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Review Article

Nutraceutical-Enriched Protein Bars: Functional Ingredients, Health Benefits, and Future Prospects

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ABSTRACT

A popular functional snack, protein bars meet the nutritional needs of a wide range of people, particularly athletes and health-conscious customers. These bars contain a high protein content, vital vitamins, minerals, fiber, antioxidants, and phytonutrients, combining convenience and health advantages. Review topics include the categorization of nutraceuticals used in protein bars, the utilization of dietary fiber, probiotics, and prebiotics, and the contribution of antioxidants and polyunsaturated fatty acids to general health. A variety of bar kinds, including fruit, fruit peel, nutritional, weight loss, energy, and protein bars, are assessed based on their composition, intended health benefits, and formulation. Protein bars, which use food byproducts, boost immune function, weight control, bone health, muscular growth, and sustainable practices. Recent developments, motivated by shifting customer preferences for natural, minimally processed, and allergy-free products, place an emphasis on fortifying products with clean-label, plant-based, and functional ingredients. Future possibilities include new formulations designed to meet certain health requirements, as well as increased sustainability through the use of digital product traceability and a variety of protein sources. A thorough summary of the advantages, formulation techniques, and changing trends in protein bar production is given in this paper, underscoring the importance of these products for worldwide nutrition and health promotion.

INTRODUCTION

Food items known as nutraceuticals provide medical and health advantages, including the prevention and treatment of disease. Two main categories of nutraceuticals are phytochemicals and antioxidants[1]. The continued rise in interest in nutraceuticals and functional foods is being driven by developments in research to identify the properties and potential applications of nutraceutical components, as well as consumer

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demand and public interest. The primary forces behind the growth of the functional food market are current health and demographic trends[3].The word itself combines the words "pharmaceutical" with "nutrition"[1,2]. Protein bars are one product that meets customer demands for a low-carb, high-protein diet[1]. Manufacturers must ascertain the optimal sweetness and texture levels to satisfy consumers while preserving a high-protein, low-carbohydrate bar, considering the magnitude of the protein bar market[1,4]. Vitamins, minerals, antioxidants, and fiber are just a few of the health-promoting elements found in fruits and vegetables. These priceless goods are necessary to guarantee the security of food and nutrition. Consuming them is essential to maintaining a healthy, well-balanced diet[1,5]. Furthermore, consumers are increasingly interested in five different protein sources: pulses, algae, insects, plant-based proteins, and cultured meat[1,6].

Nowadays, consumers demand foods that are easy to handle, store, and eat. These foods include low-calorie diets that are higher in protein, fiber, and antioxidants. Because they are so simple to use, ready-to-eat products like snack bars have a high value[46,47]. While the expanding food protein market presents new prospects for protein product development, it also presents new obstacles for food protein innovation and research[48,49]. Energy and necessary amino acids are needed for human growth and maintenance, and dietary proteins provide both. Many food proteins also have particular biological properties that can affect human health and stave off illnesses[48]. These food products' quality is also crucial. In addition to nutritional quality factors like energy, vitamins, minerals, fiber, and several bioactive components that enhance human health, consumers are mostly focused on the color and flavor of food ingredients[45,50].

Grouping of Nutraceuticals

Every food source used to create nutraceuticals is natural and belongs to one of the following groups:

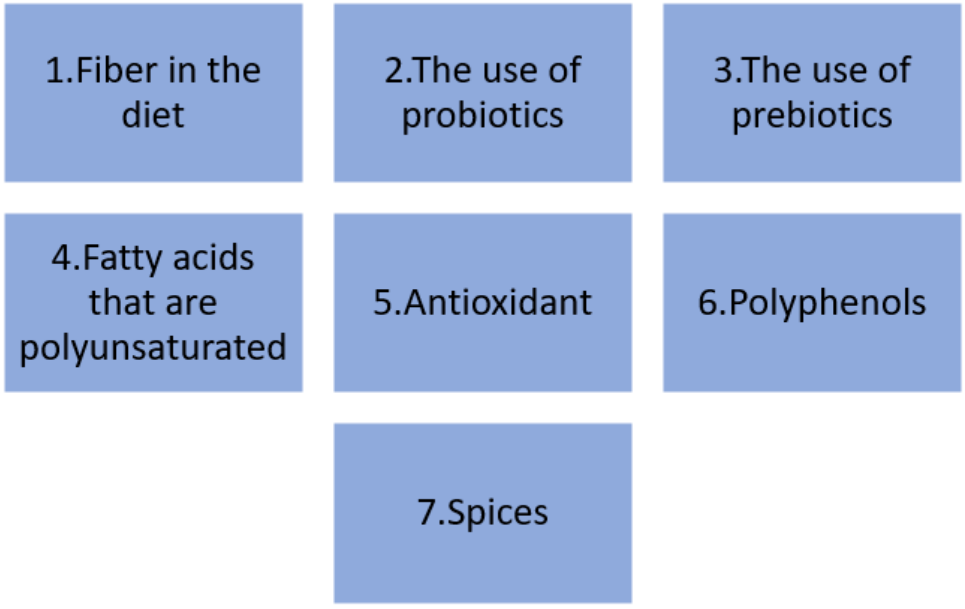

Fig 1: Grouping of nutraceuticals

Fiber in the diet

Dietary fiber (DF) is composed of naturally occurring, intact lignins and nondigestible

carbohydrates found in plants. Functional fiber (FF) is made up of separate, indigestible carbohydrates that have positive physiological effects on people. Dietary and functional fibers add up to total fiber. These definitions expand the notion of functional fibers to include resistant starches, oligosaccharides, and other indigestible carbohydrates. The Dietary Reference Intake (DRI) states that adults should consume 38 grams of fiber per day for males and 25 grams per day for women. To establish a reasonable upper consumption level for dietary or functional fiber, there was not enough data[7].

The use of probiotics

Probiotics, which are live yeasts and bacteria, are good for your health, especially for your digestive tract. Most of the time, we associate germs with illness. However, both beneficial and harmful microorganisms abound in your body. It is common to refer to probiotics as "good" or "helpful" bacteria since they promote gut health. Your body naturally contains probiotics. They are also present in a few foods and supplements[7].

The use of prebiotics

Compared to dietary fiber, the health outcome evidence for prebiotic consumption is far more sparse. However, taking prebiotics may: Increase the absorption and bioavailability of minerals including calcium, magnesium, and potentially iron; reduce a few cardiovascular disease risk factors; Encourage fullness, reduce body weight, and avoid obesity; Decrease the frequency and length of diarrhea caused by infections and antibiotics; lessen inflammatory bowel disease symptoms and inflammation; and offer preventative benefits against colon cancer[7].

Fatty acids that are polyunsaturated

Due to differences in the location of the first double C-bound, the group of polyunsaturated fatty acids (PUFAs) is separated into two groups: omega-3 (n-3) and omega-6 (n-6) PUFAs. Since the human body is unable to produce two PUFAs and they are necessary for maintaining physiological integrity, they are referred to as essential fatty acids. As a result, the diet must provide them. The first is linoleic acid (LA), which is a member of the n-6 family. The second is α-linolenic acid (LNA), which is a member of the n-3 family. The human body can convert these vital parent chemicals into long-chain (LC) fatty acids, but it is unable to interconvert n-3 and n-6 fatty acids[7].

Antioxidant

It is believed that aging and the emergence of disease are significantly influenced by the harm that free radicals cause to cells. As our first line of defense against damage from free radicals, antioxidants are crucial for maintaining optimum health and wellness. Oxygen, being an extremely reactive atom, can combine to create potentially dangerous substances called "free radicals." Free radicals can damage the body's healthy cells, causing them to lose their structure and ability to operate. Before free radicals have an opportunity to damage cells, antioxidants can stabilize or deactivate them. Antioxidants have an important role in maintaining optimal cellular and systemic health and well-being[7].

Polyphenols

Plant-based foods like fruits, vegetables, whole grains, cereal, legumes, tea, coffee, wine, and cocoa contain natural phytochemicals called polyphenols. Whole plant foods have been found to contain over 8000 different types of polyphenolic compounds, such as phenolic acids, flavonoids[39], tilbenes, lignans, and polymeric

lignans. These substances, which are secondary metabolites of the plants, provide protection against oxidants, infections, and UV light[40]. Based on the quantity of phenol rings and the structural components that hold these rings together, polyphenols can be divided into a number of groups. The two main classes of phenolic acids comprise about one-third of the polyphenolic compounds found in the diet:

a) hydroxybenzoic acid derivatives (protocatechuic acid, gallic acid, p-hydroxybenzoic acid) and

b) hydroxycinnamic acid derivatives (caffeic acid, chlorogenic acid, coumaric acid, ferulic acid, and sinapic acid). Foods high in these phenolic acids7 include berry fruits, kiwi, cherry, apple, pear, chicory, and coffee[7].

