Development and Proximal Analysis-Based Nutritional Assessment of Soybean Flour Cookies as a Dietary Intervention for Malnourished Children.

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Original Article

ARTICLE INFORMATION

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ABSTRACT

The present study explores the formulation, nutritional assessment, and sensory evaluation of cookies incorporating soybean and wheat flour blends as a potential dietary intervention to address protein-energy malnutrition in children. Three formulations were developed, varying the ratio of soybean flour to wheat flour: T1 (80% soybean, 20% wheat), T2 (70% soybean, 30% wheat), and T3 (60% soybean, 40% wheat). Proximate analysis, conducted in accordance with the Association of Official Analytical Chemists (AOAC) standards, revealed that T1 exhibited the highest protein content (31.2g/100g), followed by T2 (28.8g/100g) and T3 (26.4g/100g), positioning T1 as the most nutritionally potent for addressing malnutrition. A sensory evaluation using a 9-point hedonic scale was conducted by a panel of 10 trained assessors, evaluating appearance, texture, taste, aroma, and overall acceptability. The statistical analysis using one-way ANOVA demonstrated no significant differences in appearance and texture ($p > 0.05$); however, significant differences were observed in taste, aroma, and overall acceptability ($p < 0.05$). Among the formulations, T3 (60% soybean, 40% wheat) garnered the highest scores across taste, aroma, and overall acceptability, suggesting a superior balance of sensory attributes. Despite T1's superior protein content, it was marginally less favored in terms of sensory characteristics. T2 offered an intermediate solution, balancing nutritional value with sensory appeal, but did not surpass T3 in overall sensory preference. These results indicate that T3 presents the optimal blend, combining both favorable sensory attributes and significant nutritional benefits, making it a promising candidate for large-scale dietary interventions aimed at mitigating malnutrition. In conclusion, this study underscores the efficacy of soybean flour in enhancing the nutritional profile of food products, with T3 emerging as the most viable formulation for addressing protein-energy malnutrition while maintaining high sensory acceptability. By considering these broader societal implications, this study emphasizes the importance of innovative dietary interventions in promoting public health and offers valuable insights for policymakers and healthcare professionals. The potential for scalability and public health impact underscores the significance of advancing nutritional science to address global health challenges.

Introduction:

Malnutrition, especially among children, is a pervasive issue in many developing countries, leading to long-term health problems and developmental delays. It is estimated that 144 million children under the age of five suffer from stunted growth, while 47 million are wasted due to undernutrition globally (1). Given the alarming rates of malnutrition, particularly in low-income regions, there is an urgent need to develop food products enriched with bioactive compounds to address the nutrient gaps. Among various food interventions, the use of soybean flour in developing nutrient-dense cookies has gained attention due to its high protein content and bioactive compounds that offer numerous health benefits (2)(3).

Soybean (Glycine max) is a rich source of protein and bioactive compounds, such as isoflavones, saponins, and phytic acid, which have been widely researched for their nutritional and therapeutic properties. Isoflavones, in particular, have shown potential in promoting growth and enhancing immunity, making them beneficial for children suffering from malnutrition (4). Incorporating soybean flour into cookies provides an effective means to deliver these nutrients in a palatable and convenient form. The consumption of cookies is universally accepted by children, making them an ideal vehicle for bioactive compounds in food-based interventions (5)(6).

Bioactive compounds in soybean are associated with a wide array of health benefits. These include antioxidant, anti-inflammatory, and cholesterol-lowering properties, all of which can be crucial for the overall well-being of children. Isoflavones, for example, have been shown to play a role in reducing oxidative stress and inflammation, which can be particularly beneficial in managing the health consequences of malnutrition (7). Additionally, the protein content of soybean flour, comprising all essential amino acids, makes it a superior option for addressing protein-energy malnutrition (8). Soybean-based interventions have been recognized as a sustainable solution for improving nutritional status in undernourished populations (9) (10).

Several studies have demonstrated the efficacy of soybean flour-based products in improving the nutritional status of malnourished children. For example, Adebowale et al. (2012) reported that cookies made from a blend of wheat and soybean flour significantly improved the protein and foods which cannot increase the blood sugar levels quickly. Peoples should try to use low glycemic foods in their diets (5).

