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Development And Quality Evaluation of *Gymnema sylvestre* Leaves Powder Supplemented Nutrient-Dense Flaxseed-Based Bars

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Abstract

Diabetes mellitus is a protracted metabolic disease characterized by increased blood glucose and insulin deficiency affecting more than 33 million people in Pakistan. To design a functional food product to modulate glycemia, nutrient-rich flaxseed-based snack bars were prepared by enriching Gymnema sylvestre leaf powder, a plant having hypoglycemic and antioxidant activity. Six formulations (T0-T5) were made by replacing flaxseed flour (100-95%) successively with G. sylvestre powder (0-5%). T0 was the control, whereas T1-T5 had 1%, 2%, 3%, 4%, and 5% G. sylvestre powder, respectively. The products were evaluated for proximate composition, mineral content, total phenolic content, antioxidant activity and sensory properties. Compared with the control, the concentration of G. sylvestre slightly increased moisture (12.36-12.52%) and ash (1.94-2.22%), whereas it increased fiber (7.15-7.33%), antioxidant activity (60.57-61.59%) and minerals, especially calcium (104.8-169.2 mg/100 g) and iron (2.79-4.35 mg/100 g). Sensory analysis revealed that bars with 3% of G. sylvestre powder (T3) possessed better texture, flavor, and acceptability. The conclusion of this study is that modest supplementation with Gymnema sylvestre enhances the nutritional and functional value of flaxseed-based bars, making it a healthy dietary choice for diabetics as well as health-conscious people.

1. Introduction

Diabetes mellitus is a long-term endocrine disease involving insulin deficiency or defective insulin function, which deranges carbohydrate metabolism and causes long-term multiorgan complications. There are about 537 million adults with diabetes worldwide and this is estimated to increase to 784 million by the year 2045. Pakistan is third behind China and India and has an estimated 33 million persons with diabetes (IDF, 2021). Etiological factors include genetics, physical inactivity, dietary imbalance, side effects of drugs, hormonal changes and psychogenic stress. Though traditional oral hypoglycemic drugs like sulfonylureas and biguanides are effective in managing blood glucose levels, they come with side effects. This has resulted in growing interest in natural products and functional foods with fewer side effects (Tiwari *et al.,* 2014).

Herbal remedies have long been employed in traditional medicine systems, including Ayurveda, Traditional Chinese Medicine and Unani medicine, for diabetes management. Ayurveda, originating in India over 3,000 years ago, describes several plants with antidiabetic properties. Traditional Chinese Medicine focuses on the harmony of

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yin and yang and the movement of vital energy, suggesting herbs like bitter melon (*Momordica charantia*), ginseng (*Panax ginseng*) and berberine plants to increase insulin sensitivity and lower blood glucose concentrations. Likewise, Unani medicine recommends fenugreek (*Trigonella foenum-graecum*), black seed (*Nigella sativa*), and Indian kino tree (*Pterocarpus marsupium*) that modulate glycemia via soluble fiber, antioxidant effect and flavonoids with insulin-like activity.

Among the herbs, *Gymnema sylvestre* (Asclepiadaceae) or "Gurmar booti" is a perennial climber of woody nature commonly cultivated in Azad Jammu and Kashmir (Shaukat *et al.,* 2021; Thakur *et al.,* 2012). It contains gymnemic acids, flavonoids, saponins and cinnamic acids that reduce intestinal glucose absorption, stimulate pancreatic islet regeneration and block the perception of sweet taste, thereby controlling sugar desire (Porchezhian and Dobriyal, 2003; Laha and Paul, 2019). Beyond its antidiabetic effect, *G. sylvestre* possesses antioxidant, anti-inflammatory and cardioprotective functions and hence is a versatile herb for metabolic syndrome, obesity and cardiovascular complications commonly associated with diabetes.

Flaxseed (*Linum usitatissimum*) is a low-glycemic (<55) functional food that includes alpha-linolenic acid (35-67%), dietary fiber (22-26%), protein (20-25%), lignans and minerals like calcium and magnesium (Qamar, 2019; Khouryieh and Aramouni, 2013). The intake of flaxseed enhances glycemic control, lipid metabolism and gastrointestinal health. Pakistan stands at number 28 in the world in terms of flaxseed production, with an annual production of about 2285 tonnes. The blending of *G. sylvestre* with flaxseed ensures synergistic action, which offers antidiabetic, antioxidant and cardio protective effects.

Current lifestyles of regular skipping meals and breakfast skipping enhance insulin resistance and risk of acquiring diabetes mellitus (Pereira *et al*., 2011). Snack bars are an easily accessible, ready-to-consume product but tend to be energy-dense with low nutrients. Formulation of nutrient-dense bars, fortified with *G. sylvestre* and flaxseed addresses this issue by presenting a tasty, functional and health-enhancing option, providing bioactive compounds, fiber and essential nutrients in an easily consumable format. Thus, the aims of the present study were to (1) formulate nutrient-rich flaxseed-based bars enriched with *G. sylvestre* leaf powder, (2) analyze their nutritional value, mineral profile, antioxidant capacity, and quality traits, and (3) determine sensory characteristics and consumer acceptability.

2. Materials and Methods

2.1. Procurement of raw materials

G. sylvestre leaves and flaxseeds were procured from local markets in Faisalabad. Dates, rolled oats, walnuts, almonds and dried coconut were purchased from City Cash and Carry, Faisalabad.

2.2. Preparation of raw materials

All raw materials were manually cleaned. *G. sylvestre* leaves and dates were washed and sun-dried; dates were de-seeded and ground into a fine paste. Flaxseed, rolled oats, walnuts, almonds and dried coconut were lightly roasted at medium heat for 1 minute. *Gymnema* leaves and flaxseeds were ground into powder and stored in airtight containers for further analysis.

2.3. Analysis of *G. sylvestre* leaves powder and flaxseed powder

2.3.1. Proximate analysis

Moisture, ash, crude protein, crude fat, crude fiber and nitrogen-free extract (NFE) were determined following AACC (2010). Moisture was measured by oven-drying 15 g of sample at 105°C for 24 h. Ash content was determined by incinerating 3 g of sample at 550°C in a muffle furnace (AOAC, 2023). Crude protein was analyzed via the Kjeldahl method. Crude fat was extracted using the Soxhlet apparatus, and crude fiber was estimated following AOAC (2023). NFE was calculated by difference.

2.3.2. Mineral determination

Iron, magnesium, calcium, zinc, potassium, and sodium were quantified using atomic absorption spectrophotometry after wet digestion with nitric, hydrofluoric, and hydrochloric acids (AOAC, 2023).

