *kerensis*) was obtained from Acacia EPZ Limited, Athi River, Off Nairobi-Namanga Highway. The snack sticks were processed at the food pilot plant at the Department of Dairy and Food Science and Technology, Egerton University. Research on the Proximate and Mineral concentration of Protein-rich snack sticks was conducted at Egerton University, Department of Dairy and Food Science and Technology Laboratory. Textural properties such as hardness, springiness, and chewiness were determined at the Kenya Industrial Research and Development Institute (KIRDI), Nairobi.

2.2. Preparation of Protein-Rich Snack Stick

Green maize at the doughy grain stage (50% moisture), which has the sugars necessary for caramelization of the product, was ground using a milling machine (MILWAUKEE WISCONSIN 53207 Model No. 311), TSP was ground into a fine powder using a commercial heavy-duty blender (220 - 240 V—50/60 Hz 750 W).

Ground green maize, GA powder, TSP ground powder, spices, and salt were mixed into a smooth paste. Gum Arabic was varied at 0%, 4%, 8%, and 12%, while TSP was varied at 0%, 12%, 24%, and 36% using completely randomized design (CRD) in factorial arrangement. The final paste was stuffed using a hand-held sausage filler with an exit of 0.5 cm diameter and cut at 5 cm long. The raw products were baked in an oven (110˚C for 1 hr 30 minutes) and cooled for 30 minutes to room temperature before vacuum packaging and storage at 4˚C [22] with some modifications, as shown in Figure 1.

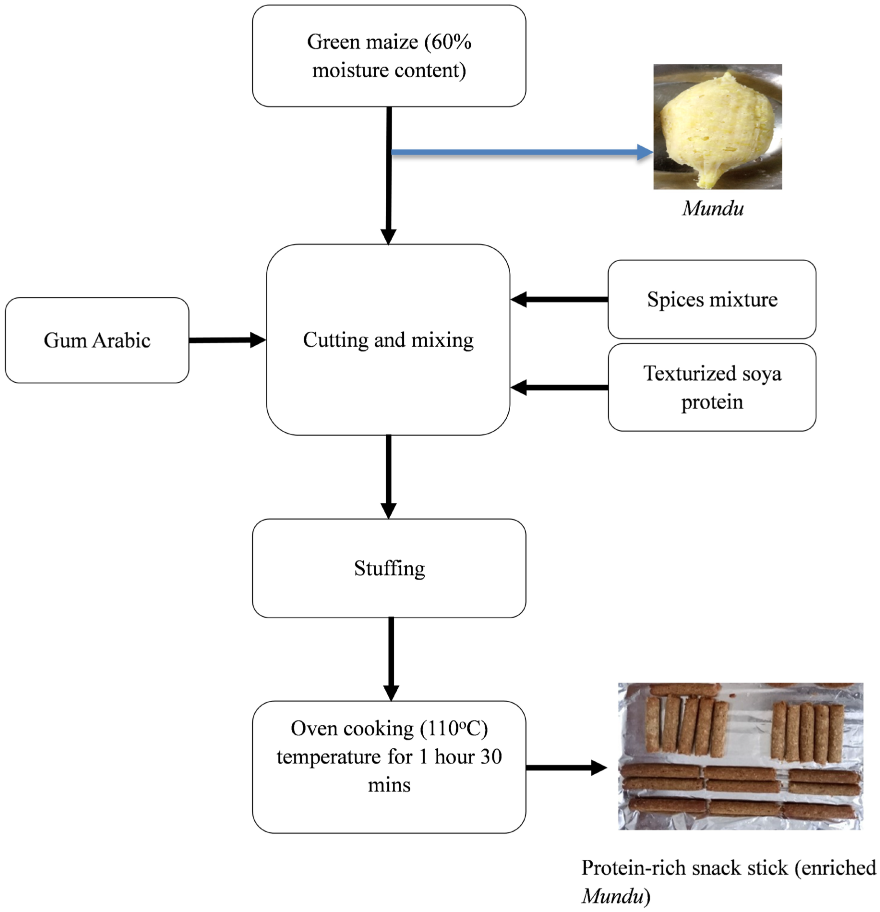

Figure 1. Protein-rich snack stick development process.

