Formulation of functional energy bars using dairy and non-dairy ingredients: A review

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**Abstract**

Bars are compact, energy-rich, composite food in which cereals are present in major amounts. Apart from meal replacers, energy bars can be used as a dense and portable source of carbohydrates. Bars are classified as ready-to-eat formulations which are usually based on whole cereal grains, seeds, plants (non-dairy ingredients) and certain animal-based products such as dairy ingredients. An energy bar (45-80 g) generally contains 3-9 g fat, 7-15 g protein, and 20-40 g carbohydrates that can supply about 200-300 kcal (840–1,300 kJ) energy. Skim milk powder and high protein powders such as milk protein concentrate and milk protein isolate can also act as a suitable ingredient of bars. A number of food constituents with proven functionality can be added in bars to improve their nutritional potential to cater the need of different consumer segments. By appropriate ingredient selection and efficient processing interventions, low cost energy bars can be developed. However, further research is necessary to find the potential of plant by-products in bars to minimize nutrient wastage and to maintain the production economy.

**Keywords:** Energy bars, functional components, milk powders, non-dairy ingredient

**1. Introduction**

Bars are proportioned and convenient composite foods, widely consumed as a potential meal replacer for supplying major nutrients in adequate quantities (Cabanilla *et al.*, 2009). Curtain *et al.*, (2019) defined bars as a compact, energy-rich, composite food in which cereals are present in major amounts. Apart from meal replacers, energy bars can be used as a dense and portable source of carbohydrates. Bars are portable and convenient to carry, hence, useful in conditions where availability of consume conventional foods is an issue in specific applications such as for the military and space food (Hill *et al.*, 2011). They also contain many other components such as seeds, nuts, dried fruits etc (Rawat *et al.*, 2015) and are mainly consumed as snacks (Williams *et al.*, 2006). Further, vitamins and minerals can be added to improve their nutritional quality (Mietus-Snyder *et al.*, 2012). Although bars are available for diversified consumer segments and liked by large population of all age groups; still, their major portion is consumed by a specific group of consumers with high energy need that particularly include children, young adults, adolescents and athletes or sport persons (Nadeem *et al.*, 2012). According to Tanskanen *et al.*, (2012), bars can be classified as ready-to-eat formulations which are usually based on whole cereal grains, seeds, plants, and certain animal-based products such as dairy ingredients. Mridula *et al.*, (2013) reported that bars are rich in carbohydrates, proteins, and vitamins which are mainly derived from the ingredients used in their formulations. Weaver, (2014) that certain ingredients yield bioactive compounds during digestion that makes bars as a potential functional food. By virtue of the presence of different ingredients with high calorific value, bars are energy-dense, hence should be consumed in moderation (Hertzler *et al.*, 2003). The energy bar is an emerging snack in the Indian market. Frying, molding, and hydrogenation are some of the techniques which are commonly involved in the processing of such food products (Svisco *et al.*, 2019). So far, legal standards for bars have not been framed in India by Food Safety and Standards Authority of India (FSSAI). The generalized process of bars production using different methods is shown in Figure 1.
2. Composition, bioactive peptides and nutritional potential of bars

As per Tiwari et al., (2016) [50] an energy bar (45-80 g) generally contains 3-9 g fat, 7-15 g protein, and 20-40 g carbohydrates that can supply about 200-300 kcal (840–1,300 kJ) energy. Fat being an energy rich constituent, plays a key role in making bars dense in calories. This needs to be minimized for specific groups. Further, fat content is more in case of protein bars as compared to energy bars in which carbohydrates are present in higher concentrations. According to Ferreti et al., (2007) complex carbohydrates are considered better than simpler ones. Presence of cereal-based constituents make them rich in many phytonutrients known for their biological activity and known to confer physiological benefits to host by acting like a potential functional food when consumed in adequate amounts.

The major source of calories in bars are fat, protein, and carbohydrates, however, many bioactive compounds such as fatty acids and peptides are also derived from them. The degree of release of such components is associated with the composition of the proteins and fats. They also provide proteins, which yield bioactive peptides during digestion. These peptides possess specific functionality and can impart physiological benefits to the host (Daliri et al., 2017) [111].

