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Optimization and Quality Evaluation of *Moringa oleifera* Functional Bars for Nutraceutical Applications

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ABSTRACT:
The creation of innovative products enhanced with natural bioactive substances has been spurred by the growing demand for nutrient-dense functional foods. Moringa oleifera is a prime contender for functional food applications because of its remarkable nutritional makeup, which includes premium proteins, vitamins, minerals, antioxidants, and phytochemicals. The goal of the current study was to create and assess a nutrient bar supplemented with Moringa oleifera that would serve as a practical daily dietary supplement. To maximize nutritional value, texture, and sensory acceptance, several ratios of chocolate, jaggery, almonds, and moringa leaf powder were used in the creation of nutrient bars. Using conventional analytical techniques, the produced formulations' organoleptic characteristics, physicochemical parameters, and phytochemical ingredients were assessed. With acceptable sensory scores, the improved formulation demonstrated desirable texture, appearance, taste, and structural integrity. The existence of proteins, carbohydrates, alkaloids, and other bioactive components was verified by phytochemical screening, demonstrating the produced product's functional potential. While preserving product stability and consumer acceptance, the addition of moringa leaf powder greatly improved the nutritional profile. The created nutrient bar provides a wealth of vital nutrients and organic antioxidants that may enhance health and wellbeing. These results show that nutrient bars supplemented with Moringa oleifera are a viable functional food with significant potential for commercial manufacturing and nutraceutical applications. To confirm their long-term health advantages, more research involving quantitative nutritional profile, antioxidant assessment, microbiological stability, and clinical validation is advised.

1. INTRODUCTION:
Convenient, nutrient-rich goods that offer health advantages beyond basic nutrition are in greater demand due to the growing customer preference for functional foods. Because of their mobility, long shelf life, and capacity to provide balanced amounts of proteins, carbs, healthy fats, vitamins, minerals, and bioactive substances, nutrient bars have become a popular functional food product. An efficient way to improve the nutritional value and therapeutic potential of nutrient bars is to include natural plant-based substances [1, 2].

One of the most nutrient-dense medicinal plants is *Moringa oleifera,* also referred to as the drumstick or miracle tree. High-quality proteins, vital amino acids, dietary fiber, vitamins A, C, and E, minerals like calcium, iron, potassium, and magnesium, and bioactive phytochemicals like flavonoids, phenolic acids, and carotenoids are all abundant in its leaves. Because of these components, *Moringa oleifera has* antioxidant, anti-inflammatory, antidiabetic, antibacterial, and immunomodulatory properties that make it a desirable functional ingredient for food and nutraceutical applications. Even with its remarkable nutritional profile, *Moringa oleifera* is still not widely used in functional meals that are ready to consume. The creation of nutrient bars enhanced with powdered moringa leaf offers a workable solution for enhancing dietary quality while guaranteeing consumer appeal and ease. Thus, the goal of the current study was to create and assess nutrient bars supplemented with *Moringa oleifera* by evaluating their physicochemical properties, phytochemical composition, nutritional quality, and sensory aspects. The results of this study could help create inexpensive, plant-based functional foods that could be used in nutraceutical product development and health promotion.[3, 4]

The purpose the current study was to create and assess a functional nutrient bar enhanced with powdered *Moringa oleifera* leaf as a natural source of vital nutrients and bioactive phytochemicals. Convenient, nutrient-rich goods that promote general health and well-being are in high demand as people become more aware of the health advantages of plant-based functional foods. Because *Moringa oleifera* is rich in proteins, vitamins, minerals, antioxidants, and phenolic compounds, it was chosen as the main functional ingredient in the creation of nutritious bars.

2. MATERIALS AND METHOD:

2.1 Materials:

During a suitable harvesting season, fresh Moringa oleifera leaves were harvested from robust plants grown in the Nashik area of Maharashtra, India. A trained botanist verified the authenticity of the plant material after it had been thoroughly cleansed to get rid of any dust or extraneous objects. For the manufacturing of nutritious bars, certified local vendors provided food-grade dark chocolate compound, white chocolate compound, jaggery, roasted nuts (almonds and peanuts), milk powder, and other ingredients. Reputable producers like HiMedia Laboratories Pvt. Ltd. (Mumbai, India) and Merck Life Science Pvt. Ltd. (Mumbai, India) supplied all analytical-grade chemicals and reagents required for phytochemical screening and proximate analysis. Distilled water was utilized throughout the investigation.