2.3. Moisture Content

The moisture content of protein-rich snack stick treatments was carried out using the oven drying method (AOAC 2008 Method 950.46). The moisture content was calculated.

$$\%\text{MC}(\text{wwb}) = \frac{\text{Weight of wet sample} - \text{Weight of dry sample}}{\text{Weight of wet sample}} \times 100$$

2.4. Crude Protein

Crude protein content was analysed using the kjedahl method (AOAC 2005, Method

978.04). About 1g of the sample was weighed into a test tube and digested with 10 ml concentrated H_2SO_4 in the presence of a copper sulphate ($CuSO_4$) catalyst in a digestion block until the colour turned blue. The digest will then be cooled to room temperature before diluting to 100 ml with distilled water. The test tube was transferred to a distillation unit where 10 ml of 40% NaOH was gradually added to the sample. Distillation was continued for about 10 minutes, and ammonia produced in the reaction was collected as ammonium hydroxide in a conical flask containing 20 ml of 1% boric acid solution with a drop of methyl red indicator. About 60 ml of the distillate was collected and titrated against 0.1 N HCl until the colour changed to pinkish-orange. The nitrogen content was calculated as

$$\%\text{Nitrogen} = \frac{\text{Normality of HCl} \times \text{Corrected acid volume}\left(\text{ml}\right)}{\text{Weight of sample}} \times 14\ \text{g} \cdot \frac{\text{N}}{\text{mol}} \times 100$$

Where:

Normality of HCl = molarity of HCl in mol/1000ml;

Corrected acid volume = (ml std. acid for sample) − (ml std. acid for blank);

14 = atomic weight of Nitrogen;

Crude protein content was calculated using the percent nitrogen content and conversion factor of 6.25 (%N × 6.25).

2.5. Ash Content

The ash content of the protein-rich snack stick sample was determined using the AOAC Official Method (AOAC 2000 method 920.39). About 5.0 g of each sample was accurately weighed and placed into dry crucibles. Samples will then be ashed in a muffle furnace at 550˚C for 6 hours. The ashed samples were cooled in a desiccator to room temperature and weighed. Total minerals content was calculated as:

$$\%\text{Ash content} = \frac{\left(\text{Weight of crucible} + \text{Ash}\right) - \text{Weight of crucible}}{\text{Weight of sample}} \times 100$$

2.6. Crude Fibre

The crude fibre was determined using the AOAC (2000) method 984.04. About 2 g of defatted sample of known dry matter content was weighed into a graduated beaker, and 200 ml of 2.04M sulphuric acid and bumping chips were added. The sample was boiled for 30 min and then filtered through a muslin cloth. It was then washed with boiling distilled water until no longer acidic, then boiled with 200 ml of 1.73M potassium hydroxide solution for 30 min and filtered through a muslin cloth. After which, it was washed again with 25 ml boiling 1.25% H_2SO_4, 3.50 ml portions of distilled water, and 25 ml ethanol. All this was carried out in a digester. The residue was removed and transferred to a pre-weighed porcelain dish (W_1) and dried in an air draft oven at 105˚C for 2 hours, cooled in a desiccator, and then weighed (W_2). The sample in the porcelain dish will then be transferred to a muffle furnace and ignited at 550˚C to a constant weight, then cooled in the desiccator and reweighed (W_3).

$$\%\text{Crude fibre} = \frac{(W_2 - W_1) - (W_3 - W_1)}{\text{Weight of sample}} \times 100$$

2.7. Crude Fat

Crude fat was determined by the Soxhlet method (AOAC, 2000, Method 920.39). Approximately 5 g ground sample of known dry matter content was weighed accurately into an extraction thimble and covered with cotton wool. The thimble was placed in the Soxhlet extractor (Model: EME 6250/CF; Cole Parmer; England), and the fat was extracted into a tared flask for 6 h using petroleum ether (B.P. 40˚C - 60˚C). The solvent was evaporated, the flask was cooled in a desiccator and weighed. The crude fat content was calculated and expressed as a percentage of the sample dry matter content.

