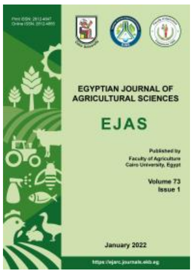
Egypt. J. Agric. Sci., 76, 2025.(3) 47-60.
10.21608/ejarc.2025.444771

Egyptian Journal of Agricultural Sciences

Journal homepage: www.ejarc.journals.ekb.eg



Production of Chocolate Protein Bars That Are Full of Nutrients and High in Plant-Based Protein and Energy

By

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ABSTRACT

To meet the demand for premium protein and allay environmental worries, new strategies must be taken into account. Nowadays, the majority of protein sources are expensive and heavily processed, which contributes to an unaffordable or/and unhealthy diet. This study aimed to create high energy protein bars from plant source by adding Moringa Oleifera leaves powder with other ingredients to production functional food. Three samples of bars were prepared (S1) as a control without Moringa, high-protein formulas bars fortified with Moringa as a high source of plant protein (S2: 5% Moringa) and (S3: 6% Moringa). After one hours of storage at 4-5°C, the formed bars were subjected to further examination (Sensory evaluation and chemical analysis tests to determine the content of moisture, protein, fat, fiber, phenols, ash, carbohydrates, antioxidants, microbiological analysis and shelf life). The results showed that the final product had a high protein content (25% - 26.5%) for samples enriched with Moringa, with the highest percentage being for the protein bar enriched with 6% Moringa leaf powder compared to the control. The 10 panelist rated the product's texture, appearance, color, and taste as good sensory acceptance, making it suitable for commercial production. This study confirms the potential of using Moringa leaf powder to produce healthy and sustainable snacks that meet the needs of athletes and nonathletic those seeking healthy eating options.

Keywords: *Energy Protein Bar, Moringa Oleifera Leaves, Functional Foods, Sensory Evaluation*.

1. INTRODUCTION

To meet specific needs and physiologic concerns, many novel food compositions are being developed, the snack bars are one of these new items (Boukid *et al.,* 2022), In this context, providing foods rich in protein and energy (Amawi *et al*., 2024), that are easy to digest and small in size, is an ideal solution to meet the needs of athletes and nonathletic, whose increased physical activity requires a daily intake of higher amounts of protein and energy. A quick and wholesome source of protein and energy are protein bars. Initially created for athletes, it is now aimed to a broad spectrum of health-conscious consumers (Loveday *et al.,* 2009). Protein bars typically have 10–40 g of protein, primarily from soy and dairy sources (Imtiaz *et al*., 2012). Nonetheless, a recent change in consumer behavior promoted the use of rice and peas as substitute plant-based protein sources (Małecki *et al*., 2020). Even while protein bars are regarded as a "good source of protein," the majority of study focuses on their rheological and technological characteristics, such as the fact that adding protein powders necessitates a high ratio of additives in order to produce goods that are palatable (Tormási *et al.*, 2025). However, very little is known about their

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Received: 10:7:2025 **Accepted: 28:7:2025** Available o**nline: 30:7:2025**

nutritional value. Furthermore, it has already been questioned whether the term "protein bar" may be deceptive in some situations (Fernan *et al*., 2018). Therefore, developing a healthy product that combines high nutritional value, good taste, and an attractive texture represents both a challenge and an opportunity (Abdel-Salam *et al*., 2022).

Moringa also has a high nutritional value; it has an unusually high vitamin, amino acid, and micronutrient content for a plant. Its leaves are notable for their high (30%) protein content, which includes 18 of the 20 essential amino acids; it also contains seven times more vitamin C than oranges, four times more vitamin A than carrots, and four times more calcium than milk. Additionally, it contains a high amount of antioxidants and fiber (Cervera-Chiner et al., 2024). All of this making it an ideal ingredient to support physical performance, enhance post-workout recovery, and contribute to improving the overall health of athletes and non-athletes alike (Masitlha *et al.*, 2024).