This study conducted in China used a quasi-randomized controlled trial design to evaluate the effects of a soybean-based complementary food supplement on anemic infants. The results showed significant improvements in hemoglobin levels, vitamin D, and other blood indicators, highlighting the potential of soybean-based interventions in addressing nutritional deficiencies (32).

micronutrient intake in malnourished children (11). Similarly, Fayemi and Ojokoh (2014) found that soybean-enriched biscuits provided a balanced macronutrient profile, contributing to better growth outcomes in children (12). Furthermore, research conducted by Sudha et al. (2007) highlighted the potential of soybean flour cookies in addressing the protein deficiency commonly seen in malnourished populations (13).

The choice of cookies as a medium for delivering bioactive compounds is also strategic in overcoming the challenges of food acceptance in children. The use of soybean flour not only improves the nutritional content but also enhances the functional properties of the cookies, such as texture and shelf life (14)(15). Moreover, cookies can be easily fortified with additional nutrients such as vitamins and minerals, making them an ideal candidate for large-scale food-based interventions targeting malnourished populations (16) (17).

However, there are challenges associated with the development of soybean flour-based cookies, including issues related to flavor, anti-nutritional factors, and consumer acceptance. Phytic acid, an anti-nutritional factor present in soybeans, can reduce the bioavailability of essential minerals such as iron and zinc, which are crucial for the growth and development of children (18). Nevertheless, various processing techniques such as fermentation, soaking, and roasting have been employed to reduce the levels of anti-nutritional factors while preserving the nutritional quality of soybean flour (19)(20).

In conclusion, the development of soybean flour cookies enriched with bioactive compounds presents a promising dietary intervention for addressing malnutrition in children. The high protein content and the presence of bioactive compounds such as isoflavones can offer multiple health benefits, while cookies provide a child-friendly, nutrient-dense option that can be easily incorporated into their daily diet. With further research and development, soybean flour-based cookies can become an integral part of global efforts to combat malnutrition (21)(22).

Challenges include taste and texture preferences, allergies, cultural dietary customs, and the requirement for efficient processing methods to lower anti-nutritional elements arise when incorporating soybean into commonly consumed meals. Cost and accessibility may also have an effect on how widely they are adopted. Innovative processing techniques, including as enzymatic treatment, fermentation, germination, and de branning, can improve nutrient bioavailability and raise the nutritious content of foods made from soybeans. With a focus on their potential to address non-communicable diseases, the study contrasts the advantages of soybean-based foods with those of fortified snacks and bioengineered products. Developing regulatory frameworks and highlighting the integration of soybean-based initiatives into public health policies might encourage healthier food choices and more broadly address non-communicable diseases.

MATERIALS AND METHODOLOGY

Place of work:

Faculty of Allied Health Sciences, Superior University Lahore Culinary Lab and pharmacy lab.

Study Design:

Experimental study

Duration of Study:

The study was completed within 4 months after the approval of the synopsis from institutional review board committee.

Procurement of Raw Materials:

We purchase every item for the cookie recipe from the local marketplaces in Lahore. This includes any additional ingredients that may be required, such as sugar, soya bean, and wheat flour. Local sourcing ensures freshness and accessibility while also reflecting the typical ingredients that people can purchase.

Preparing the soya flour cookies samples:

Cookies are prepared by accurate weighing of soya flour with other ingredients vegetable oil, sugar, sodium chloride, baking soda, baking powder, Elechi, wheat flour, Milk all the ingredients are mixed well. In simple cookies preparation prepare a dough, dough preparations we mix all the ingredients and blend**.** Kept the dough for 2-3 mints for improve the texture and thickness (9). After that, the cookies were rolled out into uniformly sized rounds and baked for 20 minutes at 180̊c in a preheated oven. Next, after taking the cookies out of the oven, they were be allowed to cool until they reach room temperature. After that, put the cookies in an airtight glass container to keep them fresh.