$$\%\text{Crude fat content} = \frac{\text{Weight of flask with sample} - \text{Weight of flask}}{\text{Weight of dry sample}} \times 100$$

2.8. Water Holding Capacity (WHC)

The water holding capacity was determined according to the method described by [23]. Twenty-five ml of distilled water was mixed with 1g of sample at room temperature for 24 hrs. After which, centrifugation at 4000× g for 25 mins, at −4˚C, was done, and the residue was collected, weighed, and dried at 80˚C. The WHC was expressed as grams of water per gram of dry sample. A high-speed refrigerated centrifuge model No: HC-3018R was used.

$$\%\text{WHC}\left(\frac{\text{g}}{\text{g}}\right) = \frac{\text{Weight of wet residue} - \text{Weight of dry residue}}{\text{Weight of dry residue}} \times 100$$

2.9. Textural Profile Analysis (TPA)

The textural properties of protein-rich snack sticks were objectively analysed using a two-bite technique. Hardness, chewiness, springiness, cohesiveness, adhesiveness, and gumminess was determined using a texture profile analyser as described by [24]. The machine was first calibrated using a 50 kg load cell prior to the actual testing. Samples were cut into 4 cm long and analysed using a Texture analyser model TX.XT. Plus Texture profile analyser with 50 kg load cell, SMS/P 75 probe, speed 5.00 mm/Sec and 50% strain.

2.10. Mineral Analysis

Calcium, iron and zinc were analysed according to AOAC (2000) Method 985.35. Two grams of sample was wet-ashed by dissolving in 5 ml concentrated hydrochloric acid (HCl) and heated gently on a hotplate in a fumehood for 30 min. The digested solution was cooled and 2 ml of conc. HNO_3 was added and reheated for 3 min. The mixture was cooled and filtered using Whatman's 42:2.5 µm filter paper. The filtrate was transferred into a 100 ml measuring flask, and deionized water was added to the mark. Analysis was done using the Atomic Absorption Spectrophotometer (AAS).

The specific wavelengths were 213.9 nm for zinc, 248.329 for iron, and 422.7 nm for calcium. Iron, zinc and calcium were analysed since they are among the most crucial and inadequate micronutrients in foods.

2.11. Cooking Loss

The protein-rich snack stick was cooked at 68˚C - 74˚C for 30 minutes. Cooking loss was determined by the expression below after the precooking stage [25].

$$\%\text{Cooking loss}(\text{g}) = \frac{\text{Initial weight before cooking} - \text{Final weight after cooking}}{\text{Initial weight before cooking}} \times 100$$

2.12. Data Analysis

The PROC GLM technique of the Statistical Analysis System (SAS Institute Inc., 2006) software Version 9.4 was utilised for data analysis. The normality and homogeneity tests were run on the data prior to analysis. The study hypotheses were assessed using analysis of variance (ANOVA), with a significance level of $p < 0.05$ established at the confidence level. Using the Tukey Honest Significant Difference method, the difference between the means was found. The samples were examined in triplicates.

3. Results and Discussion

3.1. Effect Nutritional Properties of Protein-Rich Snack Stick

An increase in GA resulted in a significant increase in fibre and moisture content of the protein-rich snack stick, as shown in **Table 1**. These results agree with findings by [26] in a prebiotic Snack Bar where the addition of GA increased both moisture and fibre content. This can be explained by the composition of the GA, which has large proportions of polysaccharides with dietary fibre [27]. Their long chains with functional groups OH and O help in binding water molecules in food. Moisture content is the most important parameter that influences other parameters in foods. Water molecules are strongly bound by the GA molecules as they possess both negative and positive charges. An increase in GA levels resulted in a significant decrease in carbohydrates from 61.13% to 54.73% because GA contains polysaccharides, which are not degraded into monosaccharides during the processing. It was also found that an increase in GA resulted in a decrease in protein content above GA (8%). However, these changes were not significant ($p < 0.05$). The ability of polysaccharides to promote water absorption may be the cause of changes in the protein-rich snack stick's protein level after GA was added. Similar results were reported by [21] [26] for biscuits produced from flour blends of wheat and water yam and snack bars incorporated with GA, respectively.