2.3.3. Total phenolic content

Total phenolic content (TPC) was determined by the Folin-Ciocalteu method. Briefly, 1 g of sample was extracted with 10 mL of 80% methanol in an ultrasonic bath for 15 min, centrifuged, filtered, reacted with Folin-Ciocalteu reagent and sodium carbonate, incubated for 2 h, and the absorbance measured at 765 nm. Results were expressed as mg gallic acid equivalents per 100 g (mg GAE/100 g).

2.3.4. Antioxidant potential

Antioxidant activity was evaluated using DPPH radical scavenging assay (Sharma and Gujral, 2014). Samples (1 g) were extracted with 10 mL of 80% methanol for 2 h, mixed with DPPH solution, incubated at 27°C for 30 min, and absorbance was measured at 517 nm. Radical scavenging activity (%) was calculated as:

$$\%\text{RSA} = \frac{\text{A control} - \text{A sample} \times 100}{\text{A control}}$$

2.4. Preparation of nutrient-dense bars

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Nutrient-dense bars were prepared following a modified method of Khouryieh and Aramouni (2013). Dates paste was slightly heated and mixed with rolled oats, walnuts, almonds, and dried coconut. Flaxseed flour was progressively replaced with *G. sylvestre* powder to produce six treatments demonstrated in Table 1 and Figure 1,2.

Table 1. The treatment plan used for nutrient-dense flaxseed-based bars

Treatments	Flaxseed powder (%)	Gymnema leaves powder (%)
T_0	100	-
T_1	99	1
T_2	98	2
T_3	97	3
T_4	96	4
T_5	95	5

T_0= 100% flaxseed flour act as control; T_1 = 96% flaxseed flour, 04% seed mix; T_2 = 92% flaxseed flour, 08% seed mix; T_3 = 88% flaxseed flour, 12% seed mix; T_4 = 84% flaxseed flour, 16% seed mix; T_5 = 80% flaxseed flour, 20% seed mix.

2.5. Analysis of nutrient-dense flaxseed-based bars

2.5.1. Compositional analysis

The proximate and mineral composition of the nutrient-dense bars was evaluated using standard methods (AACC, 2010; AOAC, 2023). Moisture, ash, crude protein, crude fat, crude fiber and nitrogen-free extract were measured, while minerals including calcium, magnesium, potassium, sodium, iron and zinc were quantified following wet digestion and atomic absorption spectrophotometry.

2.5.2. Phytochemical analysis

Total phenolic content (TPC) and antioxidant activity were determined using established protocols (Behera, 2019).

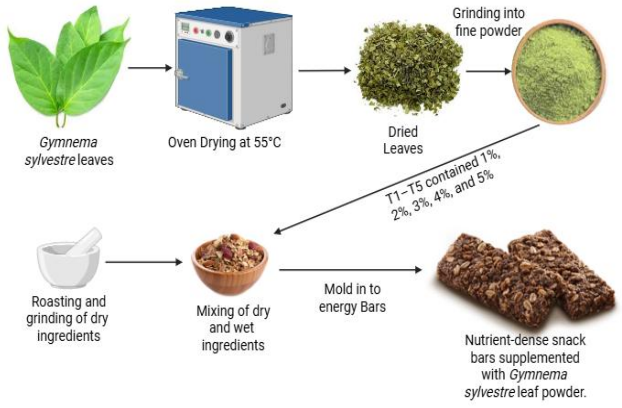


Figure 1. Flow diagram for the preparation of nutrient-dense snack bars supplemented with *Gymnema sylvestre* leaf powder.

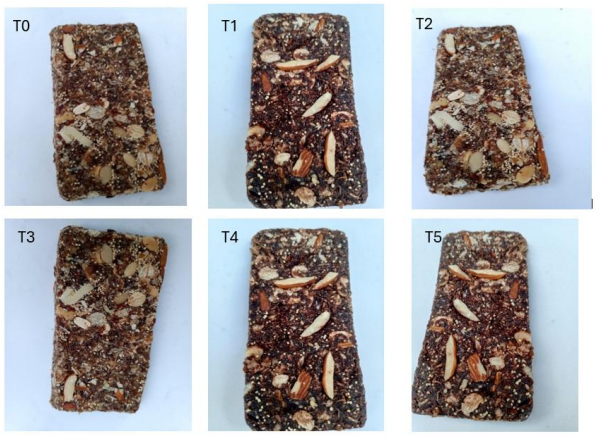


Figure 2. Preparation of different formulations of nutrient-dense bars

TPC was expressed as mg gallic acid equivalents per 100 g, and antioxidant potential was measured using the DPPH radical scavenging assay.

2.5.3. Color analysis

The color of the bars was measured using a colorimeter (Majid, 2022). Ground bar samples were evenly spread on petri plates to ensure consistent light reflection. L*, a* and b* values were recorded to quantify lightness, redness/greenness, and yellowness/blueness, respectively.

2.5.4. Texture analysis

Hardness was evaluated using a TA XT plus texture analyzer (Stable Microsystems, UK) with a 5 kg load cell. A three-point bending test was performed with a 5.0 mm stainless-steel punch probe, pretest, test and post-test speeds of 10, 2 and 10 mm/s, respectively. The maximum force required to break the bars was determined from force-time curves, with five measurements taken per treatment.

2.5.5. Sensory evaluation

A 9-point hedonic scale (Meilgard *et al*., 2016) was used to assess appearance, taste, aroma, texture, cohesiveness, mouthfeel and overall acceptability. Panelists, including NIFSAT faculty and postgraduate students, evaluated samples in randomized order, with water provided to cleanse the palate between samples.

2.6. Statistical Analysis

All experimental data were analyzed using one-way ANOVA under a Completely Randomized Design (CRD) to determine significant differences among treatments (Montgomery, 2017).

