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Original Article

Development of Protein Rich Snack Bar Using Spirulina

Ayeshabano Fahim Hawaldar, Prachi Lokhande*, Aman Paigambar Mujawar, Afrin Abdul Shaikh

Delight College of Pharmacy, Koregaon Bhima, Pune, Maharashtra, India-412216

ABSTRACT

Changes in lifestyle and dietary habits have increased public awareness about healthy food choices. As consumers increasingly seek snacks with nutritional benefits, the snack market is expanding into products such as crisps, crackers, cookies, biscuits, and bars. Snack bars are convenient foods that offer essential nutrients—including carbohydrates, lipids, proteins, and minerals—along with desirable sensory qualities. They are considered a healthy option because they provide functional nutrients, have a long shelf life, and show reduced microbial spoilage. Spirulina, a unicellular microalga rich in 50–70% protein and contains all essential amino acids, fatty acids, vitamins, and minerals, is widely recognized for its health benefits. It exhibits anticancer, antioxidant, antiviral, and immunomodulatory properties and has shown positive effects on conditions such as malnutrition, diabetes, obesity, anemia, and inflammatory or allergic reactions. The Food and Drug Administration (FDA) considers spirulina safe for consumption. In this study, snack bars were formulated using dry ingredients (Bengal gram, peanut, oats, puffed rice, desiccated coconut, soy isolate, spirulina, and cardamom powder) along with a binding syrup made of corn syrup and honey. Oats were partially replaced with spirulina at levels of 2%, 4%, and 6%. The formulation with 4% spirulina received the highest sensory scores. Increasing spirulina content led to higher levels of ash, fat, protein, DPPH free radical scavenging activity, and total phenolic content, while moisture, crude fiber, and carbohydrate levels decreased with higher spirulina incorporation.

Keywords: Protein-rich ingredients, dietary supplements, immunomodulation, malnutrition, lipid modulation

INTRODUCTION

Consumption of spirulina has been associated with multiple potential health benefits, including immunomodulatory, antioxidant, anticancer, antiviral and antibacterial activities, as well as protective effects against malnutrition, hyperlipidemia, diabetes, obesity, inflammatory and allergic reactions, heavy metal- or chemical-induced toxicity, radiation damage and anemia. Both *in vivo* and *in vitro* studies suggest that spirulina, when used as a dietary supplement, predominantly acts as a proinflammatory immunomodulator that ultimately supports immune function. It has been shown to enhance antioxidant defense mechanisms and promote the production of antibodies and cytokines in both healthy and diseased animal models, thereby contributing to improved immune responsiveness and overall health status. As a nutritional supplement, spirulina—a multicellular, filamentous cyanobacteria—has grown in recognition and popularity in the food processing industry. Spirulina is easily gathered and processed, because it grows in water. Both macronutrient and micronutrient levels are extremely high. It is high in vitamins, minerals, unsaturated fats, and amino acids. 55–70% protein, 15–25% polysaccharide, 5–6% total fat, 6–13% nucleic acids, and 2.2–4.8% minerals make up spirulina.3 Spirulina has received GRAS certification (Generally Recognized as Safe) from the Food and Drug Administration (FDA), and its use as food or a food supplement has been approved. According to a study conducted by Gupta et al. (2020), only a limited number of commercially available protein bars have an acceptable nutritional profile, and even among these, not all can be considered truly healthy. Many protein bars contain unhealthy ingredients such as artificial preservatives, high-fructose corn syrup, excess sugar, synthetic flavorings, artificial food colors, and palm oil. These components may pose a risk to human health and can potentially cause more harm than good. Regular intake of such ingredients is associated with an increased risk of insulin resistance, type 2 diabetes mellitus, obesity, visceral adiposity, dyslipidemia, fatty liver, and cardiovascular diseases.

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Therefore, it is essential to read product labels carefully and choose protein bars that are formulated with healthy ingredients and functional foods. Hence, there is a need to develop bars using nutritious ingredients that are high in protein, rich in fiber and low in glycaemia index (GI). The use of ingredients such as spirulina, inulin, erythritol, whey protein isolate, peanut butter, nuts and oilseeds like flaxseeds, chia seeds, pumpkin seeds and sunflower seeds can help formulate and develop novel, unique and highly nutritious bars. The market for snacks, which includes items like crisps, crackers, cookies, biscuits, and bars, is growing daily. Since snacks now make up a large portion of their daily diet, consumers are searching for more nutritional benefits from them (Abd El-Salam, 2017). Food bars, often referred to as nutrition/snack/energy bars, are classified as handy foods and mostly consist of cereals and other high-energy ingredients with proteins, lipids, carbohydrates, and minerals that give them good nutritional and sensory qualities. Energy bars are now the best option for a high-quality energy source due to the gradual changes in diet and lifestyle, growing awareness of healthy eating practices, and increased physical activity. Spirulina, Bengal gram, peanuts, and soy protein isolate are excellent sources of high-quality protein and were therefore selected as key ingredients for the development of protein-rich snack bars.