It was found that increasing TSP substitution significantly ($p < 0.05$) increased protein (10.56% to 29.58%) and moisture content (8.33% to 13.09%) but decreased fibre (2.90% to 2.35%) and carbohydrates (68.82% 45.44%). However, ash and fat were not significantly influenced. An increase in TSP resulted in a significant increase in protein and moisture content. A similar finding was reported by

[28] for cookies from whole wheat and full-fat soya and by [29] for beef samosas incorporated with TSP. This is due to the composition of TSP, which has up to 52% crude protein, with the rest majorly being carbohydrates that absorb and bind moisture content [30]. This explains the increase in moisture content as TSP was increased. Increases in GA and TSP had significant increases in protein from control 9.58% to 32.46%, fat from 1.32% to 11.96%, and moisture content from 4.11% to 16.25%. This is due to the high protein content in TSP and the ability of GA to bind water [22].

Table 1. Effect of Gum Arabic substitution level on the proximate composition of protein-rich snack stick.

GA (%)	Protein	Fibre	Ash	Fat	MC	CHO
0	18.93 ± 2.31^{a}	2.33 ± 0.21^{b}	2.48 ± 0.08^{a}	5.45 ± 0.86^{a}	9.16 ± 0.97^{c}	61.66 ± 4.01^{a}
4	19.89 ± 2.91^{a}	2.73 ± 0.08^{ab}	2.48 ± 0.22^{a}	7.83 ± 1.43^{a}	10.19 ± 0.60^{b}	57.21 ± 3.41^{ab}
8	21.11 ± 2.08^{a}	2.40 ± 0.10^{ab}	2.79 ± 0.11^{a}	8.20 ± 0.72^{a}	10.84 ± 0.38^{b}	54.33 ± 2.86^{b}
12	19.83 ± 2.03^{a}	2.85 ± 0.20^{a}	2.85 ± 0.10^{a}	5.96 ± 1.09^{a}	13.64 ± 0.48^{a}	54.07 ± 1.76^{b}
MSD value	2.67	0.49	0.54	2.94	0.89	5.38

Key: GA = Gum Arabic; MSD = Minimum Significant Difference; MC = Moisture Content; CHO = Carbohydrates; Means with the same letter along the column are not significantly different at $p < 0.05$.

Table 2. Interactive effect of Gum Arabic and Texturized Soy Protein on proximate composition of the protein-rich snack stick.

