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Development of fortified snack bar from *Gracilaria salicornia* (Dawson, 1954)

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Abstract

Combating malnutrition requires a comprehensive strategy, and one effective approach is food fortification. *Gracilaria salicornia*, a locally abundant seaweed species in Northern Mindanao, Philippines, is notable for its broad nutritional profile, making it valuable for food development. This study assessed the proximate composition, sensory properties, and cost-benefit ratio of snack bars fortified with *G. salicornia* powder (Gs). Four formulations with varying percentages of inclusions of Gs were evaluated: snack bars with 0% Gs, 5% Gs, 10% Gs, and 15% Gs. Subsequent proximate composition analysis revealed that the 10% Gs snack bar had the highest protein content (4.02%), while the 15% Gs had the lowest (1.76%). The 0% Gs formulation had the highest crude fat content (27.78%), and the 15% Gs had the lowest (22.49%). In terms of fiber content, the 10% Gs snack bar had the highest content (3.77%), whereas the 5% Gs had the lowest (1.14%). In terms of sensory properties, the 0% Gs snack bar received the highest overall acceptability score (8.12±0.14, liked extremely), followed by the 5% Gs (7.28±0.21, liked very much), with no significant difference from the control. The 10%Gs and 15% Gs snack bars received lower scores (5.36±0.33 and 4.88±0.43, respectively). The cost-benefit analysis indicated that fortified snack bars generated profits ranging from USD 0.15 to USD 0.16 per unit, showing that benefits outweighed costs across all treatments. The study suggests the 5% Gs and 10% Gs formulations stand out due to better nutritional profiles, moderate acceptability, and profitability.

1. Introduction

Seaweeds are non-flowering plant-like organisms that perform photosynthesis and thrive in marine environments (Muñoz and Diaz, 2022). They are typically found in intertidal, tidal, and subtidal regions (Subba Rao *et al*., 2016). In many Asian countries, including the Philippines, seaweed farming has been recognized as a sustainable livelihood for coastal communities (Allison and Horemans, 2006; Aslan *et al*., 2015; Béné *et al*., 2016). In recent years, marine algae have gained significant attention due to their abundant minerals, polyunsaturated fatty acids, vitamins, and bioactive molecules, along with low lipid content and rich polysaccharides (Gupta and Abu-Ghannam, 2011). Seaweed products are widely used in the food, pharmaceutical, and cosmetic industries, with hydrocolloids derived from seaweeds serving as food additives in processed foods (Aliste *et al*., 2000; Valderrama *et al*., 2013; Qiu *et al*., 2022). Several studies have explored the chemical composition of edible seaweeds, highlighting their significance for human health (Dawczynski, 2007; Sanjeewa, 2018; Muñoz and Diaz, 2022). Seaweeds have also shown potential in the field of medicine due to their health-promoting properties (Matanjun *et al*., 2009; Kim, 2011). Seaweeds are identified as promising candidates for the food industry, due to their favorable nutritional composition and abundance of bioactive compounds that contribute to health promotion (Alfonso *et al*., 2019). Rich in vitamins, minerals, dietary fiber, and antioxidants, seaweeds are becoming an attractive ingredient for health-conscious consumers (Nakhate and Meer, 2021). Among various seaweeds species, *Gracilaria* sp. has been widely utilized in industries, particularly in food and beverages like ice cream, candy, jelly, chocolate, milk, and other snacks (Suparmi and Sahri, 2009).

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Gracilaria salicornia was first identified in Manila, Philippines, and is now found across Asia and the Indian Ocean (Yang *et al*., 2013). The presence of *Gracilaria* species in Northern Mindanao, Philippines, has been documented in specific areas such as Kauswagan, Lanao del Norte; Dalipuga, Iligan City; and Gimangpang, Initao, Misamis Oriental (Echem and Metillo, 2011). *G. salicornia* is a red macroalga found in coastal regions, contains a rich nutritional profile, including essential vitamins, minerals, and bioactive compounds (Lumbessy *et al*., 2019). It also contains valuable polysaccharides, such as agar and agarose, which are linked to numerous health benefits (Armisén, 1991; Lee *et al*., 2022).