According to studies, MO contains over 110 bioactive compounds, each of which has a medicinal or protective quality (Bhattacharya *et al.*, 2018). Phenolics, flavonoids, and phenolic acids make up the majority of MO's phenolic components. Despite the fact that these phytochemicals are found throughout the plant, the seeds are exceptionally abundant in flavonoids and phenolic acids, particularly the polyphenols quercetin, gallic acid, and ellagic acid (Wang *et al.*, 2022). Flavonoids are frequently found in their glycoside and flavanol forms. Out of the 26 flavonoids found in MO, myricetin, rhamnetin, and kaempferol are some of the most prevalent. Furthermore, the genus's leaves contain eleven different phenolic acids, including ferulic, caffeic, chlorogenic, and syringic acids. Antioxidant, anti-photoaging, and anti-cancer effects have been demonstrated for both flavonoids and phenolic acids. However, MO's potent scavenging action, which greatly enhances its overall antioxidant, anti-inflammatory, and hepatoprotective qualities, is primarily driven by its high phenolic acid concentration (Milla *et al*., 2021& Giuberti *et al*., 2021)

Its abundant supply of iron, vitamin A, and niaziminin B, MO is a cheap, readily cultivated tree that helps strengthen one's immune system (Fajri, 2021, July &Mathpal *et al*., 2022). Fortunately, MO can serve as an alternative natural remedy because of its high phytochemistry and bioactive chemical content, which enable it to target a variety of illnesses, including cancer, infectious disorders, migraines, hyperglycemia, and hypertension. Although most vegetables lose part of their nutrients when cooked, MO leaves, whether they are cooked, crushed, or not, are an exception. Actually, boiling the leaves or grinding them into a fine powder triples their iron concentration (Camilleri, & Blundell, 2024).

Hence the idea for our research: to design a plant-based protein bar based on moringa leaf powder as a natural and rich source of protein, fiber, and bioactive compounds.

This research aims to produce a plant-based protein bar, the bar offers a balanced, natural product containing concentrated amounts of carbohydrates, proteins, fiber, and healthy fats, in addition to vitamins and minerals to become a functional healthy food high in bioactive components. The product also considers price value and important sensory aspects such as taste, color, and aroma to ensure consumer acceptance and continued demand without harming the body.

2. MATERIALS AND METHODS

2.1. Materials

All chemical analysis of extracts was done in the Food Safety and Quality Control Lab, in Cairo University's Faculty of Agriculture in Giza, Egypt. All ingredients used (cocoa, oats, flax seeds, soybean, peanut butter, Dates, Dark chocolate and Moringa oleifera leaf powder) in the manufacture of the product purchased from local market, but the Moringa leaf powder is from the Agricultural Research Center.

2.2. Methods

The following steps were followed in manufacturing the product

2.2.1. Preparing the ingredients

All dry ingredients are carefully prepared and weighed in the quantities shown in the following Table (1).

The raw dark chocolate was melted only using a bain-marie to obtain a liquid consistency that is easy to mix with the rest of the ingredients.

2.2.2. Mix the ingredients

Mix all dry ingredients together in a suitable bowl until completely smooth. Then add the melted chocolate and peanut butter to the

Table (1): Ingredients of protein and Energy Bar.

Ingredients (g/100 g)	Sample 1 (control)	Sample 2 (Bar with 5% Moringa)	Sample3 (Bar with 6% Moringa)
Raw Cocoa	5	5	5
Oats	10	10	10
Flax Seeds	1	1	1
Soybean	15	10	9
Peanut Butter	20	20	20
Dates	10	10	10
Dark Chocolate	39	39	39
Moringa Leaf Powder	0	5	6
Total	**100**	**100**	**100**

mixture and stir well until a completely homogeneous mixture is obtained.

2.2.3. Forming

The mixture was poured into suitable molds (silicone molds) applying gentle pressure to ensure consistency, equal height for all product surfaces weigh 100g each and no gaps then.

2.2.4. Cooling

The molds covered with plastic film were placed in the refrigerator for a sufficient period of time (1-2h) to ensure the product was consistent and complete the forming process then covered with special plastic film for food packaging each piece separately in preparation for testing.

The Protein bar was produced with Moringa Leaves added as a high plant source protein, antioxidant and antifungal to increase its nutritional value. The Protein Bar was tested for DPPH and Antioxidant, as well as sensory tests (taste, smell, texture, color, appearance, general acceptance) and chemical composition. (Moisture, ash, protein, fat, fiber and carbs) were measured,

2.3. Chemical Composition of Protein Bar

Determination of moisture, proteins, fats, ash and crude fiber contents in extracts were according to AOAC (2016). Protein content was determined by Kjeldahl technique AOAC (2005), using a factor of 6.25, carbohydrate content was determined using the AOAC (2000) difference.

Total carbohydrates = 100 - (g protein+ g fat +g ash + g fiber).