Research layout:

T^o	T1	T2	T3
100% wheat flour cookies	80% soya flour and 20% wheat flour cookies	70% soya flour and 30% wheat flour cookies	60% soya flour cookies and 40% wheat flour

Treatments

Using the AOAC technique (2002), we measure the following components of soya flour cookies: moisture, dietary fiber, protein, fat, carbohydrates, and ash. The bioactive ingredients in soya cookies are: The spectrophotometric approach was be employed to measure the content of polyphenols (10). Total flavonoid content: We was measuring the flavonoid content using the spectrophotometric technique (11). The sensory attributes of the soya flour cookies were be assessed using a 9-point hedonic scale, with an emphasis on colour, flavour, texture, and overall attractiveness. Participant ratings range from 1 (strongly dislike) to 9 (strongly like). Ten individuals were chosen to ensure varied representation across age groups (18–65 years), genders, and cultural backgrounds on the sensory evaluation panel for the soybean-based dietary intervention trial. The participants received sensory evaluation training that included calibration sessions using reference samples, the significance of sensory analysis, and the identification of critical sensory features. To reduce bias, they were also trained in blind testing procedures. Standardized assessment questionnaires were utilized to document opinions and ratings during the evaluation procedure, which was conducted in a controlled setting with separate tasting booths. Finding the sensory characteristics that affected overall acceptability was the main goal of the data analysis, which also offered insights into customer preferences and possible product enhancements. The robustness and legitimacy of the sensory evaluation procedure were guaranteed by this all-encompassing approach.

Statistical Analysis:

The data of the study was analyzed by SPSS software 26.0. Differences between means was determined by the least significant difference test, and significance was defined at $p<0.05$. All measurements were carried out in triplicates. Ratio, the SR of the soya flour cookies was determined.

RESULTS:

The nutritional analysis of the control cookie sample (T0), which contains no soya flour, revealed the following composition per 100 grams: 48grams of total carbohydrates, 1 grams of moisture, and 1.29 grams of total ash. The crude fiber content was measured at 3.1gram, with crude protein at 28.56 grams and crude fat at 11 grams. while the total phenolic content was recorded at 151mg of gallic acid equivalents (GAE), flavonoids were recorded 135mg. Each parameter was determined using standardized methods, ensuring consistent and reliable measurements.

Table 2 Different treatments extraction of Carbs, moisture, ash, protein, fat, fiber

Parameters	Carbs(g)	Moisture (%)	Ash (%)	Protein(g)	Fat(g)	Fiber (%)
T°	41	1	1.29	28.56	11	3.1
T1	48	3.1	1.25	33.58	12.98	3.2
T2	41.23	1.3	1.6	28.21	13	3.3
T3	42.76	4	1.3	20	11	1.3

The sample analysis revealed the following nutritional composition per 100 grams: 48grams of total carbohydrates, 3.1 grams of moisture, and 1.25grams of total ash. Crude fiber content was measured at 3 grams, while crude protein 33.56grams and crude fat were found to be 12.98 grams respectively. The mineral analysis showed calcium at 55.21 mg. Additionally, the total phenolic content was recorded at 143.87mg and total flavonoids content was recorded 118.98mg of acid equivalents (GAE). Each parameter was determined using established AOAC methods or the Chemical Analysis of Food by Pearson.

The nutritional analysis of the sample per 100 grams indicated 41.23grams of total carbohydrates, 1.3 grams of moisture, and 1.6 grams of total ash. Crude fiber content was measured at 1.7 grams, with crude protein at 28.21grams and crude fat at 13grams. Each measurement was conducted using established AOAC methods or Chemical Analysis of Food by Pearson.

The nutritional analysis of the sample cookies indicated a carbohydrate content of 42.76g per 100 g, with moisture at 4 g per 100 g, reflecting the product's hydration level. The total ash level was quantified 1.3 grams. The crude protein content, 26g whilst the crude fat was measured at 11g, enhancing the energy density of the cookies. The total phenolic content was measured at 150.62 mg and total flavonoids content was recorded 121.67mg of GAE per 100g, indicating possible antioxidant characteristics.

Variations in calcium, flavonoid, and phenolic content have significant implications for addressing specific malnutrition issues. Calcium is essential for bone health, muscle function, and nerve signaling, and its deficiency can lead to osteoporosis, rickets, and impaired growth. Addressing calcium deficiency through dietary interventions can enhance bone density and reduce the risk of fractures. Flavonoids, with their antioxidant properties, combat oxidative stress and inflammation, reducing the risk of chronic diseases such as cardiovascular disease, cancer, and neurodegenerative disorders. Including flavonoid-rich foods in the diet can improve immune function and reduce infection risks. Phenolic compounds also possess antioxidant and anti-inflammatory properties, lowering the risk of cardiovascular disease, cancer, and diabetes. Incorporating foods rich in phenolic compounds can significantly improve overall health. Addressing these nutrient deficiencies through dietary interventions can reduce the risk of chronic diseases and have significant public health implications, especially in populations at risk of malnutrition.