GA (%)	TSP (%)	Protein	Fibre	Ash	Fat	MC	CHO
0	0	9.58 ± 0.35^{f}	3.81 ± 0.1^{a}	2.37 ± 0.27^{a}	1.32 ± 0.17^{b}	4.11 ± 0.54^{g}	78.8 ± 0.88^{a}
	12	14.17 ± 0.48^{ef}	2.427 ± 0.26^{b}	2.67 ± 0.13^{a}	4.417 ± 0.19^{ab}	8.997 ± 0.14^{ef}	67.427 ± 0.81^{ab}
	24	22.7 ± 1.2^{bcd}	2.44 ± 0.31^{b}	2.48 ± 0.14^{a}	8.65 ± 0.33^{ab}	11.39 ± 0.56^{bcd}	52.35 ± 1.42^{cde}
	36	29.26 ± 0.57^{ab}	2.74 ± 0.11^{ab}	2.48 ± 0.09^{a}	7.42 ± 0.08^{ab}	12.15 ± 0.5^{bc}	45.95 ± 0.95^{de}
4	0	10.73 ± 1.01^{f}	2.62 ± 0.16^{ab}	2.34 ± 0.27^{a}	8.71 ± 0.35^{ab}	7.11 ± 0.17^{f}	68.49 ± 0.91^{ab}
	12	12.15 ± 4.78^{ef}	3.1 ± 0.1^{ab}	2.41 ± 0.09^{a}	11.96 ± 4.23^{a}	10.54 ± 0.83^{cde}	59.84 ± 9.17^{bcd}
	24	24.22 ± 0.79^{bc}	2.73 ± 0.03^{ab}	2.1 ± 0.73^{a}	4.05 ± 0.57^{ab}	11.35 ± 0.69^{bcde}	55.55 ± 0.62^{bcde}
	36	32.46 ± 1.23^{a}	2.48 ± 0.06^{b}	3.06 ± 0.44^{a}	6.59 ± 3.17^{ab}	11.77 ± 0.22^{bc}	43.64 ± 4.01^{e}
8	0	11.29 ± 0.58^{ef}	2.54 ± 0.14^{ab}	2.84 ± 04^{a}	6.1 ± 0.33^{ab}	9.11 ± 0.3^{def}	68.11 ± 0.5^{ab}
	12	18.23 ± 0.17^{cde}	2.71 ± 0.06^{ab}	2.43 ± 0.06^{a}	7.31 ± 1.74^{ab}	11 ± 0.47^{bcde}	58.31 ± 1.63^{bcd}
	24	26.15 ± 0.25^{ab}	1.85 ± 0.85^{b}	2.9 ± 0.05^{a}	11.45 ± 0.68^{a}	11.08 ± 0.48^{bcde}	46.58 ± 1.2^{cde}
	36	28.75 ± 0.57^{ab}	2.2 ± 0.03^{b}	2.99 ± 0.09^{a}	7.95 ± 0.19^{ab}	12.18 ± 0.5^{bc}	45.94 ± 0.53^{de}
12	0	10.64 ± 0.32^{f}	2.62 ± 0.17^{ab}	2.59 ± 0.27^{a}	11.29 ± 1.96^{a}	12.99 ± 0.19^{b}	59.88 ± 1.89^{bcd}
	12	16.56 ± 0.26^{def}	2.73 ± 0.06^{ab}	2.81 ± 0.15^{a}	5.27 ± 1.27^{ab}	12.3 ± 0.19^{bc}	60.33 ± 1.29^{bc}
	24	24.28 ± 0.88^{bc}	2.27 ± 0.04^{b}	2.95 ± 0.13^{a}	2.65 ± 0.11^{b}	13.04 ± 0.49^{b}	54.82 ± 1.14^{bcde}
	36	27.86 ± 0.57^{ab}	1.98 ± 0.07^{b}	3.06 ± 0.23^{a}	4.61 ± 0.07^{ab}	16.25 ± 0.07^{a}	46.24 ± 0.82^{cde}

Key: Key: GA = Gum Arabic; TSP = Texturized Soy Protein; MC = Moisture Content; CHO = Carbohydrates; MSD = Minimum Significant Difference; Means with the same letter along the column are not significantly different at $p < 0.05$.

It was found that there was a significant interaction effect of GA and TSP on protein, fibre, fat, moisture content, and carbohydrates but not on ash, as shown in Table 2. Protein, fibre, fat, moisture content, and carbohydrates had the highest mean of 32.46%, 3.81%, 11.96%, 16.25%, and 78.8%, respectively. An increase in GA and TSP led to a decrease in fiber, and carbohydrates. This is due to the masking effect of TSP, which has fewer carbohydrates and fiber as compared to green maize [31]. The protein-rich snack stick showed superior nutritional quality compared to the control, making it useful in mitigating protein-energy malnutrition, which is a major food security concern among school-going children to enhance their growth and development. The crude protein level increased from 10.73% to 32.46%. This implies that if one consumes 150 g/day of the protein-rich snack stick, meets the protein Dietary Reference intake (DRI), which is set at 46 g/day for males at 52 g and 46 g for females and approximately 0.8 g/kg of body weight/day for adults [32].