2.4. Sensory analysis

Sensory evaluation of Protein Bar was carried out by a 10 (5 from the Faculty of Sports Sciences, Helwan University and 5 from the Faculty of Agriculture, Cairo University) Egypt. Samples of Protein Bar were prepared one day earlier before the evaluation, each panelist was asked to evaluate Protein Bar samples, according to color, flavor, taste, texture and general appearance by using the method Wichchukit & O'Mahony (2015). Each sensory attribute was rated on a 9-point hedonic scale: extremely liked –9, very much liked –8, moderately liked –7, slightly liked –6, neither liked nor disliked –5, slightly disliked –4, moderately disliked –3, very much disliked –2 and extremely disliked –1.

2.5. Ethical Considerations

A research permit was obtained approval at 6/2025, from Sensory Evaluation Ethics Certificate, (ARC-IACUC) Agricultural Research Center. Ten student's voluntary as panelist to make sensory evaluation, Participants were informed of the study objectives and the safety of the product components, and the interviewer requested their consent to participate. Participants were provided with feedback after data analysis, and were assured of the confidentiality of the information shared.

2.6. Determination of Total Phenols

Total phenolic and total flavonoid content concentrations were calculated using the method of Zilic *et al.*(2012) and expressed as mg of gallic acid equivalent (GAE) and catechin equivalent (CE) per 100 g FW of sample, respectively.

The modified approach of Shimada *et al.* (1992) was utilized to measure the 1,1-diphenyl-2-picrylhydrazil (DPPH) radical scavenging activity.

2.7. DPPH Radical-Scavenging Activity

For every sample, 0.1 g was produced in 50 milliliters of methanol. A portion of the extract (100 µl, 0.2 mM) was combined with a methanol-dissolved DPPH radical. After stirring, the mixture was allowed to stand in the dark for fifteen minutes. Next, the absorbance was measured in relation to a blank at 517 nm. The formula for calculating the % scavenging effect was $[(A0 – A1) / A0] \times 100$. Thus, according to Brand-Williams *et al*. (1995), A0 represents the absorbance of the control (without sample) and A1 represents the absorbance when the sample is present.

2.8. Determination of Mineral Composition

Minerals including calcium and Iron in ached samples were determined using the method described by Association of Official Analytical Chemists (AOAC., 2016). Calcium and Iron was determined using Atomic Absorption Spectroscopy after mineralization by hydrochloric acid (M.F.A., 1982).

2.9. Microbiological analysis

2.9.1. Samples preparation

In order to provide adequate dilutions for the microbiological analysis, 25 g of each sample were combined and homogenized in a sterile mixer, and ten-fold dilutions of homogenates or liquid samples were made and inoculated into selective medium plates.

2.9.2. Yeasts and molds count

The number of yeast and mold colonies was measured and quantified per gram or milliliter of the sample FDA (2002).

2.9.3.Total Plate Count Analysis

Total Plate Count Analysis the Total Plate Count (TPC) study is used to determine the presence or absence of total microorganisms in chicken egg shell flour cookies. The working premise of TPC analysis is the development of microorganisms after 48 hours of incubation in Nutrient Agar media at 37oC. These bacteria will proliferate and form colonies that can be directly counted (AOAC, 1996).

2.10. Statistical Analysis

Using the statistical software for social science (SPSS) version 16, a one-way analysis of variance (ANOVA) and the Duncan Test were used to compare all treatment groups. The data were presented as mean ± STD, with $p<0.05$ indicating significance (Bailey, 1995).

3. RESULTS AND DISCUSSION

Data in Table (2) show approximate chemical composition, moisture analysis results of the protein bar samples with significant differences between the standard (control) sample and the samples enriched with Moringa leaf powder, reflecting the effect of Moringa addition on the physical properties of the product. The moisture content in the control sample (without Moringa) was 5.2%, while it decreased to 4.5% in the sample with 5 g of Moringa added, and to 4% in the sample with 6 g of Moringa added.

This decrease in moisture content suggests that the Moringa leaves retain some moisture or contribute to its absorption from other ingredients due to their fiber and plant compounds content. It may also result from a change in the solid-liquid balance within the bar composition. These results are consistent with those found by El Sohaimy *et al.* (2021).

From a technological perspective, moisture affects product texture, shelf life, and storability (Momanyi *et al*., 2020& Jabeen *et al.,* 2022). Bambara groundnut-M. oleifera leaf protein complex supplementation reduced moisture content and increased product stability in ready-to-use food products, according to Adewumi *et al*.,(2022). While a moderate increase in moisture may improve the softness and chew ability of the bar, it may also reduce its shelf life if not controlled within microbiologically permissible limits. Therefore, controlling the humidity level during product manufacturing is essential to achieve a balance between sensory quality and storage safety, while taking advantage of the benefits that Moringa adds in improving nutritional value.