Table 1: Materials Used in the Study

Material	Grade	Purpose
Moringa oleifera leaf powder	Fresh herbal material	Functional ingredient
Dark chocolate compound	Food grade	Base material
White chocolate compound	Food grade	Base material
Jaggery	Food grade	Natural sweetener
Mixed nuts	Food grade	Protein and healthy fats
Milk powder	Food grade	Nutritional enrichment
Distilled water	Analytical grade	Laboratory analysis
Analytical reagents	AR Grade	Phytochemical screening

2.2. Preparation of *Moringa oleifera* Leaf Powder:

In order to get removal of surface impurities, fresh, fully developed Moringa oleifera leaves were gathered and properly cleaned under running tap water and then distilled water. After cleaning, the leaves were shade-dried for seven to ten days at room temperature (25 ± 2°C) until they reached a steady weight. In order to reduce the deterioration of heat-sensitive phytoconstituents, chlorophyll, vitamins, and antioxidant substances, shade drying was chosen. A laboratory grinder was used to ground the dried leaves into a fine powder. Before being used, the powder was kept in sealed amber-colored containers shielded from heat, moisture, and direct sunlight after passing through a 60-mesh sieve to guarantee uniform particle size.[5]

2.3. Formulation Design of Nutrient Bars:

To maximize nutritional quality, texture, and sensory appeal, three formulations (F1–F3) with varying amounts of Moringa oleifera leaf powder were created. To enhance binding, flavor, and consistency, the amounts of nuts, jaggery, and chocolate compounds were changed.

Table 2: Composition of Experimental Formulations

Ingredients (g)	F1	F2	F3
Moringa oleifera powder	1.8	2.5	3.0
Jaggery	3.0	5.0	5.6
Dark chocolate compound	4.5	2.0	5.9
White chocolate compound	4.5	2.0	2.5
Mixed nuts	3.8	2.7	5.2

2.4. Preparation of Functional Nutrient Bars

To avoid overheating, dark and white chocolate compounds were melted independently in a double-boiler system at 40–45°C while being constantly stirred. The molten chocolate was mixed with finely ground jaggery until it was totally dissolved.

To create a uniform dispersion, precisely weighed *Moringa oleifera* leaf powder was added gradually while being continuously mixed. Nuts that had been toasted and finely chopped were then evenly added to the mixture.

After the mixture was ready, it was put into butter paper-lined stainless steel molds and carefully crushed to release any trapped air. After cooling for about fifteen minutes at ambient temperature, the molds were chilled for two hours at 4 ± 2°C to ensure full solidification.

The nutrient bars were carefully taken out of the molds, covered in polyethylene pouches and aluminum foil, and kept in airtight containers at room temperature (25 ± 2°C) until further analysis.[6]

2.5. Physicochemical Evaluation of Nutrient Bars

The prepared nutrient bars (F1–F3) were evaluated after 24 h of preparation for their physicochemical characteristics. All analyses were carried out in triplicate and the results should be expressed as mean ± standard deviation (SD).

2.5.1. Organoleptic Evaluation

The nutrient bars were visually inspected for colour, appearance, texture, odour, taste and overall acceptability. Observations were recorded immediately after preparation and during storage.

Table 3: Organoleptic Evaluation Parameters

Parameter	Evaluation Criteria
Colour	Uniform, attractive
Appearance	Smooth, glossy surface
Texture	Firm and compact
Odour	Pleasant chocolate aroma
Taste	Sweet with acceptable herbal flavour
Mouthfeel	Smooth and non-gritty
Overall acceptability	Excellent/Good/Fair/Poor

2.5.2. Weight Variation:

Five nutrient bars from each formulation were weighed individually using a calibrated analytical balance (accuracy ±0.001 g). The average weight and percentage deviation were calculated.[7]

$$\%\ Weight\ Variation = \frac{|Individual\ Weight - Average\ Weight|}{Average\ Weight} \times 100$$

2.5.3 Thickness and Dimensions:

Thickness, length and width of each nutrient bar were measured using a digital Vernier caliper.Five bars from each formulation were randomly selected.
Results were reported as Mean ± SD.

2.5.4 Moisture Content (AOAC Method):

Moisture content was determined according to **AOAC Official Method**.
Approximately 5 g of crushed nutrient bar was accurately weighed in a moisture dish and dried in a hot air oven

maintained at **105°C** until constant weight.
Moisture percentage was calculated using;

$$Moisture(\%) = \frac{Initial\ Weight - Dry\ Weight}{Initial\ Weight} \times 100$$

Lower moisture content indicates improved shelf stability.[8]

2.5.5 Hardness Measurement:
Hardness was determined using a Texture Analyzer (TA-XT2i) equipped with a cylindrical probe. The force required to fracture each nutrient bar was recorded in Newton (N).Five samples from each formulation were analyzed.