Spices

Since ancient times, the culinary technique of flavouring food has relied heavily on spices. Spices are fragrant vegetable compounds that can be crushed, broken, or whole. Their main use in food is for flavour, not for nutritional purposes. Foods are given distinctive flavour, aroma, and pungency by these spice components. The oleoresin, flavour, and aroma-producing volatile oil spices add to the pungency. Spices play an important role in the economy of the producing nation because, in addition to being used for flavouring and seasoning, they are widely used in medicinal products, pharmaceuticals, aromatherapy, nutraceuticals, beverages, natural colours, perfumes, dental preparations, cosmetics, and botanicals as pesticides. The wide range of compounds that these spices synthesise are responsible for these qualities. Indian spices are being consumed more globally to suit the demands of the conventional food industry due to the growing demand from the developing nutraceuticals market. Nowadays, around 15% of the nation's spice production comes from nontraditional uses of spices, such as nutraceuticals[7].

Types of Bars:

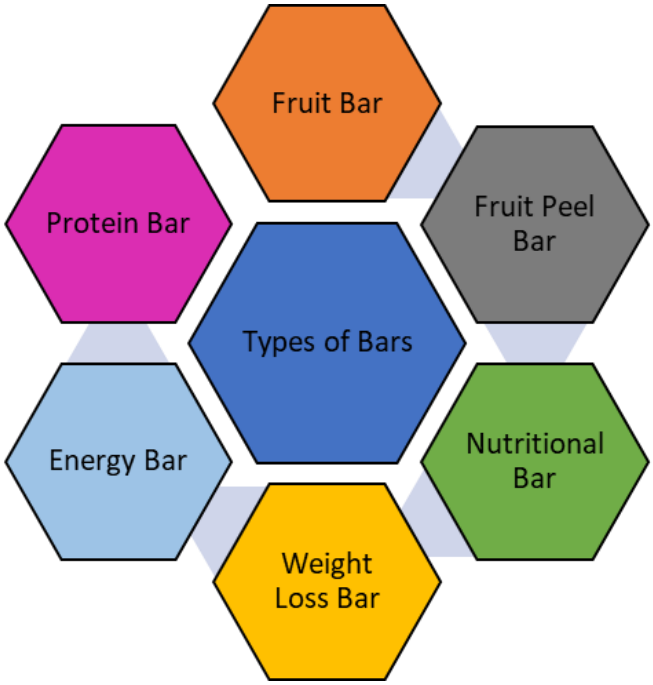

Fig 2: Types of Bars

1.Fruit bar:

To make fruit bars, different amounts of fruit pulp are combined with additives like binders, and the mixture is subsequently dried in a mechanical dehydrator. Numerous noteworthy health advantages, including as better gastrointestinal health and a lower risk of cardiovascular disease, have been linked to dates and other fruit-based ingredients [1,8,9].

2.Fruit peel bar:

Because they are difficult to dispose of, fruit peels are often considered waste and present an environmental problem for many industries[10]. Fruit and vegetable peels make up a sizable amount of the kitchen garbage produced each year. This waste is increased by an increasing population because of the increased demand for raw materials[11]. On the other hand, fruit peels are a great source of antioxidants, vitamins, and minerals. Fruit peel bars make use of this untapped nutritional potential to provide a wellness and energy boost. Banana peels' potassium content, for instance, may improve heart health and reduce blood pressure [1,12].

3.Nutritional bar:

Designed to improve the quality of the diet, nutritional bars can be used in place of morning or afternoon snacks to go along with main meals. Dates, peanuts, garden cress seeds, dry fruits, and honey are a few possible ingredients in these bars; they are all great providers of micronutrients[13]. The demand for healthy snacks is rising as a result of customers' increased desire for wholesome, practical, and health-improving goods [1,14].

4.Weight loss bars:

To combat the metabolic impacts of obesity, these bars can be used as dietary supplements [15]. Regular intake of goods made from oats has been shown to help lower cholesterol levels, which in turn lowers the risk of cardiovascular disease [1,16].

5.Energy bar:

Energy bars are compact and convenient composite foods that are commonly consumed as a possible meal substitute to provide essential nutrients in sufficient amounts. Energy bars are a dense, energy-rich composite food with a significant portion of cereals. Besides serving as meal substitutes, energy bars can act as a concentrated and portable source of carbohydrates. These bars are easy to transport, making them valuable in situations where traditional food options are limited, as well as for specific uses like military or space applications. Additionally, they include various ingredients such as seeds, nuts, dried fruits, and more [31.]