Laboratory results showed a significant increase in protein content with the addition of Moringa leaf powder to the plant-based protein bar formula (S1, S2), compared to the control sample without Moringa. The protein content of the control sample (without Moringa) was 22%.

In the sample with 5g of Moringa added, the protein content increased to 25%. While the 6g Moringa sample recorded the highest protein content at 26.46%. This gradual increase reflects the direct effect of adding Moringa as a rich plant-based protein source. The Food and Drug Administration (FDA, 2002) in the United States showed that 5% or less of the Daily Value (%DV) of protein is regarded as low, while 20% or more is regarded as high (Snetselaar *et al.*, 2021). Szydłowska *et al*. (2020) stated that in addition to having a high protein content of 15–35% w/w, high-protein bars should also include other nutritionally beneficial elements. The protein content in several studies varied from 17.13 to 21.35%, suggesting that variable environmental factors, growth circumstances, and botanical origins may be responsible for the variances in Moringa treatments. The results of the shade-drying process showed a greater protein content (21.35) (Javed *et al*., 2021). Moringa acknowledged as a possible source of necessary nutrients and protein (almost double that of milk), and it exhibits a number of health-promoting properties (Negm,2019).

Moringa leaves contain high levels of high-quality protein, including most essential amino acids, making them an effective ingredient in enhancing the nutritional value of products targeted at athletes. The difference between the 5g and 6g Moringa samples also indicates a direct relationship between the amount of Moringa added and the increased protein concentration, which supports the possibility of adjusting ingredients to achieve optimal nutritional balance according to the target group. This improvement in protein content contributes to making the product suitable for the needs of athletes or others who need higher protein levels to support muscle building and accelerate muscle recovery or vegetarians, especially in ready-made functional foods such as protein bars (Mamy *et al*.,2024).. Our results are also in agreement with those obtained by Kumar, & Rani. (2022) who indicated that Moringa leaves contain 19 essential amino acids. Since the main component of protein bars is protein, adding Moringa leaves can increase their protein level, making them a practical and healthful choice for anyone searching for a well-rounded nutritional supplement. Selahvarzi *et al.(*2021) demonstrated that amount of amino acids varies depending on the part of the Moringa tree; leaves contain 40% of the amino acids, pods 30%, and flowers 31%.

Soybeans are therefore regarded as a complete plant-based protein that can be a significant part of the diet of those who are on a plant-based diet or who are in need of high-quality protein sources Zhao *et al.,* (2022). Fish fed diets augmented with Moringa oleifera leaf meal showed considerable improvements in their haematological, biochemical, and immunological responses. The findings also indicate that greater inclusion replacement is feasible, although it was suggested that Moringa oleifera leaf meal might be used to replace 30% of the crude protein of soybean in the diet of young Cyprinus carpio fish for growth and financial reasons (Adeshina *et al.,* 2018). As the amount of powdered Moringa leaf rose from 5% to 15%, the protein content increased dramatically Gebrezgi, (2019).

The results in Table (2) show that the ash content of the three samples ranged between 0.5 ± 0.1% and 1 ± 0.1%. Statistical analyses revealed no significant differences between them ($p > 0.05$), indicating that the total mineral content of the formulations used was closed . The ash content of foodstuffs is closely related to their mineral and inorganic composition. These results were in agreement with those reported by Eid *et al.* (2025) that the ash content of all samples date energy bars with or without Moringa did not differ significantly. This value reflects the total amount of minerals such as calcium, magnesium, iron, potassium, phosphorus, and zinc. By analyzing the components of the samples used, the resulting values can be interpreted as follows:

Oatmeal is a good source of many essential minerals, particularly iron, magnesium, and zinc, and thus contributes to raising the ash content. Dates are rich in potassium and magnesium, which in turn enhance the mineral value.

Table (2): Effect of replacement ratios on proximate Chemical composition of Energy Protein Bar.

Sample	Moisture	Protein	Ash	Fat	Fiber	Carbohydrate
S1	5.2 ^{a} ±0.09	22^{c}±0.11	1 ^{a} ±0.1	29^{a}±0.1	8.8^{b}±0.14	34^{a}±0.19
S2	4.5 ^{b} ±0.2	25^{b}±0.1	0.9 ^{a} ±0.1	27^{b}±0.05	9^{a}±0.1	34^{a}±0.15
S3	4 ^{b} ±0.2	26.46^{a}±0.15	1 ^{a} ±0.1	26.5^{b}±0.1	9.3^{a}±0.08	32.74^{a}±0.15

S1: control S2: 5% Moringa S3:6% Moringa.
Different superscripts indicate significant differences using Duncan's multiple range tests ($p < 0.05$).