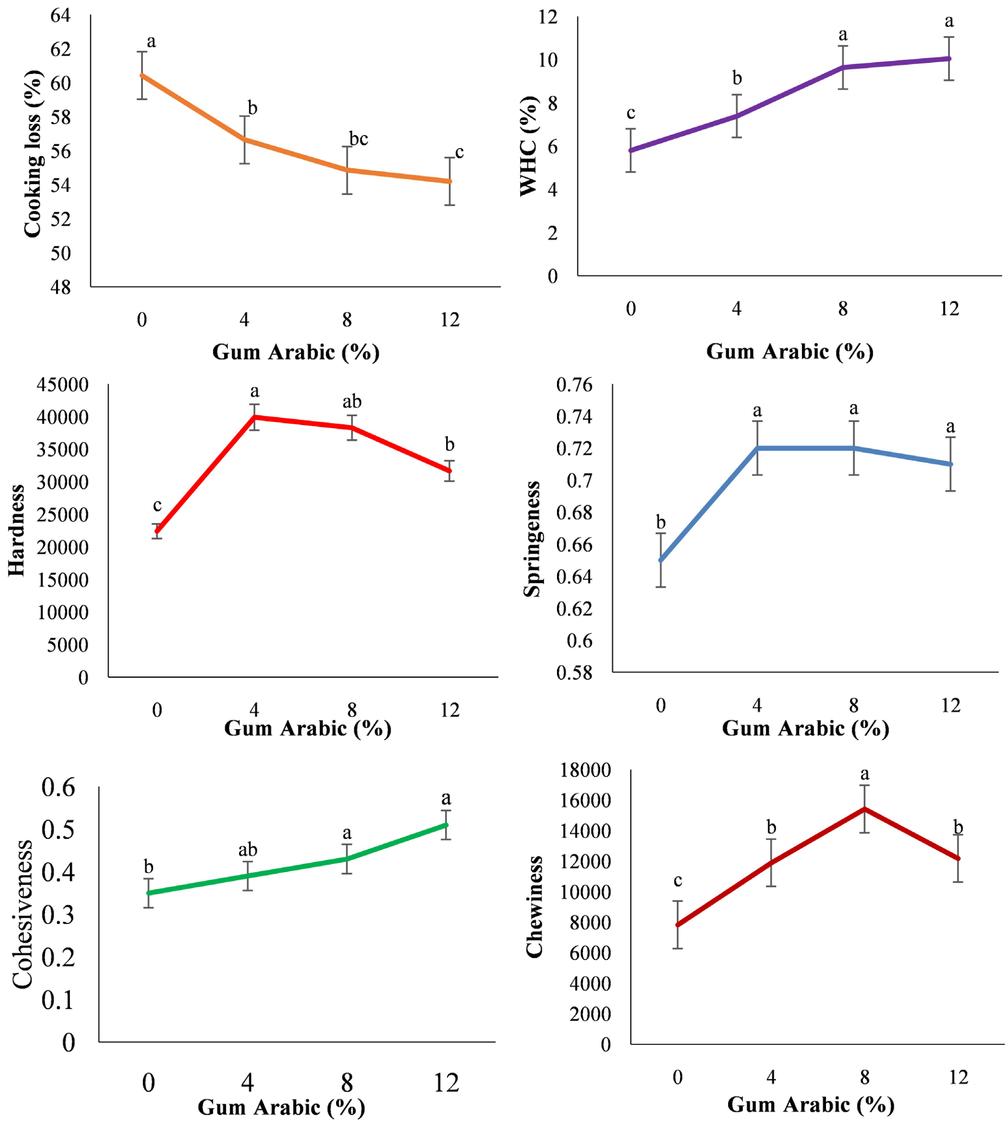

Figure 2. Effect of Gum Arabic substitutional on functional properties of protein-rich snack stick.

3.2. Effect of Gum Arabic and Texturized Soy Protein Functional properties Protein-Rich Snack Stick

The effect of GA substitutional level on the functional properties of protein-rich snack sticks is shown in **Figure 2**. Increasing GA from 0% and 12% significantly ($p < 0.05$) reduced cooking loss (60.42% to 54.19%) and increased water holding capacity (5.8% to 10.05%). Additional GA levels significantly increased the water-holding capacity of the protein-rich snack stick. The GA enhanced water holding capacity due to the presence of high molecular weight and hydrophilic nature; a similar finding was shown by [14] [32], in contrast, found an increase in GA to significantly reduced water holding capacity from 21.00% (10% GA) to 19.00% (30% GA). GA increase significantly reduced cooking loss due to the water immobilization effect of gum [33] [34].