3. Results and Discussion

3.1. Flaxseed and *G. sylvestre* powders analysis

3.1.1. Proximate analysis of flaxseed and *G. sylvestre* powder

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Table 2. Proximate composition of flaxseed and *G. sylvestre* powder (%)

Proximate composition	Flaxseed flour	Gymnema powder
Moisture	4.13±0.16	7.4±0.15
Ash	3.28±0.17	9.5 ± 0.23
Crude fiber	8.12±0.32	11.6 ± 2.23
Crude fat	38.48±2.31	5.6 ± 0.12
Crude protein	20.17±0.85	10.5 ± 1.22
NFE	25.82±1.21	55.4 ± 3.10

Table 3. Mineral composition of flaxseed and *G. sylvestre* powder (mg/100g)

Proximate composition	Flaxseed flour	Gymnema powder
Sodium (Na)	29.12±1.60	2.70±0.05
Potassium (K)	827.3±33.09	21.80 ± 0.44
Iron (Fe)	6.11±0.24	25 ± 0.74
Zinc (Zn)	4.13±0.22	21.1 ± 0.44
Magnesium (Mg)	422.50±15.2	593.1 ± 11.85
Calcium (Ca)	236.40±7.26	1560 ± 30.85

Table 4. Phytochemical analysis of flaxseed and *G. sylvestre* powders

Antioxidant properties	Flaxseed flour	Gymnema powder
TPC (mg GAE/100g)	92.64±0.21	0.563±0.01
DPPH (%)	47.67±0.40	56.9±1.363

The proximate composition of flaxseed and *G. sylvestre* powder is shown in Table 2. Flaxseed flour had 4.13% moisture, 3.28% ash, 8.12% crude fiber, 38.48% crude fat, 20.27% protein and 25.82% nitrogen-free extract (NFE). These findings are in agreement with Mueller *et al.* (2010), 7.4% moisture, 23.4% protein, 45.2% fat and 3.5% ash in flaxseed; Coskuner and Karababa (2007) of 4-8% moisture, 20-25% protein, 30-40% fat, and 3-4% ash; and Singh *et al.* (2011), 6.5% moisture, 37.1% fat, 20.3% protein and 4.8% fiber. Moisture impacts storage stability, while protein and fat have an impact on nutritional and functional quality.

G. sylvestre powder had 7.4% moisture, 9.5% ash, 11.6% crude fiber, 5.6% crude fat, 10.5% protein and 55.4% NFE. The results are consistent with Sharma *et al.* (2021), reporting 7.38% moisture, 9.49% ash, 10.94% protein, 5.80% fat and 11.5% crude fiber, attesting to the feasibility of *G. sylvestre* powders as a functional ingredient in nutrient-dense formulation.

3.1.2. Mineral analysis

The mineral composition of flaxseed and *G. sylvestre* powder is presented in Table 3. The flaxseed flour had 29.12 mg sodium, 827.3 mg potassium, 6.11 mg iron, 422.50 mg magnesium, 236.40 mg calcium and 4.13 mg zinc per 100 g. These findings are consistent with Bernacchia *et al.* (2014), who analyzed 27 mg sodium, 831 mg potassium, 5 mg iron, 420 mg magnesium, 235 mg calcium, and 4 mg zinc in 100 g of flaxseed. Hussain *et al.* (2008) also found equivalent values of 30.12 mg sodium, 822.10 mg potassium, 6.01 mg iron, 419.2 mg magnesium, 231.5 mg calcium and 4.43 mg zinc per 100 g.

G. sylvestre powder had 2.70 mg sodium, 21.80 mg potassium, 25 mg of iron, 593.1 mg of magnesium, 1560.63 mg calcium, and 21.1 mg of zinc per 100 g, indicating that it is a good source of important minerals. The findings are consistent with Dey and Khaled (2015), which showed 3 mg sodium, 22 mg potassium, 19.26 mg iron, 604.8 mg magnesium, 1580 mg calcium and 24.02 mg zinc per 100 g. *G. sylvestre* powder surprisingly had unusually high amounts of calcium and magnesium, indicating that it is apt as a functional ingredient for nutrient-dense applications.

3.1.3. Phytochemical analysis

The total phenolic content (TPC) and antioxidant activity of flaxseed and *G. sylvestre* powders are given in Table 4. Flaxseed showed a TPC value of 92.64 mg GAE/100 g, while the *G. sylvestre* powders had 0.563 mg GAE/100 g. With regard to antioxidant activity, flaxseed revealed 47.67% DPPH free radical scavenging activity, while the *G. sylvestre* powders revealed 56.9%. The findings agree with Rahman *et al.* (2014), who reported *G. sylvestre* TPC of 0.536 mg GAE/100 g, and Brodowska *et al.* (2014), who revealed 98.8 mg GAE/100 g TPC in flaxseed extracts. The results show that the two flaxseed and *G. sylvestre* powders are rich in bioactive compounds, with *G. sylvestre* powders having greater antioxidant activity in spite of their lesser phenolic content, validating their application in functional, nutrient-rich formulations.

3.2. Analysis of nutrient-dense bars

3.2.1. Proximate analysis

Proximate nutrient composition of the nutrient-rich flaxseed-based bars is presented in Figure 3. Crude fiber content increased progressively from 7.15% in control (T_0) to 7.33% in the highest-performing treatment (T_5), indicating the desirable impact of *G. sylvestre* powder on fiber enrichment. Crude protein was slightly reduced with T_0 (10.36%) being slightly higher than T_5 (9.89%), indicating slight dilution caused by the incorporation of plant material. In the same manner, crude fat content reduced significantly from 17.24% at T_0 to 15.58% at T_5, whereas the nitrogen-free extract (NFE) revealed constant increase from 50.91% to 52.42%, reflecting better carbohydrate availability. These results reveal that *G. sylvestre* supplementation improves the fiber and carbohydrate fractions with slight reduction in fat and protein content. These findings are consistent with existing results. Prabha *et al.* (2019) found elevated fat content