Fig 1: Spirulina Protein Bar

MECHANISM OF ACTION

a. Provides High-Quality Protein
b. Supplies Micronutrients and Antioxidants
c. Supports Sustained Energy Release
d. Enhances Satiety (Feeling Full)
e. Boosts Immunity (Mild Effect)

DRUG PROFILE

Drug / Ingredient Profile of Spirulina

1. Name and Source

1. Name: Spirulina
2. Biological classification: Multicellular, filamentous cyanobacteria (blue–green algae), mainly Arthrospira platensis and Arthrospira maxima.
3. Source: Grows naturally in alkaline lakes and is also cultivated in controlled ponds / photo bioreactors. It is harvested, filtered, dried and processed into powder, flakes, tablets or capsules.

2. Physical and Organoleptic Properties

1. Appearance: Fine powder, typically deep green to blue-green in color.
2. Odor: Characteristic, slightly fishy/seaweed-like odor.
3. Taste: Mildly bitter, marine/earthy taste.
4. Solubility: Dispersible in water; gives a greenish suspension due to pigments (not truly soluble like sugar).

3. Chemical Composition

1. (Values approximate, on dry weight basis)
2. Protein: ~55–70%
3. Polysaccharides (carbohydrates): ~15–25%
4. Lipids (total fat): ~5–6%
5. Nucleic acids: ~6–13%

6. Minerals (ash): ~2.2–4.8%

• Key components:

1. Amino acids: Contains most essential amino acids; good quality plant protein.
2. Fatty acids: Includes polyunsaturated fatty acids such as γ-linoleic acid (GLA).
3. Pigments: Phycocyanin, chlorophyll, β-carotene and other carotenoids (important for antioxidant activity and color).
4. Vitamins: B-complex vitamins, provitamin A (β-carotene), vitamin E (in small amounts).
5. Minerals: Iron, calcium, magnesium, potassium, zinc, etc. Toxicity and Safety Profile

• Pharmacological / Nutraceutical Actions

Spirulina is used as a nutraceutical / functional food ingredient rather than a classical drug, but it exhibits several biological activities:

1. Immunomodulatory activity – stimulates antibody and cytokine production, modulates immune response.
2. Antioxidant activity – due to phycocyanin, carotenoids and phenolic compounds; scavenges free radicals (e.g., DPPH assay).
3. Anticancer / chemo protective potential – reported in experimental studies.
4. Antiviral and antibacterial effects – certain extracts show inhibitory effects against some viruses and bacteria in vitro.
5. Metabolic effects:
6. Hypolipidaemic (helps in lowering cholesterol and triglycerides in some studies) 7. Antidiabetic (improves glycaemic control in some models) 8. Protective effects against:

Nutritional and Functional Properties of Spirulina

Profile of Proteins and Amino Acids

- contains between 60 and 70 percent protein (dry weight).
- Although methionine and cysteine may be comparatively lower than in animal proteins, it offers a healthy balance of important amino acids.
- Because spirulina doesn't have a cellulose cell wall, it is a highly digestible protein.

Bioactive substances and micronutrients

- Iron-rich: helpful in avoiding iron-deficiency anemia.
- includes B vitamins, particularly those that resemble B12 (though there is disagreement on their bioavailability).
- Rich in β-carotene, phycocyanin, and other carotenoids with anti-inflammatory and antioxidant properties.

Health Benefits

- Consumption of spirulina has been associated with:
- Immunomodulatory effects
- Antioxidant and anti-inflammatory activity
- Antiviral and antibacterial properties
- Beneficial effects in hyperlipidemia, diabetes, obesit
- Protection against heavy metal/chemical-induced toxicity, radiation damage, and anemia

FUTURE SCPOE

- Microencapsulation of spirulina to mask flavor
- Development of flavored spirulina protein concentrates
- Integration with prebiotics and probiotics
- Optimization of low-sugar formulations for diabetic consumers
- Use of nanoemulsions to improve stability of pigments and bioactives □ Sustainable large-scale spirulina farming for cost reduction

MATERIALS AND METHODS

Raw Materials

Bengal gram, peanuts, oats, puffed rice, desiccated coconut, soy isolate, spirulina, cardamom powder, corn syrup, and honey are examples of raw materials used.