3. Bars as functional foods

Highly physically active consumers such as athletes can consume energy bars as a compact source of energy. Apart from this, people on diet and individuals with nutritional problems or irregular meals can also use energy bars for their nourishment, provided that the bars do not contain anti-nutritional factors and allergens that are deleterious for health. Snack bars are highly versatile and confer nutrition (high-quality proteins, polyunsaturated fatty acids, minerals, vitamins, and fibers) in one convenient, easy to store and carry package. They can act as good carriers of healthy nutrients, bioactive compounds, and dietary fiber. Thus, it is an edible commodity that can be classified under the category of functional foods. Such foods are known to provide additional health benefits apart from original nutrients. This can be achieved by fortification and enrichment with other bioactive components derived from plant sources. Therefore, modifications in product formulations and the adoption of new technologies in processing have achieved a significant improvement in the nutritional quality of bars and also helped in meeting consumer requirements as well. Many firms in the processed-food industry are involved in the manufacturing of ultra-processed foods including candy bars, cereal bars and snack bars whose use is prevalent among adolescents. Due to enhanced sensory (flavor, color, and texture) attributes, convenience (portability, shelf life and preparation time), and efficiency, the use of energy bars in the United States has rapidly increased owing to all these important food characteristics. Ultra-processed foods are largely composed of additives including synthetic colors, flavors, sweeteners, emulsifiers, and preservatives (Ho et al., 2018, Mridula et al. 2013) [31]. These can affect food safety as well as quality. Therefore, many companies and product developers are working on formulating natural cereal-based functional composite bars that show functionality as well (Constantin et al., 2018). Further, fortification of food with micronutrients is widely used particularly to meet the recommended dietary allowance (RDA) values as specified by the National Institute of Nutrition (ICMR, 2019). Therefore, it is imperative to develop economical, protein-rich, micronutrient fortified bars, which can be better alternatives for protein-rich supplements either derived from plants (such as soy) or dairy ingredients (such as protein concentrates and isolates).

Bars containing partially hydrogenated vegetable oils might not be a healthy alternative since they contain saturated fat and trans-fat which are associated with many cardiovascular conditions (Pantazopoulos et al., 2011). High fructose corn syrup, sucrose, and glucose syrups are rich in carbohydrates that act as suitable substrates for the growth of microorganisms responsible for causing dental caries (Gupta et al., 2013). Therefore, it is imperative to develop wholesome, low-calorie and cost-effective bars while maintaining food quality using specific bioactive compounds that are important for providing functionality in novel food formulations (Cencin et al., 2010) [9]. However, sufficient processing of ingredients should not be overlooked to compromise food safety (Sanders, 1999) [43]. Apart from the basic nutrients (such as proteins and carbohydrates), components that impart functional properties can be incorporated in the composite food matrix to get desired physiological benefits (Lang, 2007) [23].

From milk and dairy products, bioactive constituents such as antioxidants, peptides, proteins, conjugated acids, linoleic acid, vitamins, oligosaccharides, and organic calcium can be derived. These components provide health benefits such as
improving hemodynamics, probiotic growth, GIT modulation, and immune-regulation (Park et al., 2015) [37].

Rao, (2003) [39] reported that many bioactive compounds derived from plants and animal sources are able to provide antimicrobial, metabolism modulating, anti-obesity, satiety modulating, hypotensive and hypocholesterolemic effects.

3.1 Utilization of dairy powders in bars

3.1.1 Milk powder

Milk powder-based bars can meet the nutritional requirements of the armed forces, especially in conditions where conventional food is not available (Farajzadeh et al., 2011). Low-fat milk powder can be a good source of protein. The milk proteins mainly consist of casein and serum proteins (also known as whey proteins), which yield many bioactive peptides during digestive hydrolysis (Chakrabarti et al., 2018) [6].

3.1.2 Milk protein concentrates/isolates (MPC/MPI)

Milk protein concentrate is categorized as a casein-dominant ingredient (Yada, 2018) which can be divided into low (< 42%), medium (60–70%) and high (> 80%) protein ingredients, while MPC with a protein content > 90% is generally termed milk protein isolate (MPI) (Agarwal, Beausire, Patel, & Patel, 2015) [2]. The casein to whey protein ratio (4:1) of MPC and MPI powders are similar to that naturally present in milk. MPCs are used as a replacement for skim milk powder, for protein adjustment of commercial products such as neutral pH ready-to-drink high protein beverages, ice-cream, Greek-style yogurt, spreads, coffee creamer and whipping cream. They are also used in the formulation of protein-fortified products, nutritional beverages, and bars, in clinical nutrition, dietary supplements and sports/performance nutrition (Agarwal et al., 2015; Singh et al., 2019; Chamberland et al., 2020) [2, 46, 7]. Milk powder, milk protein concentrates or isolates can release bioactive peptides during digestion (Park et al., 2015) [37].