Flaxseeds contain significant amounts of phosphorus and magnesium and are a rich plant source. Raw cocoa is rich in minerals, especially magnesium and iron, which increases the ash value of the sample. Peanut butter and soybeans contribute significant mineral content such as zinc and potassium. Moringa, a mineral-rich functional food, significantly increases ash content when used in sufficient concentrations. Its leaves contain high levels of calcium, iron, and magnesium, according to numerous studies.

Despite the formulation's inclusion of these mineral-rich ingredients, the lack of significant differences between samples can be attributed to two factors:

1. The relative similarity in mineral content between the different formulations, resulting in similar final ash values.

2. The amount of Moringa used may not have been sufficient to produce a significant difference in ash content, despite its high mineral value.

In agree with our results (Masitlha *et al.*, 2024) demonstrated that all formulations maintain similar mineral nutritional values, which is positive for energy or protein products that aim to provide complete nutritional value.

Chemical analysis results for the total fat content of the plant-based protein bar samples showed significant differences between the standard (control) sample (**S1)** and the samples enriched with Moringa leaf powder(**S2, S3**). The average fat content in the control (Moringa-free) sample was 29.00%, while it decreased to 27.00% in the sample supplemented with 5g of Moringa, and continued to decrease to 26.50% in the sample supplemented with 6g of Moringa.

This gradual decrease in fat content may be explained by the fact that Moringa leaves are not a rich source of fat, with their fat content ranging from only 4.03% to 9.51%, according to recent studies (Aderinola *et al.*, 2020). But we have other ingredients contain high fat Therefore, substitution of the other ingredients in the formula with Moringa leads to a relative decrease in the total fat content. Although the observed differences are small in quantitative terms, they are positive from a nutritional perspective, especially when targeting athletes, who prefer protein-rich, moderate- or low-fat products to support physical performance and maintain muscle mass without gaining fat. Therefore, the inclusion of Moringa in a protein bar enhances the product's health value without negatively impacting its nutritional balance. Kilany *et al.,(*2020) demonstrated that Male Sprauge Dawely rats that have been given a high-fat diet (HFD) may be able to lose weight if Moringa olifera seed oil extract and lycopene are administered.

Analysis of the dietary fiber content of the protein bar samples in table 2 showed significant differences between the standard (control) sample and the samples enriched with Moringa leaf powder. The fiber content in the control sample was 8.8%, while it increased to 9% in the sample supplemented with 5g of Moringa, and continued to increase to 9.3% in the sample supplemented with 6g of Moringa.

This gradual increase in fiber content indicates that Moringa is a rich source of dietary fiber, which enhances the nutritional value of the product, particularly in supporting digestive health and increasing satiety. Fiber also contributes to regulating blood sugar levels and improving bowel movements, factors that are especially important for athletes seeking to maintain a healthy nutritional balance. In context with our results (Islam *et al.,* (2020) demonstrated that adding Moringa to a protein bar positively contributes to its health benefits without negatively affecting the other nutritional components. The slight increase in fiber also confirms the possibility of exploiting Moringa to improve the nutritional value of foods directed at people with high physical activity.

The results of the chemical analysis of the carbohydrate content of the protein bar samples showed slight differences between the standard (control) sample and the samples enriched with Moringa leaf powder. The average carbohydrate content in the control sample (without added Moringa) was 34%, while it was 34% in the sample with 5g of Moringa added, and 32.74% in the sample with 6g of Moringa added. This slight variation indicates that the addition of Moringa did not significantly affect the carbohydrate content of the product. This is due to the relatively small amount of Moringa added compared to the other ingredients in the formula (such as oats and dates), which are the primary sources of carbohydrates. Our results were similarly in line with those of Rabie *et al.* (2020) who demonstrated that cookies supplemented with Moringa had a higher fiber content and a lower total carbohydrate content. Despite the slight change in proportions, this variation is considered normal within the limits of laboratory analysis and has no practical impact on the overall nutritional value of the product in terms of its energy supply. Therefore, the use of Moringa as a functional ingredient did not disrupt the carbohydrate balance of the product, which is a positive feature when developing nutritional supplements for athletes, as carbohydrates are a primary source of energy. In this context, the results are similar to those of (Salihu *et al*., 2023).

Sensory evaluation of samples is shown in Table (3). From the previous Table (3), the 6% Moringa sample was highly accepted by consumers in terms of taste, color, texture, smell, and overall acceptance, compared to the control sample, which was described as excellent. Our results showed that the sensory attributes for taste, aroma, texture, color and overall acceptability were non-significantly higher ($p>0.05$) in S3 comparison to control sample. The 5% Moringa sample was also well-received by consumers in terms of taste, smell, and overall acceptance.