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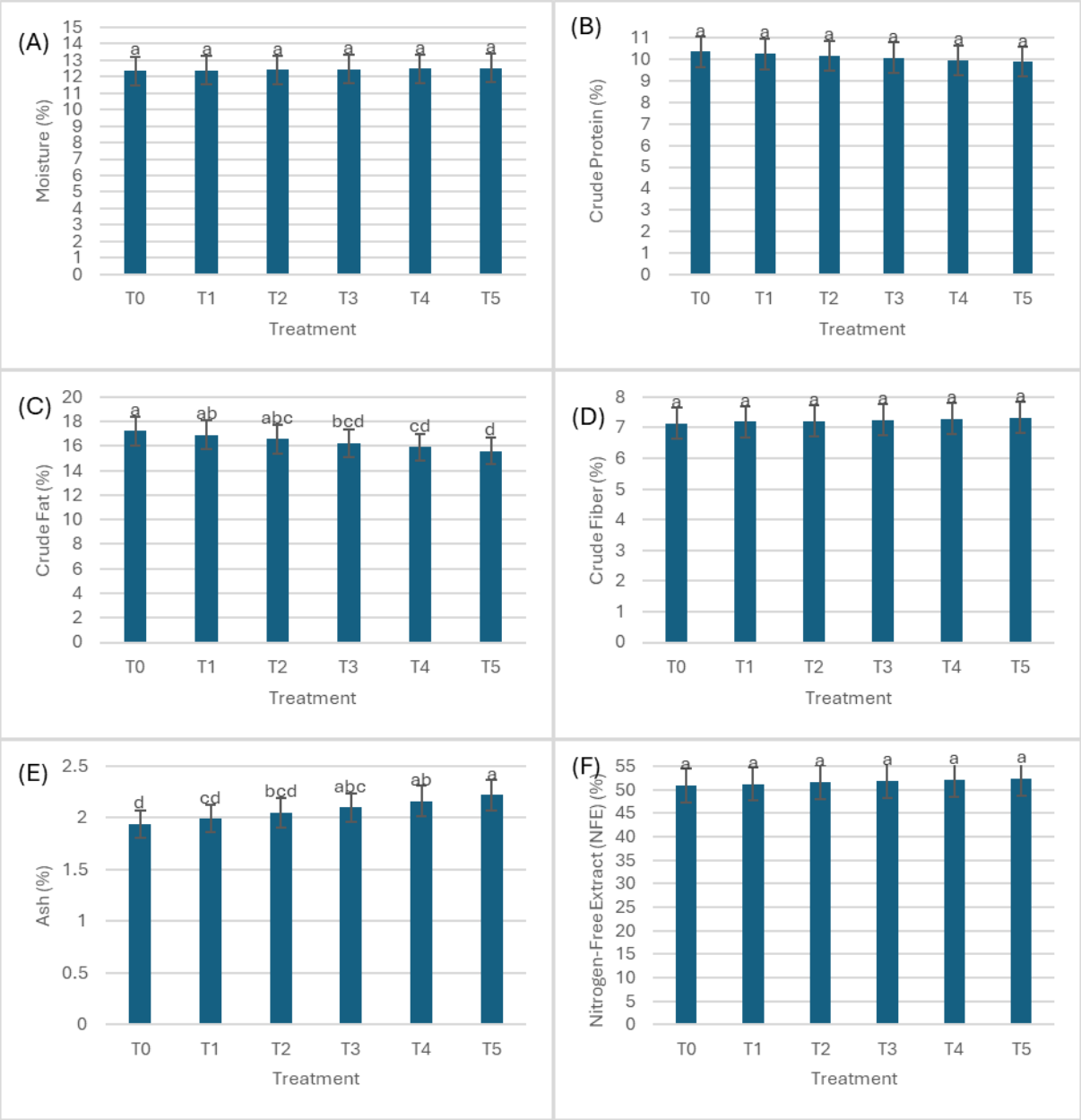


Figure 3. Proximate composition (Moisture, Crude Protein, Crude Fat, Crude Fiber, Ash, NFE) of various treatments (T_0-T_5). Various superscript letters represent significant differences ($p < 0.05$) among treatments.

(9.18%) in *Gymnema*-fortified bread relative to control (8.63%), and Indumathi *et al.* (2021) found large increases in moisture (3.65-3.97%), ash (1.76-1.84%) and fiber (8.72-10.33%) in multigrain cookies fortified with *Gymnema* leaf powder. These types of results together verify that *G. sylvestre* fortification enhances the nutritional and functional properties of food items, affirming its potential utility in creating high-fiber, health-focused products.

3.2.2. Mineral analysis

The mineral content of the nutrient-rich flaxseed-based bars was remarkably influenced by the addition of *G. sylvestre* powder. As evident from Figure 4, sodium was reduced from 6.65 mg/100 g in T_0 to 5.15 mg/100 g in T_5, which means *Gymnema* addition had a slight effect in lowering sodium content. Likewise, potassium declined slightly from 548.37 mg/100 g in T_0 to 507.73 mg/100 g in T_5. Conversely, calcium levels went up significantly from 104.87 mg/100 g at T_0 to 169.21 mg/100 g at T_5, with T_3 at

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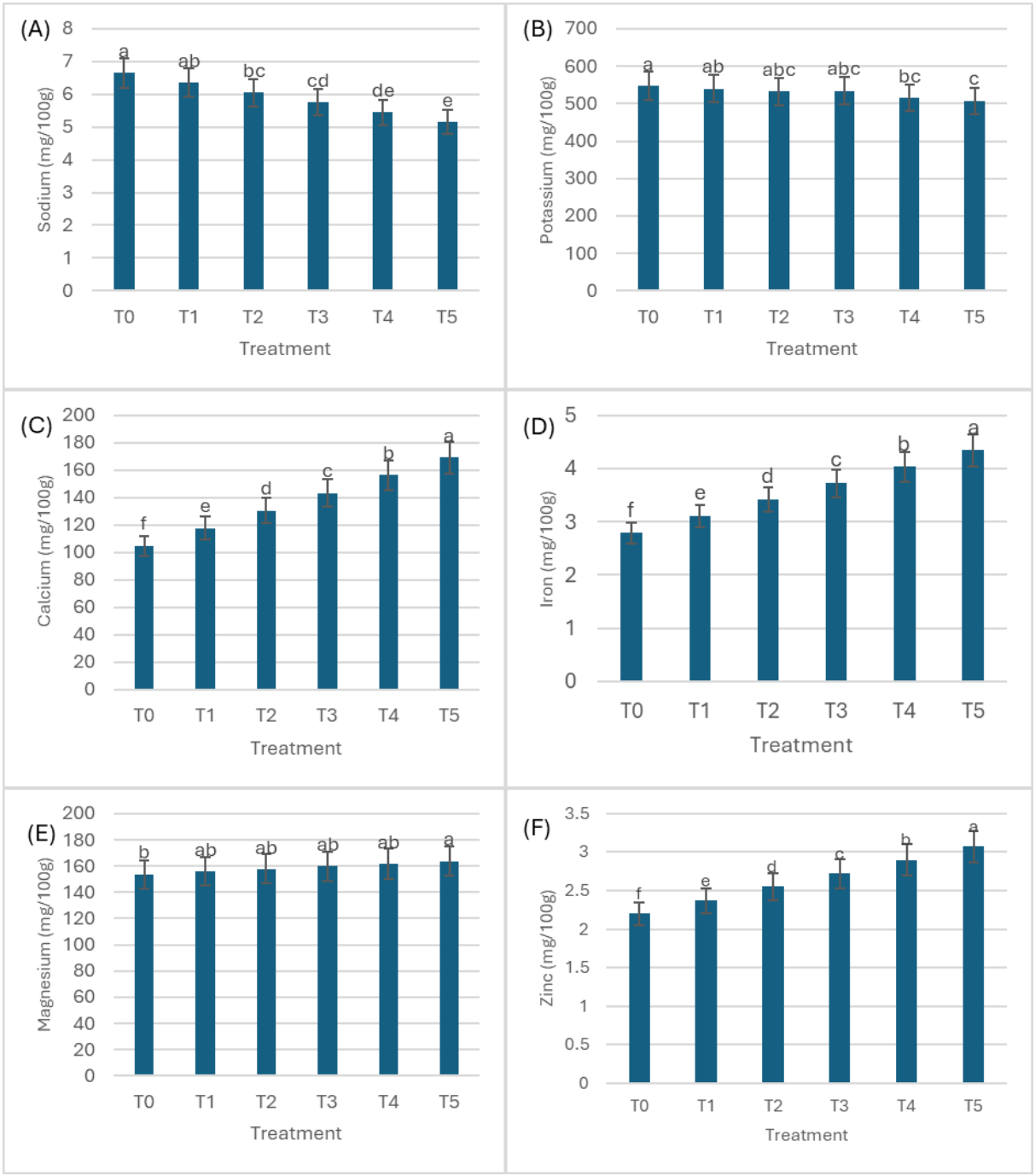