6.Protein bar:

Fig 3: Protein Bar

When participating in regular physical exercise, healthy people frequently need protein supplements to stimulate muscle growth and preserve general fitness [17]. Since protein is also crucial in the fight against malnutrition, a number of randomised controlled trials have looked at the nutritional effects of eating commercial protein bars [18]. This study's objective is to make and evaluate high-protein bars with lupine seeds, wheat germ, and different dried fruits such peanut

butter, sesame, cranberries, dates, apricots, and raisins. Along with extending the product's shelf life, the created bars are expected to enhance the product's phytochemical, nutritional, and sensory attributes. Furthermore, it is essential for the final product to meet consumers' expectations for convenience and health benefits; thus, a comparative assessment of the chemical and sensory characteristics of the raw materials and the finished bars was carried out to fulfill specific nutritional standards and to position the product as an optimal nutritional supplement for athletes in the future[44]. These items have higher protein content, exceeding 20 grams of protein per serving, and are rich in fiber, while being low in carbohydrates and sodium. They are also enriched with vitamins, minerals, and antioxidants.

The limited range of proteins included in high-protein bars that are commonly sold in stores come from both plant (mostly soy protein isolates and concentrates) and animal (mostly whey protein isolates and concentrates) sources. Studies have indicated that adding whey protein hydrolysates to high-protein bars helps preserve their soft texture, although it may also result in a little bitter aftertaste[42].Whey derivatives, including concentrates or isolates, are rich sources of proteins, specifically alpha-lactalbumin and beta-lactoglobulin. In the food industry, these types of proteins are commonly utilized due to their high nutritional value, appealing sensory characteristics (notably their milk flavor), and excellent functional benefits[43]. High-protein items, such as bars, have seen a significant rise in popularity lately. Specifically, products that are fortified with protein or primarily consist of protein can be used in offerings aimed at a diverse range of consumers [41]. Energy bars high in protein are well-known for being a great nutritional supplement for athletes, aiding in the development and maintenance of connective tissues. These days, high-protein bars play a significant role in the food industry because of the growing demand for this kind of product, particularly when it comes to foods for athletes and those following vegan and vegetarian regimens. There is a greater need for convenience and ready-to-eat food products that are fresh, natural, minimally processed, and additive-free due to the current work style and the rise in families with two working partners, which has reduced the amount of time available for cooking [19,20]. Consumers of all ages now prefer snack-style meals over fast food, whether or whether they have significant nutritional value [19,21]. Consumers now place more value on factors like convenience, sustainability, and the food products effects on their health as a result of recent shifts in their shopping habits and food consumption habits. This is a problem for the food business, particularly when it comes to perishable goods like fresh produce [19,22].

As a result, current research focuses on maximizing the use of harvested fruits and vegetables while reducing the quantity of waste generated during processing. It is advised that food products be ingested in their whole form. A product's composition may lose more vitamins, minerals, or fiber the more processed it is [23]. Thus, creating a protein snack that is nutritionally balanced is a goal that is both technically and technologically advanced. Food bars' primary qualities are their ease of consumption and sufficient nutritional value for the consumer's health. Food bars come in a variety of shapes in the markets, but the most common ones are unsweetened cereal and fruit bars, sweet fruit bars, and salty and sweet cereal bars. They are a good source of protein, fiber [24], and energy [25] due to their primary constituents [19].

Importance

Cereal bars and snack bars, which are popular among teenagers, are manufactured by numerous

companies in the processed food sector. The use of energy bars has rapidly expanded in the United States due to improved sensory qualities (taste, color, and texture), convenience (portability, shelf life, and preparation time), and efficiency. Bars are lightweight and easy to transport. They are therefore helpful in situations where eating traditional cuisine is not feasible. Applications may be very specialized, such as for space food and the military. Energy bars are a substantial and portable source of carbohydrates that can be used as a meal substitute. Additionally, they supply proteins that, when digested, can produce bioactive peptides. These peptides have particular functions and can help the host's physiology. Athletes and other physically active consumers can use energy bars as a portable energy source. In addition, energy bars can be used for nutrition by those on a diet, those with nutritional issues, or those who eat irregularly, as long as they don't contain allergens or antinutritional ingredients that are harmful to their health [26].