Overall, the control and 6% Moringa samples were similar in terms of acceptance, and both outperformed the 5% Moringa sample. In agree with our results Gupta and Gupta (2021) showed that growing interest in using Moringa as a food ingredient in processed products such as snacks. Studies have shown that replacing some of ingredients in biscuits or snacks with Moringa leaf powder can improve the nutritional value of these products. This includes improving the protein, vitamin, and mineral content, which keeping or even increasing customer acceptance enhances their acceptance among health-conscious consumers, according to Szydłowska *et al,*. (2020) fruit flavor, which the current study used dates for, had a good effect on the overall sensory quality of high-protein bars. Subramaniam and Basri, (2024) noted that incorporation of higher amount of Moringa flower powder excellent protein sources contributed to a much darker colour for protein bar, may be easily added while the bars are being made without changing their textural or sensory qualities. Because Moringa contains phenol compounds, its flavor is described as astringent and bitter (Methakullawat and Lorjaronephon, 2019) So, the general acceptability of the product may be increased by adding dried fruits, sugar, and nuts, which can help to cover up the unpleasant flavor and bitter taste of Moringa leaf (Barakat & Alfheeaid, 2023 & Iqbal *et al.*,2021) which make a good sensory evaluation for our bar protein including peanut butter, date, raw cocoa and dark chocolate with Moringa.

In contrast with our results Adewumi *et al*. (2022) noted that because of the high concentration (80 g) of MO in the mix, the Moringa bars received poor ratings for look, color, and odor. Coello *et al*. (2021), who discovered that while adding 18% Moringa had acceptable sensory acceptance (appearance, texture, and odor), adding 15% to 30% Moringa reduced the taste score and overall acceptability. According to Supriyanto *et al*., (2022), adding up to 10% Moringa powder to the snack bar's recipe had no effect on the snack bar's flavor, color, or smell. The dark green color of Mo may be the reason why Mounika *et al*., (2021) found that snacks made with 5% MO had a greater overall sensory acceptability but product acceptability declined with increasing MO supplementation levels, This was also in line with the findings of Subramaniam & Basri,

Table (3): Effect of replacement ratios on Sensory evaluation of Energy Protein Bar.

sample	Appearance	Color	Texture	Smell	Taste	Overall Acceptability
S1	7.4^{a}±1.51	7.8^{a}±1.3	9^{a}±1	8.6^{a}±1.34	8.4^{a}±2.07	9^{a}±1
S2	7.4^{a}±0.89	8.4^{a}±1.14	8.4^{a}±0.89	8.4^{a}±0.89	8.8^{a}±0.83	8.4^{a}±1.14
S3	8.4^{a}±1.51	8^{a}±0.7	9.4^{a}±0.89	8.8^{a}±0.83	9.2^{a}±0.83	9.2^{a}±0.83

S1: Control S2: 5% Moringa S3:6% Moringa.
Different superscripts indicate significant differences using Duncan's multiple range tests ($p < 0.05$).

(2024) who indicated that the bar protein's taste, aroma, texture, color, and general acceptance were all non-significantly greater with 10g Moringa.

3.1. Total Phenol

The results of the chemical analysis in Table (4) displayed that total phenolic content showed clear differences between the control sample and the samples enriched with Moringa leaf powder, which reflects the effect of Moringa as a rich source of phenolic compounds with high biological activity.

The control sample recorded the lowest phenolic content, averaging 10.45 mg/g. This content increased significantly in the sample supplemented with 5 g of Moringa, reaching 28.91 mg/g, and reached its highest value in the 6 g Moringa sample, at 32.58 mg/g.

Total phenols are effective antioxidant compounds and play a significant role in reducing oxidative stress, improving immune response, and reducing inflammation. These benefits are particularly important for athletes and non-athletes who are exposed to continuous physical exertion. These results indicate a direct relationship between the amount of Moringa added and the increased phenol content. This supports the product's functional value as a natural source of antioxidants and enhances its health benefits as a suitable snack for athletes and those interested in preventative nutrition.

These results are consistent with a recent study by Fejér *et al*. (2025), who found that Moringa leaf extracts contain high total phenol contents, which contributes to their antioxidant activity.

Table (4): Effect of replacement ratios on Total Phenol and Antioxidant of Protein Energy Bar.