Efforts to cultivate *G. salicornia* for agar production have been undertaken (Smith et al., 2004), but recent studies have classified it as an invasive species due to its ability to form dense beds that displace native species and disrupt ecosystems (Nelson *et al*., 2009; Fukunaga *et al.,* 2014; Campbell *et al.,* 2014). Several studies documented the utilization of some invasive species as a food source as a means of controlling its population (Varble and Secchi, 2013; Huth *et al*., 2018; Pacheco *et al*., 2020). This approach highlights one potential benefit of utilizing invasive seaweed in food production: to mitigate their environmental impact.

On the other hand, malnutrition, an inadequacy in energy and nutrient intake (Food and Agriculture Organization (FAO), 1999; United Nations World Food Programme, 2012), affects millions worldwide, particularly in developing countries (Stein, 2009). One form of malnutrition, Protein-Energy Malnutrition (PEM), arises from a deficiency of both macronutrients and micronutrients (Crichton *et al*., 2019). PEM prevalence varies across regions, ranging from 0.8% to 24.6%, and is influenced by rurality (Raynaud-Simon *et al*., 2011). Experts have identified malnutrition as having a significant negative impact on individual health, social welfare, and economic productivity (Stein, 2009). Given the rich nutritional profile of *G. salicornia*, its utilization also provides an opportunity as a powerful tool for addressing malnutrition and its associated health risks.

Food fortification refers to the addition of vitamins and minerals to commonly consumed foods during processing to enhance their nutritional value. It is a proven, safe, and cost-effective strategy for addressing micronutrient deficiencies (Olson *et al*, 2021). There is growing interest in fortified foods in the Philippines, particularly in Filipino snacks, due to their health benefits (Calubaquib and Suyu, 2020). One method of food fortification involves incorporating nutrient-rich ingredients into commonly consumed food products (Ahsan *et al*., 2023; Lysakowska *et al*., 2024; Moin *et al*., 2024). In the Philippines, Filipinos view snacking as a source of nutrition and prefer snacks with health and nutrition benefits (Juliano and Bagabaldo, 2024). Many studies conducted at the country level have reported favorable results regarding the impact of food fortification on micronutrient status (Olson *et al*., 2021). Food fortification presents a dual benefit: it can reduce the environmental impact of invasive species such as *G. salicornia*, while simultaneously serving as an effective strategy to combat malnutrition and its related health challenges.

Globally, snack foods derived from grains, tubers, fruits, vegetables, meats, and milk constitute a significant industry, generating approximately 520 billion USD in sales in 2020. The main consumers of these products are people from the USA, Europe, Canada, South Korea, and Australia, with yearly consumption varying between 5 and 22.5 kg (Serna-Saldivar, 2022). Given the high consumption of snacks, snack bars are an ideal subject of food fortification efforts. Some studies documented promising consumer acceptance of food products fortified with seaweeds (Etemadian *et al.,* 2018; Nurcahyanti *et al*., 2021; Perdani *et al*., 2024). However, there is still a global need to promote the widespread adoption of fortified snacks made with seaweeds (Jayakody and Vanniarachchy, 2023). Despite the potential nutritional benefits of *G. salicornia*, with limited incorporation into food products, the gap still exists. Therefore, this study aims to develop a snack bar fortified with *G. salicornia* and evaluate its proximate composition, sensory properties, and cost-benefit ratio.

2. Materials and methods

2.1 Product description

The developed product is a fortified snack bar (Figure 1) with varying concentrations (0%, 5%, 10%, and 15%) of *G. salicornia* powder (Gs) added to various ingredients such as creamer, rolled oats, crispy rice, raisins, peanuts, and butter. Each snack bar weighed 52 g, conforming to the prevailing weight of commercially available snack bars.

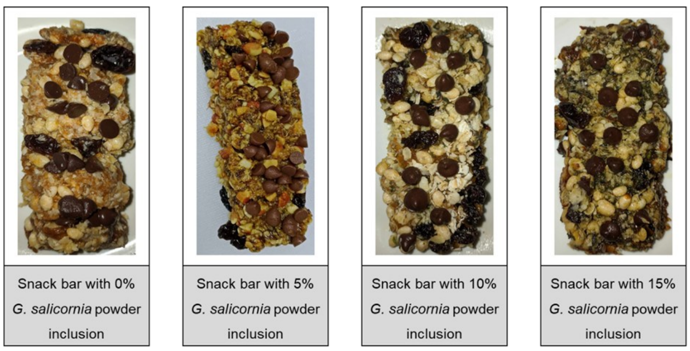

Figure 1. Fortified snack bars with different % inclusion of *G. salicornia.*

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2.2 Collection of Gracilaria salicornia

Permission was secured from Barangay Mukas and the Local Government Unit (LGU) of Kolambugan, Lanao del Norte, before the *G. salicornia* was collected from its collecting site. The collection of seaweed samples was done in the month of November 2023 at Mukas, Kolambugan, Lanao del Norte (8.10210°N and 123.84258°E). The seaweed was cut about 2-3 inches above the holdfast from the base where it attaches to the substrate. The harvested seaweed was placed inside an aseptic insulating container for transport. The total mass of the seaweed amounted to 4 kg, meeting the stipulated requirements essential for subsequent processing and analysis.