Novel dairy-based functional foods can be formulated using MPCs since they are rich sources of protein. However, solubility characteristics are the most variable and need to be controlled to use the ingredient effectively in products such as in the preparation of bar mixtures, fillings, and coatings. Protein content and process parameters are the major factors affecting this property. High-protein nutrition (HPN) bars (~2 g MPC/100 g) have a tendency to lose moisture and harden during storage that led to the loss of acceptability (Kumar et al., 2018) [53]. Bars containing MPI in formulation not only lacked cohesion but also had crumbly texture. This may be prevented by having control over the storage conditions. However, bars formulated using spirulina had the ingredient ratio adjusted that yielded a bar with lower hardness. Moreover, it did not lack cohesion and integrity as compared to those made with MPI. High protein nutrition (HPN) bars with extruded MPC80 showed slower hardening compared to bars formulated with unmodified MPC. Extruded MPC80 bars were significantly softer, less crumbly, and more cohesive than the control. However, the bars became firmer and less cohesive during storage (Banach, 2016).

4. Valorization of non-dairy ingredients in the manufacturing of bars

Plant ingredients also contribute to physicochemical and biological properties not imparted by dairy counterparts. This effect is associated with the presence of phytochemicals such as phenolic compounds. Coconut powder can provide dietary fiber while cacao imparts characteristic chocolate flavor and color. Lecithin emulsifies while butylated hydroxytoluene (BHT) is associated with preventing rancidity by lowering the rate of fat oxidation. Therefore, this antioxidant can be used in bars to preserve the flavor profile (Lin, 2016).

There are many potential ingredients that can be used in bars to impart functionality (Constantin et al., 2018). Amaranth is rich in phenolics and antioxidants (Karamac et al., 2019) [22]. Oat is a good source of soluble fiber such as β-glucan (Marais, 2017) [12]. Flaxseed is rich in omega-3 fats (Mrudula et al., 2011). Sorghum is rich in policosanols, tannins and 3-deoxyanthoycanidins (Cardoso et al., 2017) [12]. Seeds such as sunflower, pumpkin, chickpea, are rich in phytochemicals showing many medicinal properties (Guo et al., 2017; Veronezi et al., 2012; Ivan et al., 2019) [18, 52]. Dates contain polyphenols that show activity against cancer and cell damage (Yasin et al., 2015). Jeriva is rich in tocopherol, carotenoids, linoleic and oleic acids (Coimbra et al., 2012) [9]. Rose petals are associated with prevention of oxidative stress (Marmol et al., 2017) [20]. Lentils are rich in polyphenolic compounds (Ganesan et al., 2017) [16]. Pear and apple are rich in antioxidants and lipids (Leontowicz et al., 2002) [24]. Acerola is rich in flavonoids, anthocyanins, phenolics and ascorbic acid (Prakash et al., 2018) [38]. Banana is a good source of phytosterols, carotenoids, and phenolics (Singh et al., 2016) [45]. Brown rice is rich in tocotrienol, tocopherol, oryzanol, and amino acids (Ravichanthiran et al., 2018) [40]. Chicha, sapucaia, gurgueia nuts are rich in lipids and tocopherol (Demoliner et al., 2018) [13]. Sweeteners provide flavor, consistency, integrity, and firmness (Rippe et al, 2013) [42]. Fig contains many volatiles and phenolics (Mawa et al., 2013). Raisins are rich in antioxidants and antimicrobials (Abouzeed et al., 2018) [1]. Nuts and dried fruits are rich in carotenoids and many phenolics (Hernandez-Alonso et al., 2017) [19]. Soy can yield bioactive peptides on protein hydrolysis (Chatterjee et al., 2018) [8]. Hence, all above mentioned food material can be incorporated in bars to enhance their sensory attributes, nutritional value and functional attributes by sound technological interventions. Other ingredients like binding sugars syrups, flavor, color, antioxidants such as Vitamin E, plant extract such as rosemary extract are also added to improve the shelf life and taste of the product ( Nieto et al., 2018) [33].