Sample	Total phenols mg/g	Antioxidant %
S1	10.45^{c}±0.18	31^{c}±2.64
S2	28.91^{b}±0.22	61.36^{b}±1.78
S3	32.58^{a}±0.47	72.71^{a}±2.09

S1: control S2: 5% Moringa S3: 6% Moringa.
Different superscripts indicate significant differences using Duncan's multiple range tests ($p < 0.05$).

3.2. Antioxidant

The quantitative assessment of antioxidant activity in the protein bar samples showed clear differences supporting the effect of adding Moringa leaf powder as an effective functional ingredient. The antioxidant activity value in the control sample (free of Moringa) was 31.00٪, while it increased significantly to 61.36 ٪in the sample supplemented with 5 g of Moringa, and the highest value was recorded in the 6 g of Moringa sample at 72.71٪.

These results reflect a direct increase in antioxidant activity with increasing Moringa intake, indicating that Moringa leaves contain high concentrations of active compounds, such as phenols and flavonoids, which are known for their ability to combat free radicals and protect cells from oxidative damage. In agree with our result Eid *et al.,(*2025) with increasing Moringa concentrations, the antioxidant activity of date energy bars fortified with various ratios of Moringa increased.

This improvement in antioxidant activity represents an additional advantage of the product, especially for athletes, as antioxidants help reduce the effects of oxidative stress resulting from intense exercise and enhance muscle recovery and overall health. Therefore, adding Moringa to protein bars can be considered a successful step toward creating a complete functional food product that not only provides essential nutrients but also supports the prevention of cellular damage associated with high physical activity. These findings are consistent with those of Cervera-Chiner *et al.* (2024).

3.3. Iron

Table (5) shows the effect of iron content of three protein bar samples analyzed to evaluate the effect of adding Moringa leaf powder on the product's mineral content. The control sample (without Moringa) showed the lowest iron concentration, averaging 1.38 mg/g.

Meanwhile, the iron concentration increased to 5.59 mg/g in the sample supplemented with 5 g of Moringa, and to 6.43 mg/g in the sample supplemented with 6 g of Moringa. This significant increase indicates that Moringa is a rich source of iron, which positively impacts the nutritional value of the product. The results show a direct relationship between the amount of Moringa added and the increased iron content in the bar, with a 1 g increase contributing to an increase in iron concentration of approximately 0.84 mg/g. These results reflect the effectiveness of Moringa in improving the product's mineral content, strengthening its role as a functional food useful in preventing iron deficiency anemia. This is particularly important for athletes, who require adequate iron levels to maintain physical performance and efficient oxygen transport throughout the body. These results are consistent with Masitlha *et al.* (2024).

3.4. Calcium

The results in Table (5) represent that the chemical analysis of the calcium content in the protein bar samples showed clear differences between the control sample and the samples enriched with Moringa leaf powder. The control sample, recorded the lowest calcium content, with an average of 37.13 mg/g. However, the content increased significantly in the sample supplemented with 5 g of Moringa, reaching 102.87 mg/g, and continued to rise in the 6 g Moringa sample, reaching 115.88 mg/g. This significant increase indicates that Moringa leaves are a rich source of calcium, which is clearly reflected in the improved mineral composition of the final product. The direct relationship between the amount of Moringa added and the increased calcium content is evident, supporting the idea of using it as an effective functional ingredient to enhance the nutritional value of the product. This high calcium content is of particular importance for athletes, as calcium plays a key role in supporting bone health, muscle contraction, and nerve function, directly contributing to improved physical performance and injury prevention.

These findings are consistent with a recent study by Yun *et al.*,(2020) &Masitlha *et al.*(2024), which showed that Moringa leaves contain a high percentage of calcium, supporting their use as a natural source for enhancing the mineral content of food products. Kim and Kim (2019) found that Mo had the greatest calcium amount, measuring 826 mg/100 g. According to Jin *et al*. (2014), the two main minerals found in Mo were calcium and potassium. It is commonly known that Mo contains up to 17 times as much calcium as milk (Rockwood *et al*., 2013).

Table (5): Effect of replacement ratios on Iron and calcium of Protein and Energy Bar.

Sample	Iron mg/g	Calcium
S1	$1.38^{c}\pm0.06$	$37.13^{c}\pm3.23$
S2	$5.59^{b}\pm0.04$	$102.87^{b}\pm0.32$
S3	$6.43^{a}\pm0.05$	$115.88^{a}\pm0.63$

S1: control S2: 5% Moringa S3:6% Moringa. Different superscripts indicate significant differences using Duncan's multiple range tests ($p < 0.05$).