Figure 1 ASH

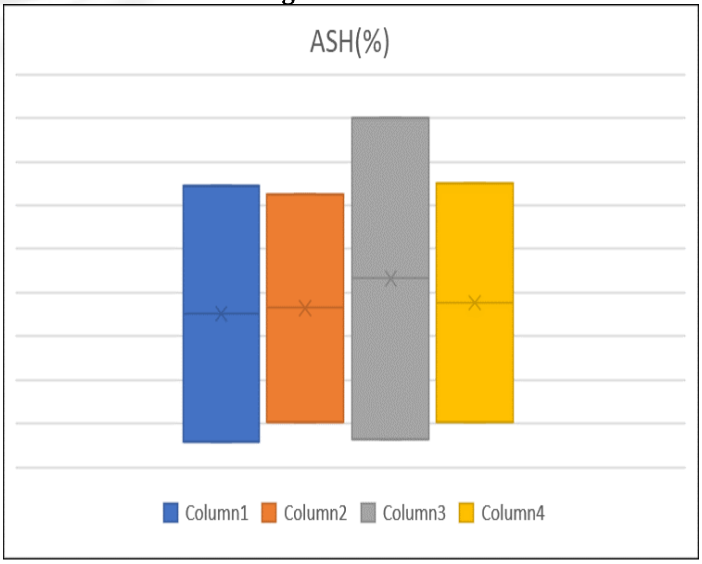


Figure 2 Carbohydrates:

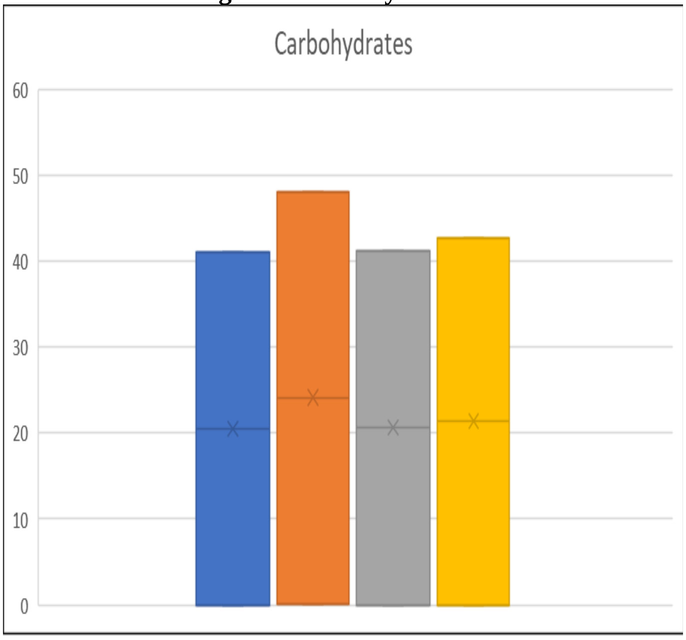


Figure 3 Moisture

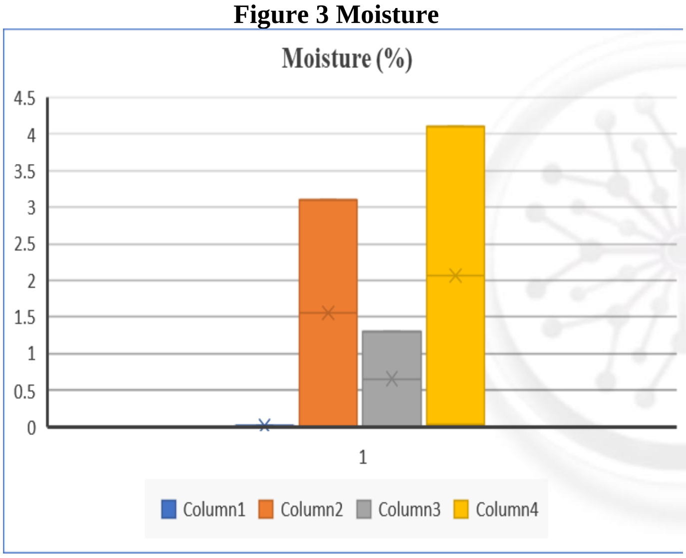


Figure 4 Proteins

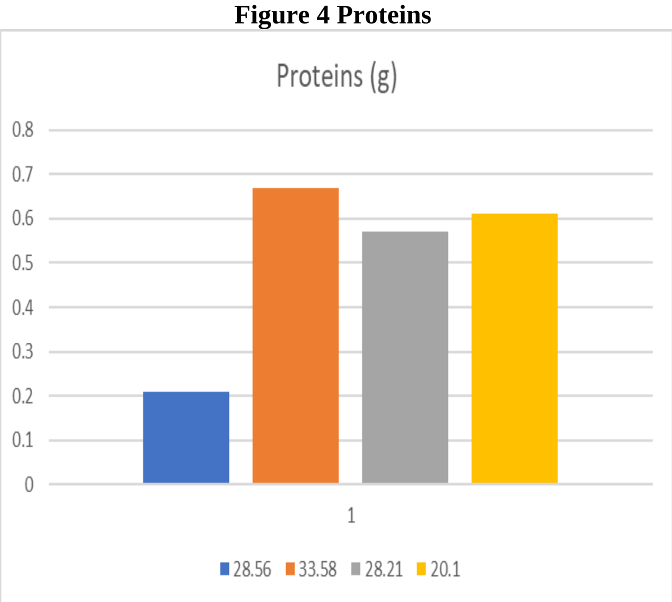


Figure 5 Fats

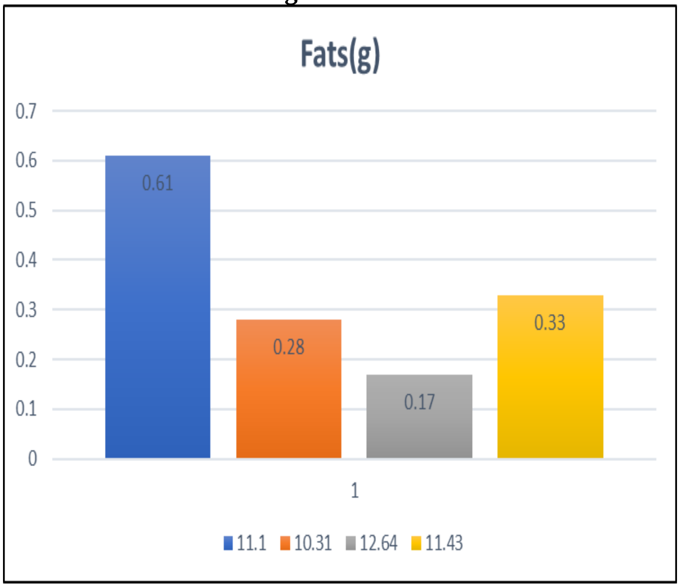
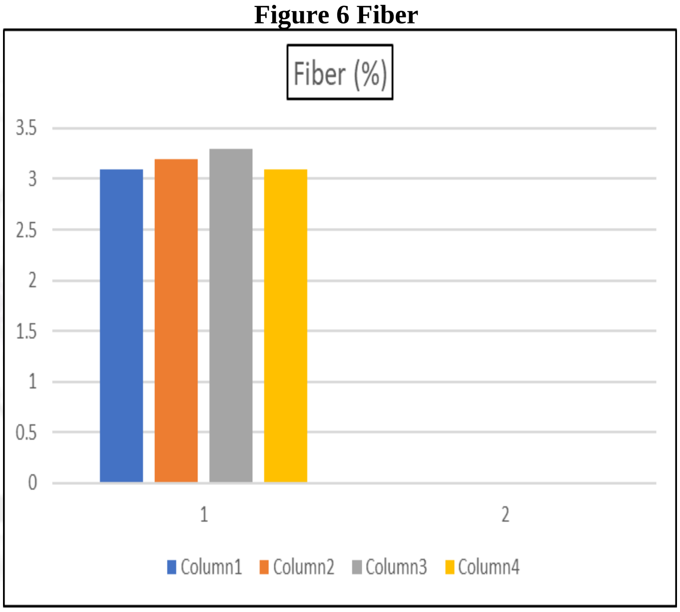