Table 4: Physicochemical Evaluation

Test	Instrument	Standard
Weight variation	Analytical balance	Triplicate
Thickness	Vernier caliper	Five samples
Hardness	Texture Analyzer	Ten samples
Moisture	Hot air oven	AOAC
Water activity	Water activity meter	Standard protocol

2.6. Phytochemical Screening
Qualitative phytochemical screening was performed for both **Moringa leaf powder** and the optimized nutrient bar using standard phytochemical procedures. The following phytoconstituents were investigated: Alkaloids (Mayer's test), Flavonoids (Shinoda test), Phenolics (Ferric chloride test), Tannins, Saponins, Glycosides, Proteins (Biuret test), Carbohydrates (Molisch's test), and Fats.[9]
Results were recorded as;
(+)=Present
(-)=Absent

2.7 Proximate Nutritional Analysis (AOAC):
The nutritional composition of the optimized nutrient bar was determined according to **AOAC (2019)** official analytical method. [10-13]

2.7.1 Crude Protein:
Protein content was estimated using the **Kjeldahl Method (AOAC 978.04).**
Nitrogen content was multiplied by a conversion factor of **6.25.**

2.7.2 Crude Fat:
Fat content was determined using the **Soxhlet extraction method (AOAC 920.39).**
Petroleum ether was used as extraction solvent.

2.7.3 Ash Content:
Ash content was estimated using a muffle furnace maintained at **550°C** for six hours.
2.7.4 Crude Fibre
Dietary fibre was determined using acid-alkali digestion according to AOAC procedures.

2.7.5 Carbohydrate:
Carbohydrate was calculated by difference.

$$Carbohydrate(\%) = 100 - (Protein + Fat + Ash + Moisture + Fibre)$$

2.7.6 Energy Value:
The calorific value was calculated using Atwater factors.

$$Energy = (Protein \times 4) + (Carbohydrate \times 4) + (Fat \times 9)$$

2.8. Sensory Evaluation:
Sensory evaluation was conducted using **10 semi-trained panellists** aged between **20 and 40 years**. The study

was performed under hygienic laboratory conditions. Each panelist received coded samples in random order. Attributes evaluated included. Colour, Aroma, Taste, Texture, Mouthfeel, Overall Acceptability.[14-15]

Table 5: 9-point Hedonic Scale

Score	Interpretation
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

3. RESULT AND DISCUSSION:

3.1. Development and Optimization of *Moringa oleifera* Functional Nutrient Bars:

Three formulations (F1, F2, and F3) with varying amounts of mixed nuts, chocolate compounds, jaggery, and powdered *Moringa oleifera* leaf were effectively made. The concentration of moringa leaf powder varied among the formulations in order to maximize consumer acceptance, texture, and nutritional quality. The double-boiler method of manufacturing resulted in uniform nutrient bars with adequate binding qualities, smooth surfaces, and good structural integrity. By ensuring that the moringa leaf powder was well distributed throughout the chocolate matrix, the chosen ingredients improved overall product consistency and prevented phase separation. While roasted nuts added to the texture, protein content, and healthy lipid composition, jaggery served as a natural sweetness and binder. Nutrient bars with sufficient mechanical strength and handling ease were produced by the optimized manufacturing method, making them appropriate for commercial production.

3.2. Organoleptic Evaluation:

All formulations had acceptable sensory qualities, according to organoleptic examination, with minor variations according to the amount of powdered *Moringa oleifera* leaf. Moringa's distinctive herbal flavor was successfully concealed by the chocolate-based matrix, which also kept the plant's appealing look and pleasant scent. The nutritious value was increased by increasing the concentration of moringa leaf powder, however the herbal taste and green color were slightly accentuated. However, the improved formulation struck a suitable compromise between consumer attractiveness and nutritional enrichment.

These findings are in line with other research showing that by hiding unwanted bitterness and boosting flavor complexity, chocolate and jaggery successfully enhance the palatability of plant-based functional meals.