Table (6) represented microbiology test of energy and protein bar as the percentage of Moringa fortification increased, the overall plate count declined. The decrease in moisture contents brought about by the fortification of protein bars with Moringa could be the cause of these outcomes. The overall number of plates decreased as a result of this reduction, which also inhibited the growth of yeast and mold. The fortification samples and date energy bars' total bacterial counts fell within the same limits as those seen in other, comparable investigations (Munir *et al*., 2018 & Jabeen *et al.*, 2020). Similarly, Ibrahim *et al.* (2021) discovered no visible mold and no hazardous bacteria or fecal coliforms in date energy bars up to the 12th day of storage at room temperature.

In agree with our results Eid *et al*. (2025) reported that Energy date bars fortified with varying ratios of Moringa (2.5%, 5%, 7.5%, and 10%) showed negative yeast and mold counts up to the fifteenth day under storage conditions. The antiviral, antifungal, and antibacterial qualities of the phenolic chemicals in Moringa may be the cause of this outcome (Oyeyinka *et al*., 2023). Akter *et al*. (2025) Moringa treated pickles showed significantly (P < 0.05) lower levels of free fatty acids, total viable count, and psychrotrophic bacteria than untreated cucumbers over the storage period. Mohamed *et al.*, (2023), showed that adding 2.5% Moringa oleifera leaf powder to fresh oriental sausage significantly affects its microbiological and chemical quality, extending its shelf life until the ninth day of chilling storage at 4Â°C.

Table (6): Effect of replacement ratios on Microbiology test of energy and protein bar unit (log10 CFU/gm).

Sample	Total Count	Molds& Yeasts	Psychrotrophic Bacteria
S1	2.60	Clear	2.63
S2	2.48	Clear	2.56
S3	2.30	Clear	2.46

S1: control S2: 5% Moringa S3:6% Moringa.

Conclusion

In conclusion, this research successfully developed a complete nutritional value chocolate plant-based protein bar fortified with Moringa leaf powder as a source of plant protein, specifically designed to meet the essential nutrient needs of athletes and non-athletic. A delicate balance has been achieved between high nutritional value, palatable taste, and the right texture, making the product a healthy and effective option for supporting physical performance and recovery after athletic exertion or as a healthy snack for non-athletes to regain their energy after a long day at work. This achievement underscores the importance of investing in natural ingredients to produce innovative functional foods that contribute to promoting overall health and meeting the demands of modern lifestyles.

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إنتاج ألواح بروتين الشوكولاتة المليئة بالعناصر الغذائية والغنية بالبروتين النباتي والطاقة

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ملخص

يجب في الوقت الحاضر أخذ استراتيجيات جديدة في الاعتبار لتلبية الطلب على البروتين وتبديد المخاوف البيئية. فإن غالبية مصادر البروتين باهظة الثمن ومعالجة بشكل كبير، مما يساهم في اتباع نظام غذائي غير صحي أو غير ميسور التكلفة. هدفت هذه الدراسة إلى انتاج ألواح بروتين عالية الطاقة من مصدر نباتي عن طريق استبدال جزء من فول الصويا بمسحوق أوراق المورينجا مع باقى المكونات. تم تحضير ثلاث عينات من الألواح (S1) كمجموعة ضابطة بدون المورينجا، وألواح عالية البروتين مدعمة بالمورينجا كمصدر عالي للبروتين النباتي5 :S2) ٪(و6 :S3) ٪ (بعد ساعة واحدة من التخزين عند 4-5 درجة مئوية، خضعت الألواح المشكلة لمزيد من الفحص (التقييم الحسي واختبارات التحليل الكيميائي لتحديد محتوى الرطوبة والبروتين والدهون والألياف والفينولات والرماد والكربوهيدرات ومضادات الأكسدة والتحليل الميكروبيولوجي ومدة الصلاحية). أظهرت النتائج أن المنتج النهائي يحتوي على نسبة عالية من البروتين (25% - 26.5%) للعينات المُدعّمة بالمورينغا، وكانت أعلى نسبة في لوح البروتين المُدعّم بمسحوق أوراق المورينجا بنسبة 6% مقارنةً بالمجموعة الضابطة. وقد قيّم المشاركون العشرة قوام المنتج ومظهره ولونه وطعمه على أنه جيد من حيث التقبل الحسي، مما يجعله مناسبًا للإنتاج التجاري. تؤكد هذه الدراسة إمكانية استخدام مسحوق أوراق المورينجا لإنتاج وجبات خفيفة صحية ومستدامة تلبي احتياجات الرياضيين وغير الرياضيين الذين يبحثون عن خيارات غذائية صحية.

المجلة المصرية للعلوم الزراعية – المجلد (76) العدد الثالث (يوليو 2025) 47-60.