Figure 4. Mineral content (Sodium, Potassium, Calcium, Iron, Magnesium, Zinc) of different treatments (T_0-T_5). Different superscript letters indicate significant differences ($p < 0.05$) among treatments.

142.44 mg/100 g presenting an equitable improvement over the control. The magnesium content also increased steadily from 153.83 mg/100 g at T_0 to 163.88 mg/100 g at T_5, with iron and zinc levels rising from 2.79 mg/100 g at T_0 to 4.35 mg/100 g at T_5. These outcomes show that *G. sylvestre* supplementation was successful in enhancing the levels of vital minerals like calcium, magnesium, iron, and zinc but decreasing sodium and potassium levels to a small extent.

These results agree with previous research. Subedi and Upadhyaya (2019) stated that oat bars fortified with

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Table 5. Mean value for phenolic content and antioxidant potential of nutrient-dense bars formulations

Treatment	TPC (mg GAE/g)	DPPH (%)
T_0	250.2120±5.00	60.57 ± 4.24
T_1	249.8337±4.99	60.77 ± 4.25
T_2	249.4560±4.98	60.98 ± 4.26
T_3	249.0780±4.98	61.18 ± 4.28
T_4	248.6990±4.97	61.39 ± 4.29
T_5	248.3210±4.96	61.59 ± 4.31

flaxseed had an iron content of 5.48 mg/100 g, while Indumathi *et al.* (2021) found that multigrain cookies enriched with *G. sylvestre* contained elevated levels of sodium (58.73 mg/100 g) and potassium (231.65 mg/100 g) with increased *Gymnema* inclusion. These findings together attest that the mineral composition of functional foods is highly affected by *Gymnema* enrichment by making their nutritional content more superior.

3.2.3. Phytochemical analysis

The total phenolic content (TPC) and antioxidant capacity of the nutrient-rich flaxseed-based bars were analyzed to assess the effect of *G. sylvestre* powder supplementation (Table 5). TPC varied from 250.21 mg GAE/g in the control (T_0) to 248.32 mg GAE/g in T_5, decreasing slightly but steadily with the rise in *Gymnema* levels. Comparing treatments, T_3 had a relatively uniform phenolic content (249.07 mg GAE/g), which was at par with the control, indicating that moderate supplementation did not hugely impact the phenolic content. Conversely, the antioxidant capacity, quantified by the DPPH assay, rose increasingly with *Gymnema* addition from 60.57% in T_0 to 61.59% in T_5.

The treatment T_3 had an optimal improvement (61.18%), which was due to the beneficial effect of *Gymnema* bioactives on free radical scavenging activity. These outcomes indicate that despite increased *Gymnema*