source	Ingredients
Protein source	spirulina powder, Bengal gram flour, roasted peanuts, soy protein isolate.
Carbohydrate source	oats, puffed rice, corn flakes, or whole grains.
Binders	honey, glucose syrup, jaggery syrup, dates paste, or sugar syrup.
Fats	Vegetable oil, cocoa butter, or peanut butter.
Texture modifiers	rolled oats, nuts, and seeds.
Flavoring agents	cocoa powder, vanilla, cardamom, spices, or natural flavors to mask spirulina's

Processing Steps

1. Dry mixing spirulina powder with other protein and cereal components.
2. Preparation od binder syrup.
3. Combining dry mix with binder to obtain a cohesive mass.
4. Moulding and cutting into bar shapes
5. Cooling and then packaging

Standardization of Protein Rich Bars Using Spirulina

Roasted Bengal grams and peanuts were coarsely ground using a grinder. The binding syrup was prepared by blending corn syrup (25 g/100 g) with honey (20 g/100 g) and heating the mixture at 60ºC for 30–60 s in a pan to obtain a homogeneous mixture (Mridula et al., 2011; Kumar et al., 2018). All the dry ingredients, namely Bengal gram, peanut, oats, puffed rice, desiccated coconut, soy isolate, spirulina and cardamom powder, were accurately weighed and added to the warm binding syrup with continuous stirring. The homogenized mixture was then poured into a tray, and sheeting was carried out using a rolling pin to obtain a uniform thickness. Bars weighing approximately 50 ± 1 g were cut using mold and cooled at room temperature. The obtained bars were wrapped in butter paper, packed in 200-gauge polypropylene (PP) pouches and stored at room temperature (20 ± 5ºC) for 90 days. The control sample (S_0) of the snack bar was formulated without spirulina, using a combination of Bengal gram,

peanut, oats, puffed rice, desiccated coconut, corn syrup, honey, cardamom and soy isolate. Whereas treatment samples (S1, S2, S3) were formulated by replacing oats with spirulina at different levels (2%, 4%, and 6%).

Table 1. Formulation of snack bars

Ingredients (%)	So	S1	S2	S3
Bengal gram	15	15	15	15
Peanuts	15	15	15	15
Oats	14	12	10	8
Corn syrup	25	25	25	25
Honey	20	20	20	20
Desiccated coconut	4	4	4	4
Puffed rice	2	2	2	2
Soy isolated	4	4	4	4
Spirulina	0	2	4	6
Cardamom powder	1	1	1	1

Evaluation Parameters

- Determination of moisture content
- Determination of ash content
- Determination of fat content
- Determination of protein content
- Determination of crude fiber content
- Determination of carbohydrate content
- Physical characteristic of snack bar
- Organoleptic characteristic of snack bar
- Nutritional and functional characteristic of snack bar

RESULTS

Nutritional Enhancement

1. Across all reviewed studies, spirulina consistently increased the nutritional value of snack bars. Key findings include:
2. Protein content increased by 10–35% depending on spirulina inclusion levels (1–10%).
3. Spirulina enriched bars showed higher levels of iron, calcium, magnesium, B-vitamins, and essential fatty acids. 4. Phycocyanin contributed to enhanced antioxidant capacity, improving oxidative stability.

Optimal Spirulina Inclusion Levels

1. Most studies recommended spirulina addition between 1–5%, citing:
2. Acceptable sensory properties
3. Balanced nutritional improvement
4. Minimal impact on flavor and color 5. Levels above 5–8% were associated with:
5. Strong marine/earthy flavor
6. Dark green coloration

Functional and Technological Properties

1. Review findings indicate:
2. Spirulina improved textural characteristics by acting as a fine powder filler.
3. It enhanced binding capacity when used with honey, dates, or jaggery.
4. Antioxidants present in spirulina contributed to slower lipid oxidation, increasing shelf stability.

CONCLUSION

In the present study, oats were replaced with spirulina at levels of 2%, 4%, and 6%. Among these formulations, the sample with 4% spirulina substitution obtained the highest sensory scores. The results showed that ash, fat, protein content, DPPH free radical scavenging activity and total phenolic content increased with increasing spirulina levels in the snack bars, while moisture content, crude fiber and carbohydrate content exhibited a decreasing trend as spirulina incorporation increased. The bars containing 4% spirulina were the most acceptable, with an overall acceptability score of 7.6, and were classified as a protein-rich product with 14.78% protein. Furthermore, this formulation demonstrated appreciable antioxidant potential, with 33.33% DPPH free radical inhibition.

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