2.3 Preparation of Gracilaria salicornia powder

The collected *G. salicornia* was washed with distilled water at least 3 times to remove epiphytes and any other dirt attached to the seaweed. Cleaned *G. salicornia* was dehydrated at 70°C for 4 hours and 30 min. Dehydrated *G. salicornia* was pulverized using a pulverizer for 4 min, and it was placed in a well-sealed container at 25°C. After 5 to 10 min being pulverized, the powdered form of *G. salicornia* was added to other snack bars for the experiment. Aseptic conditions were observed and maintained throughout the preparation process.

2.4 Preparation of snack bar

Other snack bar ingredients, the rolled oats, crispy rice, and crushed peanuts, were toasted for 5 min in a medium-heated pan (149-204°C). For agglutination of the snack bar, the slurry was prepared in a stainless-steel container, and the ingredients (butter, creamer, and brown sugar) were heated and mixed with dry ingredients for 3 min until a uniform mixture was obtained. The formulation for each treatment is shown in Table 1. The mixture was placed on a slab and levelled with a roller pin, topping it with chocolate chips. After cooling for 1 h at 2°C, the mixture was cut into rectangular bars with a weight of 52 g. The snack bars were then chilled for 2 hours at 25°C. It was contained in a well-sealed and sterile container to minimize the addition of moisture content. Aseptic conditions were observed and maintained throughout the preparation of the snack bar.

2.5 Packaging of the final product

The products were kept in a ziplock plastic pouch to retain their quality. For the final product, each pouch contained one snack bar weighing 52 g. Samples were sent for sensory evaluation. The samples for laboratory analysis were packed, weighing 45 g for each treatment, and were sent immediately after packaging.

Table 1. Fortified snack bar formulations.

Treatment	Ingredients	% Inclusion	Quantity (g)
Control	Creamer	16	8.32
	Brown sugar	12	6.24
	Rolled oats	15	7.8
	Crispy rice	17	8.84
	Crushed peanuts	12	6.24
	Raisins	12	6.24
	Butter	14	7.28
	Chocolate chips	2	1.04
Treatment 1	*G. salicornia* powder	5	2.6
	Creamer	15.2	7.9
	Brown sugar	11.4	5.93
	Rolled oats	14.2	7.38
	Crispy rice	16.1	8.37
	Raisins	11.4	5.93
	Crushed peanuts	11.4	5.93
	Butter	13.3	6.92
	Chocolate chips	2	1.04
Treatment 2	*G. salicornia* powder	10	5.2
	Creamer	14.4	7.48
	Brown sugar	10.8	5.62
	Rolled oats	13.4	6.97
	Crispy rice	15.2	7.9
	Raisins	10.8	5.62
	Crushed peanuts	10.8	5.62
	Butter	12.6	6.55
	Chocolate chips	2	1.04
Treatment 3	*G. salicornia* powder	15	7.8
	Creamer	13.6	7.07
	Brown sugar	10.2	5.3
	Rolled oats	12.6	6.55
	Crispy Rice	14.3	7.44
	Raisins	10.2	5.3
	Crushed peanuts	10.2	5.3
	Butter	11.9	6.2
	Chocolate chips	2	1.04

2.6 Proximate analysis

Approximately 45 g of a snack bar for each treatment was sent to Mindanao State University at Naawan (MSUN) – Institute of Fisheries Research and Development (IFRD) Chemistry Laboratory for proximate analysis, 10 min after packaging of the samples.

2.6.1 Total ash

Total ash content was determined following AOAC Official Method 930.05.

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2.6.2 Moisture content

Moisture content was determined following ISO 17892-1:2014(E).

2.6.3 Crude protein content

Crude protein content was determined using the Kjeldahl method, following ISO 5983-1:2005.