It was found that there was a significant ($p < 0.05$) influence of GA and TSP interaction on functional properties of protein-rich snack sticks. Cooking loss was reduced (64.65% to 54.46%) while water holding capacity increased (1.93% to 14.9%). An increase in TSP level had a significant ($p < 0.05$) influence on both cooking loss and water holding capacity. Cooking loss reduced from 59.17% to 51.12%, while water holding capacity increased from 5.47% to 12.91%. Proteins and starch have the ability to bind and absorb water in foods, and by holding water, they can reduce cooking loss [35] [36].

3.3. Effect on Textural Properties of Protein-Rich Snack Stick

An increase in GA had a significant reduction in the hardness of the protein-rich snack stick. Binders like GA absorb and covalently bind water molecules, resulting in products being softer [37]. This outcome was observed due to the hydroxyl groups present in the hydrocolloid structure of GA, which allows water interactions through hydrogen bonding. Increasing GA levels had a significant increase in springiness from 0% to 4 %, followed by gradual insignificant decreases from 4% to 12%. This is due to the fact that the control had no hydrocolloid that could bind water to improve springiness. The addition of GA led to a significant ($p < 0.05$) increase in chewiness up to 8%, followed by a decrease to 12% GA. Additionally, GA increased cohesiveness because of the interaction between water and gum. Gums dissolve in water to improve viscosity, hence reducing chewiness force [18]. The snack's textural qualities were significantly impacted by the interaction between GA and TSP. The interaction resulted in an increase in hardness, springiness cohesiveness, and springiness compared to the control. Hydroxyproline, serine, and threonine are the primary constituents of the peptide domain. It is believed that GA acquires amphiphilicity from the hydrophilic polysaccharide domain and the hydrophobic peptides domain [38].

The addition of TSP had a significant reduction in hardness, springiness, cohesiveness and chewiness. This can be attributed to water-holding capacity of the TSP. One common non-meat protein utilised in meat products is TSP. It has strong emulsion and gel qualities that may improve the meat products' ability to retain water and their texture [39].

3.4. Effect of Gum Arabic and Texturized Soy Protein on Minerals

Addition of GA significantly ($p < 0.05$) increased calcium (184.86 to 186.68), iron (105.18 to 107.34) and zinc (1.50 to 1.67). Addition of TSP significantly ($p < 0.05$) increased calcium (166.10 to 200.28), iron (98.61 to 112.64) and zinc (0.94 to 2.09). Calcium was found to be the most concentrated mineral, increasing from 163 mg/100 in the sample containing GA 4%-TSP-0% to 200.76 mg/100g in a sample containing GA 12%-TSP36%. Gum Arabic and TSP addition led to a significant increase ($p < 0.05$) in calcium, iron, and zinc concentration of the protein-rich snack stick. This is a result of the substantial presence of the above minerals in green maize, GA and TSP [40] [41]. Calcium was found to be the most concentrated mineral and was abundance in treatment (GA 12% - TSP 36%), which ranged from 200.76 mg/100g to 163 mg/100 (GA 4% - TSP 0%) of the sample due to high mineral content in TSP as raw material [42].

3.5. Correlation between Proximate and Functional Properties

The coefficients of correlation between proximate and functional properties are shown in **Table 3**. Protein was significantly ($p < 0.05$) positively correlated with Moisture content (r = 0.61) and Water holding capacity (r = 0.75), but significantly negatively correlated with carbohydrates (r = −0.89), cooking loss (r = −0.53), hardness (r = −0.32), springiness (r = −0.30) and cohesiveness (r = −0.30). Fibre was significantly negatively correlated to hardness (r = −0.34), springiness (r = −0.52), and chewiness (r = −0.38). Ash was positively correlated to water holding capacity (r = 0.42) and negatively correlated with carbohydrate (r = −0.32) and cooking loss (r = −0.42). Fat was significantly positively correlated to springiness (r = 0.30) and negatively correlated to carbohydrates (r = −0.41). Moisture content was significantly positively correlated to water holding capacity (r = 0.75) and cohesiveness (r = 0.35) but significantly negatively correlated to carbohydrate (r = −0.77), cooking loss (r = −0.62) and hardness (r = −0.33). Carbohydrates were significantly positively correlated to cooking loss (r = 0.63) but significantly negatively correlated to water holding capacity (r = −0.78). Cooking loss was only significantly negatively correlated to water holding capacity (r = −0.76) without a significant positive correlation observed. Water holding capacity was significantly negatively correlated to hardness (r = −0.42) and springiness (r = −0.29). Hardness was significantly negatively correlated to cohesiveness (r = −38). Springiness was significantly positively correlated to cohesiveness (r = 0.31).