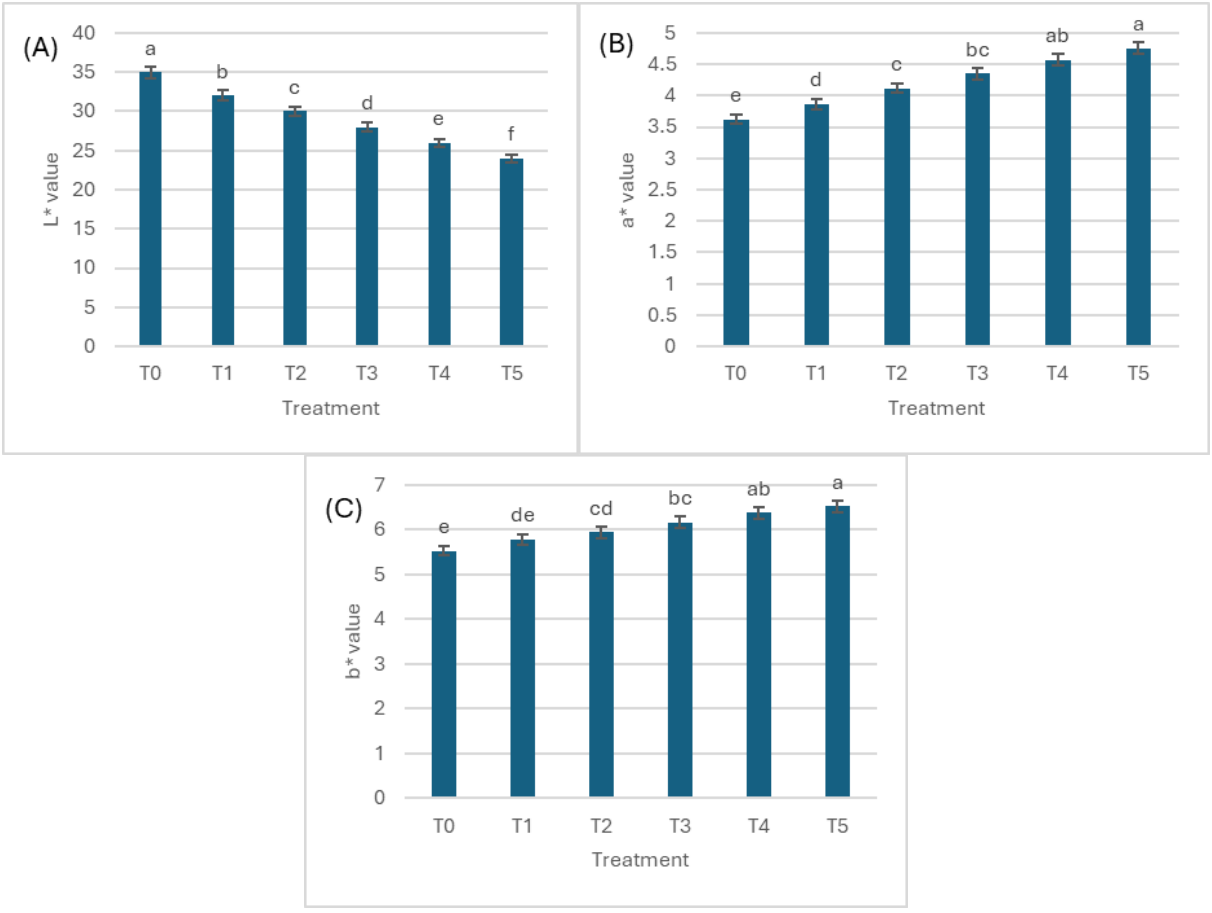


Figure 5. Effect of different treatments (T_0-T_5) on the color parameters of the samples: (a) L (lightness), (b) a (red-green), and (c) b* (yellow-blue). Data are presented as mean ± SD. Different letters indicate significant differences ($p < 0.05$) among treatments.

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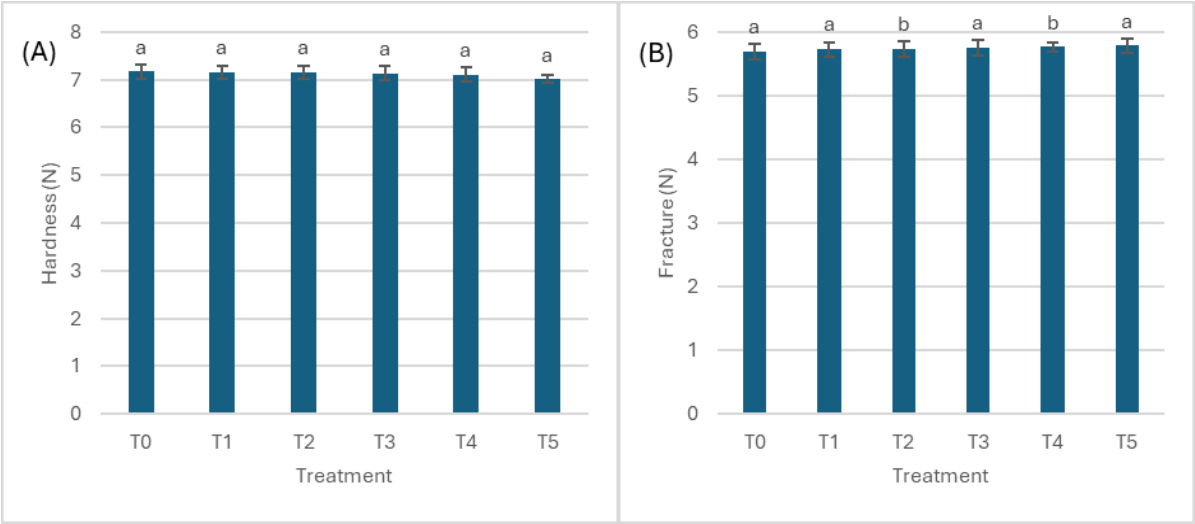


Figure 6. Effect of different treatments (T_0-T_5) on the hardness and fracture of the samples. Data are presented as mean ± SD, and different letters indicate significant differences ($p < 0.05$) among treatments

addition decreasing TPC slightly, it improved the antioxidant capacity, suggesting the presence of other antioxidant compounds in the powder that offset the slight reduction in the phenolics. The results concur with Ramiya *et al.* (2022), which identified that fiber-enriched herbal crackers with 5% *G. sylvestre* leaf powder powder showed improved antioxidant activity (DPPH value of 32.7%) and phenolic content (4.66 mg GAE/g), reaffirming the functional potential of *Gymnema* in increasing the antioxidant activity of food products.

3.2.4. Color analysis of nutrient-dense bars

The color characteristics (L*, a* and b*) of the nutrient-rich bars illustrated significant differences between treatments, as from Figure 5. Control (T_0) had a lightness (L*) value of 34.97, which decreased progressively to 28.00 in T_3 and then again to 24.00 in T_5. It reveals that inclusion of *G. sylvestre* powder darkened the bars, with moderate addition (T_3) resulting in a nice golden-brown color and increased supplementation (T_5) resulting in a much darker and less aesthetically pleasing color. The a* values (redness) increased from 3.62 in the control to 4.20 in T_3 and 4.76 in T_5, showing the trend towards redness with more *Gymnema* content.

Similarly, the b* yellowness values also rose gradually from 5.53 at T_0 to 5.95 at T_3 and 6.52 at T_5, reflecting higher warm tones in color. The T_3 treatment had a well-balanced color profile with moderate redness and yellowness overall, resulting in better appearance compared with control and T_5. These findings indicate that moderate *Gymnema* addition (T_3) improved overall visual attributes of the bars, while over-addition (T_5) led to darker color and reduced brightness. Similar color behavior was achieved by Khouryieh and Aramouni (2013) in cereal bars with flaxseed flour when increased addition of plant materials reduced L* values and enhanced a* and b* values.

3.2.5. Texture analysis

Texture of the nutrient-dense bars, tested for hardness and fractureability, demonstrated non-significant treatment differences, as seen in Figure 6. Hardness, defined as the maximum force needed under the first compression cycle and equivalent to the initial bite, varied from 7.17 N in T_0 to 7.01 N in T_5, presenting a gradual decrease with rising levels of *G.sylvestre* powder. Intermediate concentrations (T_1-T_4) had values of 7.16, 7.15, 7.14, and 7.11 N, respectively, indicating that the addition of *G. sylvestre* powder lowered the firmness of the bars to some extent, making them softer in texture. Fractureability, which measures how easily the bars fracture when subjected to stress, rose gradually from 5.70 N in T_0 to 5.79 N in T_5, with intermediate treatments (T_1-T_4) registering 5.73, 5.74, 5.75 and 5.77 N, respectively.