2.6.4 Crude fat

Crude fat content was determined following AOAC Official Method 2003.05.

2.6.5 Crude fiber

Crude fiber content was determined following ISO 6865:2000.

2.6.6 Carbohydrates

The carbohydrates were determined by difference for carbohydrate content using this formula: Carbohydrates (%) = 100% - % (water content + protein content + ash content + fat content). This method assumes that all other components (water, protein, ash, and fat) account for the total weight of the sample, with the remaining percentage being attributed to carbohydrates.

2.7 Sensory evaluation

Sensory evaluation of the samples was performed using the consumer's acceptability or hedonic test 30 min after packaging. A total of 25 panellists with ages ranging from 20-26 years old were purposively selected and instructed to conduct sensory evaluation on the color, appearance, aroma, texture, taste, aftertaste, and overall appearance. Each parameter was scored on a scale ranging from 1 (dislike extremely) and 9 (like extremely). The sensory evaluation was done to prove that the fortified snack bar was fit for consumption. Panel-stationary was the set-up of the evaluation. Five grams for each sample were prepared. The samples were coded accordingly: 0% Gs (SN1), 5% Gs (SN2), 10% Gs (SN3), and 15% Gs (SN4).

2.8 Cost-benefit analysis

The total production cost in all treatments was evaluated by determining the total cost of direct materials (ingredients and packaging), direct labor (worker), and overhead costs (electricity and fuel). The purpose of this was to understand the cost breakdown associated with each treatment. Also, it helped calculate the profit margins for each treatment and assessed which one was more profitable and cost-effective. All costs were calculated in Philippine pesos (PhP) and subsequently converted to United States dollars (USD) for consistency and comparability.

2.9 Statistical analysis

The data from the proximate analysis and sensory evaluations were analysed using One-Way Analysis of Variance (ANOVA) to determine if there were significant differences in treatment at a 95% confidence level. It was followed by post hoc using Tukey's HSD Test to compare treatments that are significantly different. The data were run using SPSS IBM software. The standard error of the means (SEM) was also obtained and reflected. The result of sensory evaluation was plotted using a radar-filled chart to determine the most acceptable and most preferred formulation.

3. Results and discussion

Proximate composition (Table 2) showed that among the treatments, snack bars with 15% Gs had the highest ash content (9.93%), while the 0% Gs had the lowest ash content (1.73%). In terms of moisture, 10% Gs had the highest content (11.75%), while the 5% Gs had the lowest content (9.53%). Moreover, the highest protein content was observed in 10% Gs (4.02%), while the lowest protein content was observed in 15% Gs (1.76%). Notable percentages of crude fat were also observed in the products, with 0% Gs obtaining the highest content (27.78%) and the 15% Gs obtaining the lowest (22.49%).

The result of this study revealed that 10% Gs had the highest crude fiber content (3.77%), while 5% Gs exhibited the lowest content (1.14%). Apart from that, the result for carbohydrates indicated that the 0% Gs had the highest carbohydrate content (55.05%), whereas the 10% Gs had the lowest content (45.19%).

3.1 Effect of Gracilaria salicornia powder on the proximate composition of snack bars

The first finding of the study revealed that there were no trends in the proximate composition of fortified snack

Table 2. Proximate composition of fortified snack bar from *G. salicornia.*

Sample Name	Ash (%)	Moisture (%)	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Carbohydrates (%)
0% Gs	1.73±0.15	11.14±0.07	2.85±0.02	27.78±0.03	1.44±0.30	55.05±0.02
5% Gs	3.94±0.04	9.53±0.19	3.32±0.01	27.67±0.04	1.14±0.06	54.42±0.02
10% Gs	9.21±0.23	11.75±0.06	4.02±0.01	26.06±0.02	3.77±0.03	45.19±0.05
15% Gs	9.93±0.17	11.56±0.20	1.76±0.03	22.49±0.04	3.28±0.13	50.95±0.02

Values are presented as mean±SEM. All values showed no statistically significant difference (p>0.05).

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bars as the quantity of Gs powder increased, with one notable exception in ash content. The increase in the quantity Gs powder in the snack bar had led to a positive increase in the ash content. This was due to salts and inorganic substituents, which also include metal salts and trace minerals such as potassium, sodium, calcium, magnesium, aluminum, iron, copper, and zinc present in the snack bars (Tabarsa *et al*., 2012; Lumbessy *et al*., 2019). As the concentration of Gs powder increased, so did the mineral content, resulting in a higher ash content in the snack bars.