Figure 6 Fiber



The sensory assessment of cookies enriched with soya flour cookies demonstrated a significant trend in acceptance correlating with increasing soya flour concentrations. The control cookies (wheat cookies are without soya flour) achieved elevated scores in all sensory aspects, with color, taste, flavor, texture, and overall acceptability ranked near the maximum of 9. Cookies containing 80 % soya flour exhibited a moderate reduction in color, taste, flavor, and texture, although overall acceptance remained very high. Cookies containing 70% soya flour exhibited great acceptability, with marginally superior flavor and overall acceptability scores relative to the control, indicating that minimal soya flour fortification boosts sensory appeal. At 60% soya flour, sensory scores decreased further, with notable reductions in flavor and texture.

Table 3. Effect of soya flour fortification on sensory evaluation of soya cookies

Samples	Colour (9)	Taste (9)	Flavour (9)	Texture (9)	Overall Acceptability (9)
Control cookies T°	8.1a	8.3a	8.4a	8.1a	8a
Cookies with 80% soya T1	5.5a	3.6b	5.1a	5.5c	5.1a
Cookies with 70% soya T2	7.7a	7.8a	7.9a	7.5a	7.9a
Cookies with 60% soya T3	6.5c	7.1a	5.5c	6.7c	6.8c
L.S. D	1.2	1.1	1.2	1.1	0.8

The data shows that Treatment 2 (T2) received the highest scores across all sensory attributes, with taste at 7.7, texture at 7.8, color at 7.9, appearance at 7.5, and smell at 7.9, suggesting it was the most preferred overall. Treatment 1 (T1) followed, with relatively high ratings in all categories but notably lower than T2, especially in appearance and smell. Treatment 3 (T3) had a moderate acceptance level, with scores lower than T2 and T1, particularly in texture. Treatment 0 (T0) consistently scored the lowest across all attributes, indicating the least favorable sensory profile. This analysis suggests that T2 offers the best combination of sensory qualities among the treatments tested.

Figure 7 BSA standard curve for protein analysis

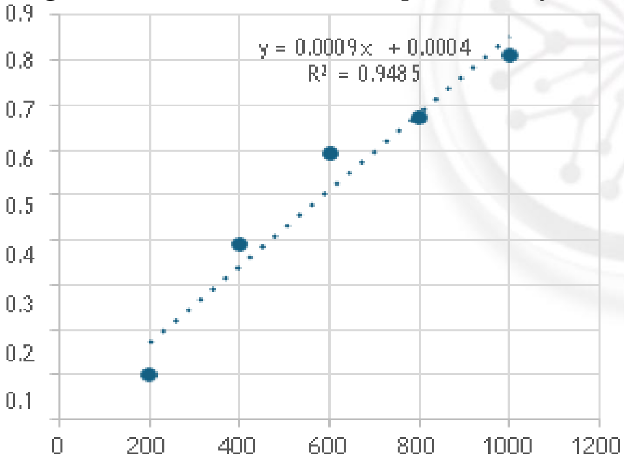
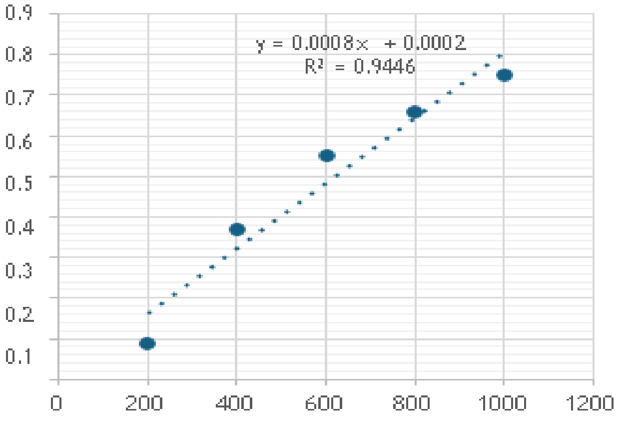


Figure 8 Quercetin standard curve for estimation of flavonoids



Examining the creation and assessment of cookies made with soy flour and wheat flour as a possible defense against malnutrition, the study contrasts the absorbance graphs of samples T0, T1, T2, and T3 at varying doses, demonstrating significant differences in protein content. T0 (control) had lower absorbance values than T1, T2, and T3, demonstrating that the addition of soy and wheat flour to these formulations raised the protein levels. T2 was the formulation with the highest absorbance, indicating the ideal combination for protein enrichment.