This increasing trend implies greater pliability and lower brittleness with higher levels of *Gymnema* incorporation. The result is consistent with the study of Kaur *et al.* (2019), which stated that flaxseed-enriched energy bars showed a lowered hardness value (12.01 N) and improved fractureability (80.83), highlighting the contribution of functional ingredient addition in textural property modulation.

3.2.6. Sensory analysis

Sensory evaluation was conducted to determine consumer acceptability and overall acceptability of formulated nutrient-rich bars using a 9-point hedonic scale, testing significant factors like color, flavor, aroma, texture, holding strength, chewiness, and overall acceptability.

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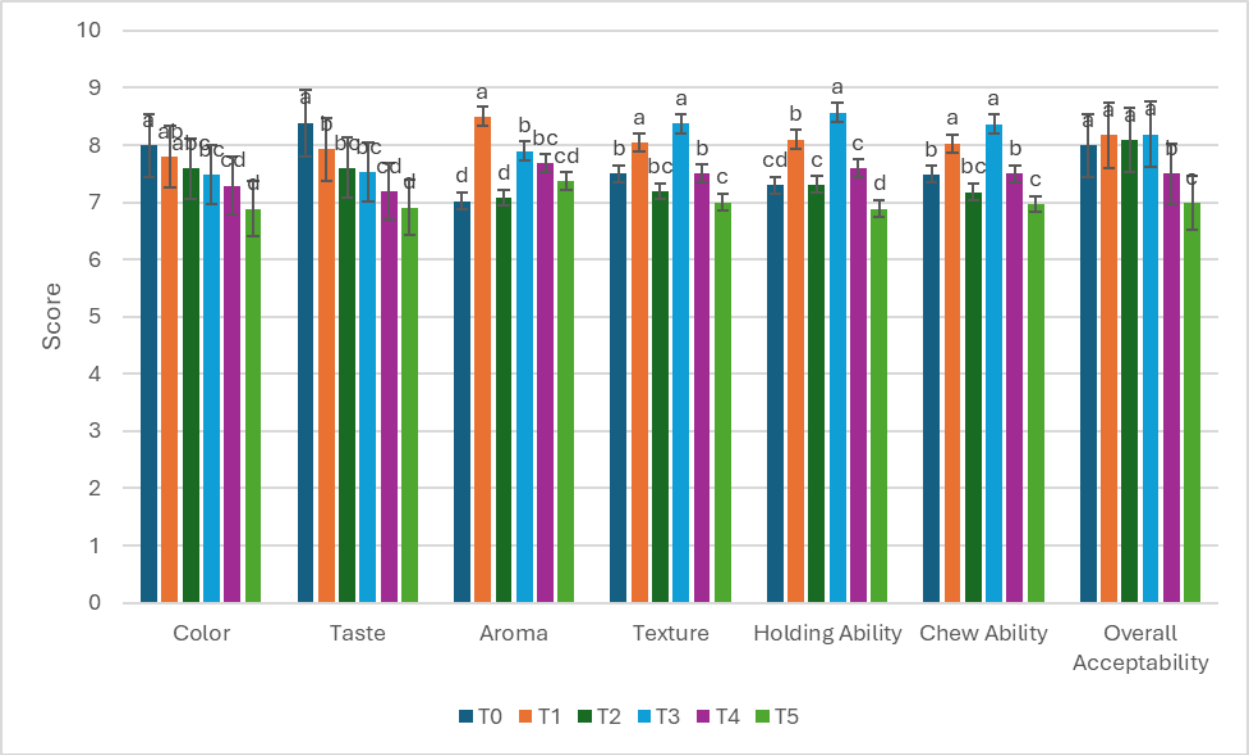


Figure 7. Sensory acceptance of various treatments (T_0-T_5) for color, taste, aroma, texture, holding strength, chew strength, and overall acceptability. Different superscript letters represent significant differences ($p < 0.05$) between treatment.

As shown in Figure 7, color scores ranged from 6.98 to 7.99, and T_0 was highest at 7.99 and T_5 was lowest at 6.98, suggesting that the greater concentrations of *G. sylvestre* powder darkened the bars slightly and made them less attractive. Taste scores ranged from 6.91 to 8.39, and T_0 was highest at 8.39 and T_5 was lowest at 6.91, suggesting that the greater supplementation concentrations decreased palatability. Aroma scores ranged from 7.02 to 8.50, with the highest score (8.50) going to T_2 and the lowest (7.02) going to T_0. Texture scores ranged from 7.00 to 8.38, with the highest score going to T_3 (8.38) and the lowest going to T_5 (7.00), indicating that moderate addition of *Gymnema* positively affected mouthfeel and cohesiveness. Holding ability scores ranged from 6.89 to 8.57, where T_3 had the highest value (8.57) and T_5 the lowest (6.89). Similarly, chewability ranged between 6.97 and 8.37, where T_3 recorded the highest acceptability (8.37), while that of T_5 was the lowest (6.97). Total acceptability ranged from 6.99 to 8.19, with T_3 being the highest acceptable treatment (8.19), followed by T_1 (8.17), T_2 (8.09), T_0 (7.99), and T_4 (7.50), while T_5 was the lowest acceptable (6.99).

These findings indicate that supplementation with moderate levels *G. sylvestre* powders enhanced the sensory attributes of the bars, but high concentrations had a detrimental impact on consumer acceptability. The findings are in agreement with Ramiya *et al.* (2022), which reported that the highest sensory acceptance was achieved by fiber-rich herbal crackers with 5% *G. sylvestre* leaf powder.

Conclusion

The present research was successful in developing nutrient-dense snack bars with *G. sylvestre* leaves powder with both nutritional and functional benefits. Proximate analysis confirmed a well-balanced constitution of the optimal protein, fat, fiber and carbohydrate contents, and mineral profiling indicated major contributions from sodium, potassium, calcium, magnesium, iron, and zinc. Phytochemical analysis indicated high total phenolic content and very good antioxidant activity, indicating the potential of the bars to fight oxidative stress. Color and texture analysis confirmed that *Gymnema* enrichment impacted appearance and structural characteristics, with hardness decreased and fractureability increased at high levels of supplementation. Consumer acceptability of moderate levels of *Gymnema* inclusion was found by taste panel testing to be best with T_3. Overall, the experiment confirms that *G. sylvestre* can be effectively incorporated into handy ready-to-eat snack bars to yield a natural, functional, and

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acceptable food ingredient for diabetes management and overall health.

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Conflict of Interest

The authors declare no conflict of interest.