There was a significant positive correlation between protein and moisture content (r = 0.61%) due to the large proportions of proteins and starch that absorb water in TSP, which majorly contributed to protein in the snack stick. The protein showed significant ($p < 0.05$) weak and strong negative correlations with fiber (r = −0.45) and carbohydrates (r = −0.90), respectively, due to the substitution of TSP with green maize and GA, which has high portions fiber [43]. Carbohydrates had a negative correlation with moisture content (r = −0.76) and a positive correlation with fiber (r = 0.50). Ash (r = −0.32) had a significant negative correlation with carbohydrates [44] and had similar results.

There was a weak negative significant correlation between hardness and cohesiveness. Similarly, a weak, significant negative correlation was observed between springiness and cohesiveness. This can be attributed to gums' ability to absorb water. Cohesiveness is the tendency of intermolecular attraction. When this intermolecular force is reduced, it equally makes the product softer and less springy [37].

Table 3. Coefficients of correlation between proximate and functional properties.

	Protein	Fibre	Ash	Fat	MC	CHO	CL	WHC	Hardness	Springiness	Cohesiveness	Chewiness
Protein	1.00											
Fibre	−0.25^{Ns}	1.00										
Ash	0.31*	−0.12^{Ns}	1.00									
Fat	0.03^{Ns}	0.10^{Ns}	−0.01^{Ns}	1.00								
MC	0.61*	−0.00^{Ns}	0.24^{Ns}	0.18^{Ns}	1.00							
CHO	−0.89*	0.10^{Ns}	−0.32*	−0.41*	−0.77*	1.00						
CL	−0.53*	0.19^{Ns}	−0.42*	−0.22^{Ns}	−0.62*	0.63*	1.00					
WHC	0.75*	−0. 05^{Ns}	0.42*	0.08^{Ns}	0.75*	−0.78*	−0.76*	1.00				
Hardness	−0.32*	−0.34*	−0.17^{Ns}	0.22^{Ns}	−0.33*	0.27^{Ns}	0.10^{Ns}	−0.42*	1.00			
Springiness	−0.30*	−0.52^{Ns}	−0.06^{Ns}	0.30*	−0.13^{Ns}	0.15^{Ns}	0.21^{Ns}	−0.29*	−0.20^{Ns}	1.00		
Cohesiveness	−0.30*	0.46*	0.14^{Ns}	0.20^{Ns}	0.35*	0.03^{Ns}	−0.17^{Ns}	0.12^{Ns}	−0.38*	0.31*	1.00	
Chewiness	0.17^{Ns}	−0.38*	0.20^{Ns}	0.03^{Ns}	0.09^{Ns}	−0.02^{Ns}	0.03^{Ns}	−0.08^{Ns}	0.15^{Ns}	0.20^{Ns}	−0.35^{Ns}	1.00

Key: * = Significant ($p < 0.05$); Ns = Not significant ($p < 0.05$); MC = Moisture Content; CHO = Carbohydrates; CL = Cooking Loss; WHC = Water Holding Capacity. Means with the same letter along the column are not significantly different at $p < 0.05$.

4. Conclusion

The nutritional, functional, and textural properties of protein-rich snack sticks were significantly influenced by the inclusion of GA and TSP. Protein-rich snack sticks were nutritionally superior and well-balanced meal snacks compared to control. The protein-rich snack stick can be conveniently served to groups that are adversely affected by poor nutrition. Therefore, more research needs to be done to determine if there are anti-nutrient factors in the snack sticks.

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Conflicts of Interest

Regarding this paper's publication, the authors declare that they have no conflicts of interest.

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