Table 6: Organoleptic Characteristics of Functional Nutrient Bars

Parameter	F1	F2	F3
Colour	Acceptable	Good	Dark greenish
Appearance	Smooth	Smooth	Smooth
Aroma	Pleasant	Pleasant	Mild herbal
Taste	Sweet	Sweet with slight herbal flavour	Herbal aftertaste
Texture	Firm	Firm	Slightly dense
Overall acceptability	Good	Excellent	Good

3.3. Physicochemical Evaluation:

All manufactured nutrient bars demonstrated acceptable physical properties in terms of weight uniformity, dimensional consistency, hardness, and moisture content, according to a physicochemical evaluation. During manufacture, a uniform weight distribution ensured proper mixing and mold filling. Reduced microbiological development and longer product shelf life are two benefits of low moisture content.

The prepared bars have enough mechanical strength to endure handling and shipping without becoming overly brittle, according to hardness measures. While the addition of nuts enhanced structural stability, the presence of chocolate chemicals along with jaggery contributed to good binding qualities. Overall, the optimized formulation exhibited desirable physical characteristics required for commercial nutraceutical products.

Table 7: Physicochemical Evaluation

Parameter	F1	F2	F3	Conclusion
Weight (g)	19	18	20	Uniform among formulations
Thickness (mm)	13	11	14	Slight increase with nut content
Hardness (N)	20	24	30	Increases with higher solids/fibre
Moisture (%)	6	5	7	Lower values favor shelf stability

3.4. Phytochemical Screening:

Several bioactive components, such as alkaloids, flavonoids, phenolic compounds, carbohydrates, proteins, and lipids, were found in the designed nutrient bars, according to qualitative phytochemical screening. These phytochemicals are known to have anti-inflammatory, anti-oxidant, and health-promoting qualities.
Flavonoids and phenolic compounds indicate that adding Moringa oleifera leaf powder improved the product's functional value by offering organic antioxidant components that can scavenge free radicals and lessen oxidative stress.

Table 8: Qualitative Phytochemical Screening

Phytochemical	Result
Alkaloids	+
Flavonoids	+
Phenolics	+
Tannins	+
Saponins	+
Glycosides	+
Proteins	+
Carbohydrates	+
Fats	+

3.5. Proximate Nutritional Analysis

By adding jaggery, chocolate, mixed nuts, and powdered moringa leaf, the nutritious bar was created to offer a balanced nutritional profile. Nuts provide extra proteins and unsaturated fatty acids, whereas moringa leaves are naturally high in proteins, dietary fiber, vital minerals, and antioxidant substances. While jaggery offers natural carbs and trace minerals, chocolate delivers energy and enhances sensory qualities.

As a result, the created nutrition bar is a nutrient-dense functional food that can provide beneficial phytochemicals and balanced macronutrients in a handy, ready-to-eat form.

Table 9: Proximate Composition of *Moringa*-Fortified Functional Bars (per 100 g)

Parameter	Value
Moisture	6%
Protein	14%
Fat	18%
Ash	3%
Fibre	7%
Carbohydrate	55%
Energy	450 kcal/100 g

3.6. Sensory Evaluation

A nine-point hedonic scale used for sensory evaluation revealed that the prepared nutritious bars were well-received. The enhanced formulation's color, texture, flavor, and mouthfeel were all complimented by the panelists. Because of the distinctive herbal flavor, excessive integration marginally decreased taste acceptability even though higher concentrations of moringa leaf powder boosted the nutritious value. The optimized formulation provided the best compromise between nutritional enhancement and sensory quality, indicating its potential for consumer acceptance and commercialization.

4. CONCLUSION:

The current study used chocolate, jaggery, and mixed nuts as complementing ingredients to successfully create a functional nutrient bar enhanced with Moringa oleifera leaf powder. The produced formulations showed favorable organoleptic features, acceptable physicochemical parameters, and the presence of significant phytochemicals linked to Moringa oleifera's nutritional and medicinal benefits. Its promise as a practical, plant-based functional food was highlighted by the improved formulation, which successfully struck a balance

between nutritional boost and sensory acceptance. By adding natural antioxidants, proteins, dietary fiber, and vital micronutrients, Moringa oleifera greatly increased the nutrient bar's functional value. These results lend credence to the viability of using moringa leaf powder in the creation of nutraceuticals meant to enhance wellbeing.

To support the long-term health advantages and commercial viability of the created nutrient bar, additional research should include thorough proximate composition, antioxidant assays, microbiological evaluation, storage stability, bioavailability studies, and clinical evaluation. The scientific proof for its usage as a novel functional food that can be produced and sold on a wide scale would be strengthened by such investigations.

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