Authors' Contribution

Muneeba Javed contributed to the conceptualization, methodology and data curatio; Mian Kamran Sharif contributed as supervisor and preparation of the original draft, while Hafiz Rizwan Sharif provided supervision, validation, formal analysis, and critical review and editing of the manuscript. Maira Abdul Razzak was responsible for investigation, visualization, resource management, Areej contributed to the review and editing process.

References

AACC (American Association of Cereal Chemists). (2010). *Approved methods of the American Association of Cereal Chemists* (11th ed.). AACC.

AOAC (Association of Official Analytical Chemists). (2023). *Official methods of analysis of AOAC International* (22nd ed.). Oxford University Press.

Behera, S. K. (2019). Phytochemical analysis and antioxidant activities of *Gymnema sylvestre* R. Br. leaf extracts. *Free Radicals and Antioxidants, 9*, 12–15.

Bernacchia, R., Preti, R., & Vinci, G. (2014). Chemical composition and health benefits of flaxseed. *Austin Journal of Nutrition and Food Sciences, 2*, 10–45.

Brodowska, K., Catthoor, R., Brodowska, A. J., Symonowicz, M., & Ska, E. B. L. (2014). A comparison of antioxidant properties of extracts from defatted and non-defatted flax (*Linum usitatissimum*) seeds. *Albanian Journal of Agricultural Sciences, 13*, 16–23.

Dey, P., & Khaled, K. L. (2015). Quantitative estimation of some essential minerals of *Gymnema sylvestre* as a potential herb in counteracting complications of diabetes. *International Journal of Research Studies in Biosciences, 3*, 71–74.

Hussain, S., Anjum, F., Butt, M., & Sheikh, M. (2008). Chemical composition and functional properties of flaxseed (*Linum usitatissimum*) flour. *Sarhad Journal of Agriculture, 24*, 649–653.

IDF (International Diabetes Federation). (2021). *IDF Atlas.* https://idf.org/aboutdiabetes/what-is-diabetes/facts-figures

Indumathi, D., Sujatha, R., & Sundaram, P. S. (2021). Evaluation of nutrient, mineral analysis and quality characterization of *Gymnema sylvestre* multigrain cookies for diabetes. *Journal of Pharmaceutical Research International, 33*, 638–648.

Kaur, P., Sharma, P., Kumar, V., Panghal, A., Kaur, J., & Gat, Y. (2019). Effect of addition of flaxseed flour on phytochemical, physicochemical, nutritional, and textural properties of cookies. *Journal of the Saudi Society of Agricultural Sciences, 18*, 372–377.

Khouryieh, H., & Aramouni, F. (2013). Effect of flaxseed flour incorporation on the physical properties and consumer acceptability of cereal bars. *Food Science and Technology International, 19*, 549–556.

Laha, S., & Paul, S. (2019). *Gymnema sylvestre* (Gurmar): A potent herb with anti-diabetic and antioxidant potential. *Pharmacognosy Journal, 11*, 201–206.

Majid, A. (2022). Sensorial and physicochemical characterization of snack bar with gum arabic (*Acacia seyal*) addition. *Food Research, 6*, 319–329.

Meilgaard, M. C., Civille, G. V., & Carr, B. T. (2016). *Sensory evaluation techniques* (5th ed.). CRC Press.

Montgomery, D. C. (2017). *Design and analysis of experiments* (9th ed.). John Wiley & Sons.

Mueller, K., Eisner, P., Yoshie-Stark, Y., Nakada, R., & Kirchhoff, E. (2010). Functional properties and chemical composition of fractionated brown and yellow linseed meal (*Linum usitatissimum* L.). *Journal of Food Engineering, 98*, 453–460.

Pereira, M. A., Erickson, E., McKee, P., Schrankler, K., Raatz, S. K., Lytle, L. A., & Pellegrini, A. D. (2011). Breakfast frequency and quality may affect glycemia and appetite in adults and children. *Journal of Nutrition, 141*, 163–168.

Porchezhian, E., & Dobriyal, R. M. (2003). An overview on the advances of *Gymnema sylvestre*: Chemistry, pharmacology and patents. *Die Pharmazie–An International Journal of Pharmaceutical Sciences, 58*, 5–12.

Prabha, V. K. N., Vasanthadevi, K. P., & Vijayaraghavan, R. (2019). Formulation of *Gymnema sylvestre* mix incorporated foods for diabetes mellitus. *International Journal of Pharmaceutical and Medicinal Research, 10*, 14–24.

Rahman, M. M., Habib, M. R., Hasan, M. A., Al Amin, M., Saha, A., & Mannan, A. (2014). Comparative assessment on *in vitro* antioxidant activities of ethanol extracts of *Averrhoa bilimbi*, *Gymnema sylvestre* and *Capsicum frutescens*. *Pharmacognosy Research, 6*, 36–41.

Ramiya, S., Janarny, G., & Gunathilake, K. D. P. P. (2022). Development of healthy fiber-rich herbal crackers from whole wheat, finger millet, rice bran and *Gymnema sylvestre* leaves. *South Asian Research Journal of Natural Products, 5*, 71–89.

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Sharma, D., Sood, S., Verma, R., & Thakur, A. (2021). Development and storage stability of multiseed energy bars for sports persons. *Himachal Journal of Agricultural Research, 47*, 66–76.*

Sharma, P., & Gujral, H. S. (2014). Cookie-making behavior of wheat–barley flour blends and effects on antioxidant properties. *LWT–Food Science and Technology, 55*, 301–307.

Shaukat, M. B., Abbasi, K., & Majeed, Y. (2021). Indigenous plants of Pakistan for the treatment of diabetes: A review. *Agrobiological Records, 4*, 44–63.

Singh, K., Mridula, D., Rehal, J., & Barnwal, P. (2011). Flaxseed: A potential source of food, feed and fiber. *Critical Reviews in Food Science and Nutrition, 51*, 210–222.

Subedi, B., & Upadhyaya, N. (2019). Preparation and quality evaluation of flaxseed incorporated cereal (oat) bar. *Journal of Food Science and Technology Nepal, 11*, 65–68.

Thakur, G. S., Sharma, R., Sanodiya, B. S., Pandey, M., Prasad, G. B. K. S., & Bisen, P. S. (2012). *Gymnema sylvestre*: An alternative therapeutic agent for management of diabetes. *Journal of Applied Pharmaceutical Science, 2*, 1–6.

Tiwari, P., Mishra, B. N., & Sangwan, N. S. (2014). Phytochemical and pharmacological properties of *Gymnema sylvestre*: An important medicinal plant. *BioMed Research International, 2014*, 1–18.

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