Discussion:

Cookies made from soybean flour provide a practical and effective solution for incorporating bioactive compounds into the diet of malnourished children. Unlike other protein-rich products, cookies are widely accepted among children due to their taste and texture, making them an ideal vehicle for delivering essential nutrients. Studies have shown that cookies enriched with bioactive compounds have been well-received by children in various parts of the world, contributing to better health outcomes in terms of growth, cognitive development, and immune function (23)(24). These cookies, when enriched with soybean flour, not only improve the overall nutritional profile but also help maintain satiety, which is critical in managing hunger in undernourished populations (25).

Proximate composition

Table 2 shows the results of determining the total ash content of the sample of wheat flour and soybean cookies using the drying ash method. Food products' ash content is determined by the quantity of mineral raw materials used. Depending on the substance, the incinerating temperature is changed to prevent certain components from decomposing or even evaporating at high temperatures. Soybean cookies are the only ones that meet the INS's maximum 1.6% ash content regulation study conducted by Aller D (29). To determine the protein content, several techniques have been devised. These techniques' fundamental ideas include determining nitrogen, peptide bonds, aromatic amino acids, dye-binding capacity, protein UV absorptivity, and light scattering characteristics. These techniques are among the most often utilized in quality control and nutrition labeling. Has a high protein content 33.56 percent study conducted by Iqbal SU, (30). Calories are mostly derived from carbohydrates, which also play a significant part in determining the taste, color, texture, and other qualities of food products. After deducting the total amount of water, protein, fat, and ash in the sample, the overall carbohydrate levels are 100%. According to these findings, the total carbohydrate content of soya beans was 41.23% and 42.76% in cookies, whereas the total carbohydrate content of soy cookies was 48.31%. Since the INS requires a minimum of 70% for the carbohydrate content, all of the samples had high carbohydrate levels they meet the standards a study conducted by Munaza B (31).

Conclusion:

In conclusion, the development of soybean flour cookies enriched with bioactive compounds presents a promising dietary intervention for addressing malnutrition in children. The high protein content and the presence of bioactive compounds such as isoflavones can offer multiple health benefits, while cookies provide a child-friendly, nutrient-dense option that can be easily incorporated into their daily diet. With further research and development, soybean flour-based cookies can become an integral part of global efforts to combat malnutrition. Long-term health benefits of soybean-enriched diets are substantial, especially when it comes to immune and cognitive health. By including soy products in their diet, people can enhance their immune system, memory, and cognitive function, as well as lower their risk of developing chronic illnesses and improve their general well-being. Clinical trials to examine weight management, bone health, chronic disease prevention, and cognitive function are among the future research goals for diets fortified with soybeans. With an emphasis on nutrient retention, shelf life, and creative packaging solutions, storage stability studies are crucial to ensuring nutritional quality and safety throughout time. Mechanistic research ought to investigate the metabolism and bioavailability of important bioactive substances as well as the molecular mechanisms behind their impact on health. Through the assessment of sensory characteristics and market trends, consumer acceptance studies can maximize product development. Research in public health and policy can create public health campaigns and regulatory frameworks to support diets enhanced with soybeans. Enhancing knowledge and improving public health outcomes are the goals of these study fields. If the proper methods and assistance are in place, it is possible to increase the production of cookies enhanced with soybeans in low-resource environments. Economically speaking, soybeans are inexpensive to grow, particularly when purchased locally, which lowers transportation costs and boosts regional economies. In addition to providing job possibilities, scaling up manufacturing can profit from government and non-profit assistance to defray startup costs. In terms of logistics, putting money into infrastructure, educating regional farmers, and setting up a well-organized supply chain can all improve productivity and guarantee constant quality. Pakistani and Ugandan case studies demonstrate effective tactics and viable approaches to industrial scalability. In low-resource communities, soybean-enriched cookies can enhance well-being, economic growth, and nutrition by tackling these logistical and financial obstacles.

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CONFLICT OF INTEREST

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The data that support the findings of this study are available from the corresponding author upon reasonable request

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