5. Packaging

Packaging influences product quality perception significantly. Packaging design is an effective marketing tool used by companies. Products with complicated designs and matte packaging are generally priced higher, although the composition is similar. Many consumers associate matte finish with better quality and such products gain more demand from higher-income groups. Many brands are more discoverable than others because of extensive marketing. (Padmarshree et al., 2012) [34]. Recently, the energy bar market has received a significant boost from health-conscious consumers and the growth of high-income groups. However, the development of low-calorie bars needs more research. India is one of the biggest economies in the world but 70% of the population lives in rural areas. Therefore, there is a need for developing cost-effective substitutes. Many bars are rich in nutrients such as total fat, trans fat, cholesterol, mono, and polyunsaturated fatty acids, omega-3 and omega-6 fatty acids, saturated fat, calcium, iron, vitamins (C, E, D, A), phosphorus, sodium, and potassium (Curtain et al., 2019) [10]. However, allergen information is also imperative to be
declared regarding the presence of gluten, milk, soy, peanuts, and almonds (Valenta et al., 2015) [51]. Thus, appropriate packaging material can protect and enhance the shelf-life of different bars.

6. Storage induced changes in bars
Moisture loss during storage increases hardness with a concomitant reduction in water activity. This can reduce consumer acceptability without having any significant effect on food safety (Pallavi et al., 2013). Mridula et al., (2011) reported that onset of rancidity when the product is exhausted from all the free radical scavenging antioxidant molecules can lead to the development of oxidized flavor. Mold growth can occur if the sugar content is inadequate or if it is replaced with sweetening substitutes such as stevia and high-intensity sweeteners such as sucralose, saccharin and so on (Membre et al., 1999) [59]. Loss in crunchiness occurs due to penetration of moisture from the syrup outside towards inside of the individual ingredient units such as cereal puffs, nuts, etc. (Pallavi et al., 2013). Changes in appearance and flavor during storage due to chemical reactions and light-induced degradations if the packaging is not opaque. (Rawat et al., 2015) [41]

Table 1.

| Ingredients used for making bars | Functional components | Functionality | Reference |
|---------------------------------|-----------------------|---------------|-----------|
| Flaxseed, Oats, soy protein isolates, honey, Corn syrup puffed rice, nuts and raisins | dietary fibre, oil, protein and phenolic compounds, lignan | lowering plasma cholesterol and triacylglycerides, reduce the blood glucose, bind estrogen receptors and act as anti-carcinogenic agents, avoiding prostrate, breast and endometrial cancers. | Mridula et al., 2011 |
| Brown sugar, rice crispies, wheat flour, honey, syrup, fig/date mix, maltodextrin, sodium caseinate, apricots, raisin, fish oil | omega-3 long-chain polysaturated fatty acids (PUFA) | reduction in cardiovascular diseases, inflammation and cancer | Nielsen et al., 2009 |
| Ripe banana, maltodextrin, caramenage, Palm sugar, Rice flour, table sugar, ORS, coconut milk | electrolytes, dietary fibre, minerals such as potassium and phosphorus, and antioxidants | Reduction in dehydration, reduces energy depletion | Ho et al., 2016 |
| Welsh onion extract, nuts, grains, cranberry, vitamin-mineral mix, oligosaccharide sugar, apple concentrate, xanthan gum | dietary fiber content, resistant starch, Vitamin C, protein | Anti-fungal, antioxidative. Obesity and metabolic activity control, essential amino acids, antiplatelet, anti-hypertensive activity | Sung et al., 2014 |

7. Conclusion
Bars are supplemental cereal-based foods that are formulated to target consumers requiring immediate energy and need replacing full-meals. Unlike energy drinks, energy bars do not contain caffeine, unless ingredients like coffee powder or tea extracts are incorporated. Nutrient bars, particularly protein bars, contain protein and carbohydrates in significant amounts, which can contribute to the presence of bioactive compounds apart from meeting the basic nutritional requirements. Therefore, researchers need to attempt the formulation of low-calorie energy bars from diverse protein-rich ingredients to maximize the range of phytochemicals incorporated and to increase their bioavailability as well among adolescents. However, in developing countries meeting needs of lower income can be achieved by formulating economical products. Further research is necessary to find the potential of plant by-products in bars to minimize nutrient wastage and maintain the production economy as well. It can be a promising approach for improving nutritional availability to school-children and physically active adolescents to meet nutrition requirements specified by the food authorities.

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