Furthermore, appreciable amounts of carbohydrates, fats, and protein were quantified in the snack bars. Gs may have possibly contributed to the amount of carbohydrates quantified as it is a good source of these macronutrients, particularly in the form of agar and agarose (Chung *et al*., 2011). The total carbohydrates in the food product were not solely derived from the incorporation of snack bars. Other ingredients, such as sugar and chocolate chips, were also deemed to contribute to the overall carbohydrate content. The percentage of daily carbohydrate intake recommended by health professionals ranges from 45% to 65% of total daily calories, and this translates to about 225 to 325 g of carbohydrates if consuming a 2,000-calorie diet per day (Clemente-Suárez *et al*., 2022). Based on the maximum recommended intake of carbohydrates per day, 0% Gs, 5% Gs,10% Gs, and 15% Gs can provide percent daily values of 16.95%, 16.74%, 13.90%, and 15.68%, respectively. Additionally, traces of fibers were also found in the fortified snack bars, ranging from 1.44% to 3.77%. This is important in controlling blood sugar levels and lowering cholesterol (Clemente-Suarez *et al*., 2022).

The result of the ANOVA revealed that there was a significant difference ($p<0.05$) in the sensory properties of fortified snack bars. Specifically, the 0% Gs received significantly higher scores ($p<0.05$) in appearance (8±0.23), taste (8.04±0.18), texture (7.36±0.22), and aroma (7.72±0.23) compared to other treated samples, while 15% Gs appeared to have the lowest sensory scores in appearance (5.24±0.41), taste (4.2±0.38), texture (5.2±0.42), and aroma (6±0.49). Furthermore, regarding overall acceptability, the 0% Gs achieved a significantly higher ($p<0.05$) score of 8.12±0.14, indicating it was rated as 'like extremely', whereas the 5% Gs, 10% Gs, and 15% Gs obtained scores of 7.28±0.21, 5.36±0.33, and 4.88±0.43, respectively.

3.2 Effect of G. salicornia powder on the sensory attributes of snack bars

Figure 2 shows that among the samples evaluated, the 0% Gs was the most acceptable across all sensory attributes, including taste, texture, appearance, aroma, and overall acceptability. Following the 0% Gs, 5% Gs, and 10% Gs exhibited intermediate acceptability, while 15% Gs was rated as the least desirable. Consequently, significant differences in all sensory characteristics were found in the study. Preference for certain flavors, texture and ingredients in Filipino snacks and dishes, which may not include seaweed, could contribute to lower acceptance of products with seaweed derivatives. Filipino foods and confectionery are known for their unique flavors and ingredients, which may not traditionally incorporate seaweeds as prominently as in other countries like Japan, Korea, and China (Moss and McSweeney, 2021). For example, there are panelists who said that they did not like the snack bars with a higher % inclusion of Gs powder because of its very strong aroma and bitter flavor. The unfamiliarity of their senses to the snack foods with seaweed derivatives may have impacted how they rate the snack bars.

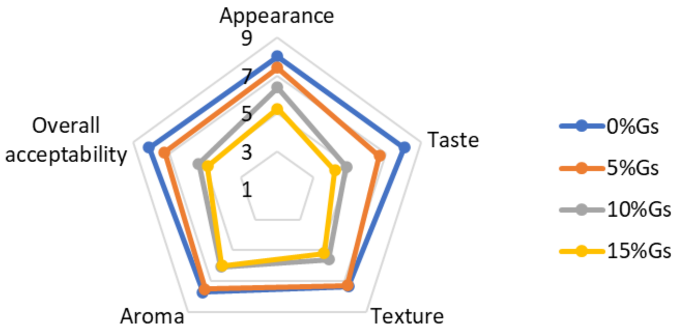

Figure 2. Sensory radar chart showing color, texture, taste, aroma, and overall acceptability of fortified snack bar with varying percentage of Gs powder inclusion.

3.3 Profitability of fortified snack bars

Based on the cost-benefit analysis, it can be deduced that all the formulations have immense potential to be introduced in the market due to their profitability. The advantage of these products in the market lies in their competitive prices. For instance, the fit bars in Philippine convenience stores are typically priced at USD 0.435 with a declared net weight of 22 g. Conversely, Nature Valley Chewy Fruit and Nut Granola Bars on Shopee Philippines are priced at USD 0.77. However, the fortified products examined in the study can be sold at even lower prices, based on their minimum selling price, despite having a declared net weight of 52 g. With the current cost-of-living crisis, consumers are prioritizing affordability and convenience when buying foods and snacks (Thiele *et al*., 2017).