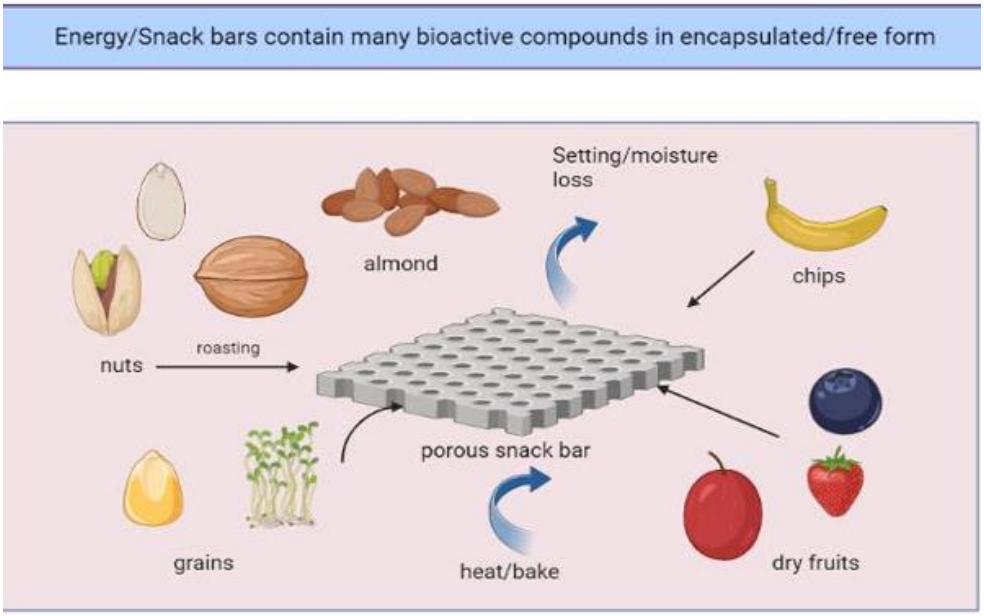

Fig 4: Process of formulation of snack bars from various ingredients [26]

Health Benefits of Protein Bar [1,27-37]

1. Better Bone Health: Calcium and other vital minerals found in some protein-rich bars aid to maintain skeletal strength and lower the chance of osteoporosis.

2.Improved Cognitive Function: The fatty acids in these bars are transformed into neurotransmitters that are essential for brain function, including as serotonin and dopamine.

3. Strength Training and Recovery: Because protein is necessary for both muscle growth and recovery, bodybuilders and athletes use these bars.

4. Weight Management: By increasing satiety and decreasing appetite, high-protein bars help people lose and maintain weight.

5. Assistance for Bariatric Patients: These bars can be utilized in bariatric treatment to help patients regular their weight after surgery.

6. Nutritional supplements: Helpful for people who have problems with malabsorption or nutritional deficiencies.

7. Promotes immunological Function: Immunoglobulins and other substances that promote immunological health and lower the risk

of infections may be found in protein bars.

8. Stable and Cost-Effective: Protein bars are highly valued for their reproducible production, easy modification, cost-effectiveness, reusability, and chemical and thermal resilience.

9. International Consumer Benefit: As a result of the food industry's globalization, customers now have access to a large range of superior nutritional products.

10. Discarded byproducts may contain an equivalent or even higher concentration of antioxidant and antibacterial chemicals than the finished products.

11. Protein bars can support a circular economy model, promote sustainability, and help achieve the global objective of "no waste" by using food byproducts.

Future Prospects

In the future, there may be attempts to create bars based on a variety of ideas, such as low-fat bars for patients undergoing cholecystectomy, dietary fiber-rich bars to prevent constipation, dairy-free bars for lactose intolerant individuals, soy-free bars, immunity-improving bars, probiotic bars, bioactive peptide-rich bars, Jain bars (without honey, roots, and tubers), bars for managing cholesterol and sodium, bars for enhancing memory and reducing stress, and nutrient-enriched bars for expectant and nursing mothers [38]. Diversification of protein sources (particularly plant and microbial proteins), fortification with gut-targeted and functional ingredients, clean-label and low-sugar reformulations, and increased regulatory and evidence-based scrutiny of health claims will all shape the future of protein bars. In the upcoming three to seven years, digital traceability and sustainability (upcycling and lower-impact proteins) will influence product acceptance and premium positioning.

CONCLUSION

Protein bars are an important development in the functional food and nutraceutical industries, successfully satisfying the growing demand from consumers for quick, nutrient-dense, and healthful snack options. Different protein sources, fibres, antioxidants, vitamins, and minerals are all integrated into their composition to assist weight management, immune system function, muscle growth, and cognitive function. The changing market trends support global health and environmental goals by emphasising plant-based, clean-label, and sustainable ingredients. Protein bar innovation in the future is probably going to concentrate on improved bioactive ingredients, sustainable production practices, and customised formulations for certain dietary requirements. All things considered, protein bars represent a potential dietary supplement that enhances public health and wellness by fusing consumer convenience with nutritional effectiveness.

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