The results in Table 3 illustrated that 10% Gs yielded the highest expected profit of USD 0.198 from the production of 11 snack bars. This was followed closely by 0% Gs and 5% Gs, both with expected profits of USD

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Table 3. Total costs, total benefits, and expected profit of fortified snack bars based on minimum selling price.

Snack bar formulation	Cost to produce	Minimum selling price	Number of units per formulation	Expected Profit per formulation
0% Gs	USD 0.291	USD 0.306	11	USD 0.165
5% Gs	USD 0.307	USD 0.322	11	USD 0.165
10% Gs	USD 0.292	USD 0.310	11	USD 0.198
15% Gs	USD 0.284	USD 0.297	11	USD 0.143

Table 4. Total cost, total benefit, and expected profit of fortified snack bars based on the price of commercial snack bars in the market.

Snack bar formulation	Cost to produce	Minimum selling price	Number of units per formulation	Expected Profit per formulation
0% Gs	USD 0.291	USD 0.435	11	USD 1.584
5% Gs	USD 0.307	USD 0.435	11	USD 1.408
10% Gs	USD 0.292	USD 0.435	11	USD 1.573
15% Gs	USD 0.283	USD 0.435	11	USD 1.672

0.165. Hence, 15% Gs had the lowest expected profit of USD 0.143. Moreover, Table 4 assumed that the selling price of the products was based on the price of commercial snack bars in the market. The projected profit in all product formulations was incredibly high. The highest expected profit was found in 15% Gs with a value of USD 1.672, followed by 0% Gs, 10% Gs, and 5% Gs with expected profits of USD 1.584, USD 1.573, and USD 1.408, respectively.

3.4 Interaction between different analyses

Proximate and sensory analyses reveal complex interactions between *G. salicornia* (Gs) powder inclusion and snack bar properties. Increasing Gs content raised ash levels due to the seaweed's mineral content (Tabarsa *et al*., 2012; Lumbessy *et al*., 2019). Protein content peaked at 10% Gs but declined at 15%, indicating a non-linear effect possibly due to varying protein concentrations in Gs powder.

From a sensory perspective, the results showed that snack bars containing 0% Gs were the most highly rated in all sensory attributes, including appearance (Figure 3), taste (Figure 4), texture (Figure 5), aroma (Figure 6), and overall acceptability (Figure 7). This suggests that while Gs powder contributes beneficial nutrients, higher concentrations, particularly 15%, resulted in lower sensory acceptability due to the strong aroma and bitter flavor associated with seaweed, which could be unfamiliar or off-putting to the target consumer group. The lower acceptability of the 15% Gs formulation could be attributed to the Filipino preference for more familiar flavors in snack foods, as noted in previous studies (Moss and McSweeney, 2021).

The profitability analysis further highlighted the economic potential of the fortified snack bars. Despite lower sensory scores for higher Gs concentrations, the product's competitive pricing, relative to other snack bars

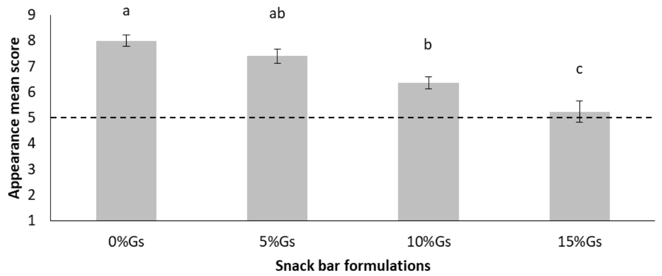

Figure 3. Appearance mean score of 0% Gs, 5% Gs, 10% Gs, and 15% Gs. Bars with different notations are statistically significantly different.

Figure 4. Taste mean score of 0% Gs, 5% Gs, 10% Gs, and 15% Gs. Bars with different notations are statistically significantly different.

in the market, makes it a viable option for commercialization. The 10% Gs formulation showed the highest expected profit from production, which suggests that a moderate concentration of Gs may provide an optimal balance between nutritional enhancement and market appeal. However, the profit margins for all formulations were relatively high, indicating that fortified snack bars, regardless of Gs concentration, have potential for market success, particularly if priced competitively in light of current economic conditions.

In summary, the interaction between the proximate composition, sensory properties, and profitability of the fortified snack bars demonstrates that while Gs powder can enhance the nutritional profile of the products, its higher concentrations may negatively affect sensory

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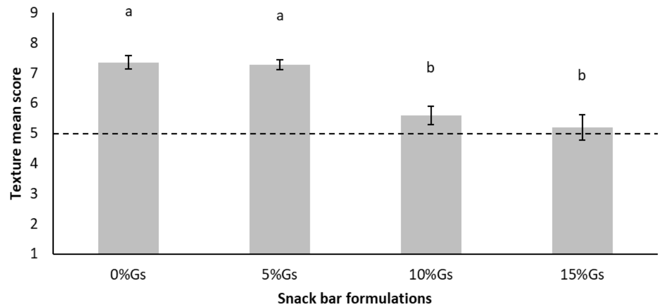

Figure 5. Texture mean score of 0% Gs, 5% Gs, 10% Gs, and 15% Gs. Bars with different notations are statistically significantly different.

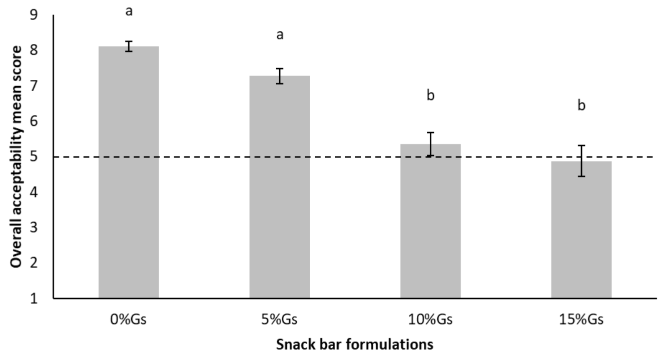

Figure 7. Overall acceptability mean score of 0% Gs, 5% Gs, 10% Gs, and 15% Gs. Bars with different notations are statistically significantly different.

acceptability. As such, a balanced approach to Gs inclusion is necessary to optimize both nutritional value and consumer preference. Additionally, the profitability analysis underscores the market potential for these products, suggesting that they could offer a cost-effective solution for addressing both nutritional deficiencies and the environmental challenges posed by invasive species like *G. salicornia*.

4. Conclusion

Based on the consolidated results, it can be concluded that 5% Gs and 10% Gs were the best formulations due to their high nutrient levels, better sensory acceptability scores, and high profitability. Both treatments were comparable to the control. Additionally, it can be recommended that the inclusion of Gs powder in a snack should not exceed more than 5% per serving to make it more acceptable to consumers. In terms of formulation, a larger quantity of binder – such as butter, creamer, and caramelized sugar – would be beneficial for the agglutination of the snack bar to maintain its compactness.

The inclusion of Gs powder in snack bars brought significant opportunities to the food industry. Its physicochemical characteristics confirm its nutritious value, providing a valuable option for health-conscious consumers. Moreover, sensory evaluation results indicate higher product consumer acceptability, contributing

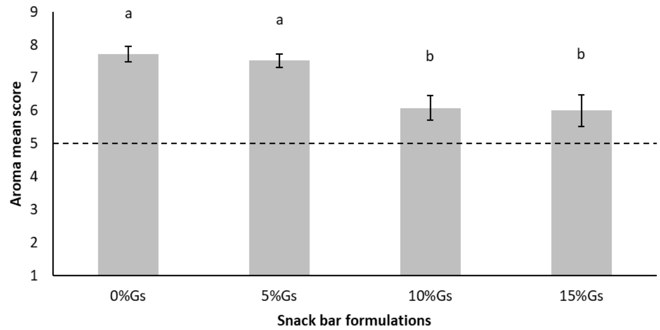

Figure 6. Aroma mean score of 0% Gs, 5% Gs, 10% Gs, and 15% Gs. Bars with different notations are statistically significantly different.

insights into the food industry concerning profitability. These characteristics may complement the large-scale production potential of the snack bar, establishing the Gs powder-added snack bar as a valuable addition to the food sector while minimizing its possible negative environmental impacts.

Conflicts of interest

The authors declare that they have no conflicts of interest regarding the research presented in this thesis. The research was conducted in an impartial manner, and there are no financial, personal, or professional relationships that could be construed as creating a conflict of interest with respect to the content of this manuscript.

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