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Millet Bars-Healthier Alternative to Cereal Bars: A Review

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ABSTRACT

The demand for quality nutritious food is growing worldwide, that promote health and wellbeing for consumers and helps in reducing the risk for non-communicable diseases and improve the quality of life. The lifestyle changes of consumers, higher health consciousness and nuclear families has created the food industry to invent and innovate creative products by incorporating functional novel ingredients to enhance the nutrient quality and percent daily value per serving of the product. Millet-based bars are versatile products that can be developed as an alternate to existing cereal-based bars. However, technological constraints of manufacturing millet-based bars can be overcome by adding either hydrocolloids, enzymes, any pre-processed starches or by biofortification, genetic engineering or by introducing additional processing technique like fermentation. Incorporation of millets as major functional ingredient in snack food, especially in snack bar, helps to improve the nutritional attributes of the products and to overcome nutritional deficiencies at large.

Key words: Cereal bars, Health benefits, Millets, Snack bars, Technological constraints.

There is an increasing demand in the global market for convenient and nutritious natural food products. Snack bars are commonly known as nutribars or granola bars is introduced into global market two decades ago. Owing to higher protein, fat, carbohydrate and mineral content, food bars are considered as food or snacks which provide good nutritional quality as well as sensory attributes (Chitkara *et al.*, 2019).

To meet the demands of the growing market, there is an increasing necessity to innovate, improve, or by modifying the composition of snack bars for additional health benefits (Ho *et al.*, 2016). These products can be modified to several extensions and can be used as supplementary or as food for special purposes (Santos *et al.*, 2011). The current scenario in the food industry is to develop good quality highly nutritious food using plant sources (Meethal, 2017).

Food concerns have increased among consumers at different levels. Some prefer food that ensures lesser risk to the health throughout their lifetime while few prefer food that will not worsen the already existing health disease condition (Bastos *et al.,* 2014). Foods consumed by school-going children should contain a high amount of vitamins, minerals, proteins, carbohydrates and fats. There are limited foods that provide wholesome nourishment to young children. Therefore, utilizing the emerging trends of nutraceutical and functional foods, this gap can be filled (Nadeem *et al.*, 2012).

An attempt was made in this review by using search databases like Google scholar, Springer Link, Science direct and IEEE. The materials were identified by using potential keywords like millets, snack bar, health benefits, functional characteristics, *etc.* The total number of records identified was nearly 5000 and further selected based on the title and abstract suitable for the study. The selection of the articles was screened by reading the entire content on the wellness of the concept and design. The total number of articles included in the review was 62.

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Millets

Millets are crops that grow in the semiarid zone of moderate rainfall and are generally regarded as annual warm-weather grasses. It is widely found in tropical and subtropical regions of moderate rainfall in the world and grows within 3-4 months. The grain requires minimal energy relative to the more traditional crops (Weber and Fuller, 2008). Millets are accepted as functional foods and nutraceuticals due to dietary fiber, proteins, minerals, vitamins and antioxidants (Truswell, 2002). Millets are an alkaline food, helps in maintaining the pH balance in the body to prevent illness (Sarita, 2016). The content of crude fiber in sorghum and millets range from 2-11.9% whereas dietary fiber content ranges from 2.2-28.5% (Saldivar and Ramirez, 2019). Sorghum and millet contribute to mainly insoluble dietary fiber and significantly to antioxidant activity due to high levels of phenolic acids and polyphenols. It was also reported that consumption of food that contains these grains lower the gastrointestinal transit time prevents gastrointestinal problems and decrease the glucose release into the bloodstream.

Millets are found to exhibit superior nutrient availability in comparison to cereals and are cost-effective. They contain nearly 70% of starch as polysaccharides, which contributes

to slower digestion than cereals. Despite their excellent nutrient profile, these crops are not popular and are underutilized in India (Pathak *et al.*, 2000). Knowledge regarding the physical properties of millets is required to construct a suitable processing technique, develop innovative products and also to retain its quality throughout storage (Balasubramanian and Vishwanatan, 2010).

In millets, 51-78% of grain weight is represented by starch granules. The native starch granules of millets are pseudo-crystals which makes them insoluble in cold water, exhibit birefringence and are inaccessible to enzyme attack. Starch contributes energy that is required for seed germination (Rooney and Pflugflelder, 1986). Pearl millet contains starch granules which are loosely packed in a discontinuous protein matrix and has a high water-holding capacity and higher swelling power and solubility than other starches (Badi *et al.*, 1976; Abd Allah *et al.*, 1987). Foxtail millet and proso millet contain starch compounds that are less soluble and higher water-binding capacity than wheat starch (Lorenz and Hinze, 1976).

The protein content of millets depends upon agronomic and environmental conditions like water availability, temperature and fertility as well as genotype. Millets contain a higher amount of protein when compared with other cereals due to a higher germ to endosperm ratio. This property may also improve the amino acid composition. Prolamines and glutelins are two predominant protein fractions in millets and lack in lysine similar to cereals (Saldivar and Ramirez, 2019).

Minerals are required for several biological functions such as electrolyte balance, enzyme cofactors, protein formation and stabilization, excitation of nerves and muscle conductivity and to maintain the bones and teeth crystalline structure. Minerals are abundant in millets. Calcium content in finger millets is ten times higher than that of staple cereals. Pearl millet is a rich source of iron and zinc, known to be minor minerals, that helps in maintaining mineral deficiencies like anaemia, impaired growth, *etc.*, (Datir *et al.,* 2018).

In general, phenolic compounds can donate hydrogen atom that acts as antioxidants. Phenolic compounds present in plants can function as metal chelators, singlet oxygen quenchers and reducing agents (Naczk and Shahidi, 2004). Millets contain high amounts of p-coumaric and ferulic acid among other phenolics. These compounds act as antiviral, anticancer, antiplatelet aggression, antimicrobial and anti-inflammatory (Chandrasekara and Shahidi, 2010). Whole millet acts as anti-oxidants, chelating agents and helps in risk of disease reduction (Chandrasekara and Shahidi, 2011).

The intake of whole-grain food is found to prevent the onset and in the management of diabetes mellitus. A low incidence of diabetes was found in millet consumers (Shobana *et al.,* 2009; Kim *et al.,* 2011). α-glucosidase and pancreatic amylase reduce the postprandial activity of hypoglycaemia by inhibiting the enzymatic hydrolysis of carbohydrates (Shobana *et al.*, 2009). Millets contain higher amounts of fibre and sugars and indicate a relatively low glycaemic index and help in lowering glucose levels (Chavan and Patil, 2016).

Millet grains are known as anti-nutrients which help in the reduction of breast and colon cancer (Thompson, 1993) and are rich in antioxidants and phenols to delay aging and metabolic syndrome. It also showed that methanolic extracts of kodo millet and finger millet inhibit glycation and collagen linkage (Hedge *et al.,* 2002). Effects of anxiety, depression, insomnia, migraine and heart attack can be reduced due to a good amount of magnesium present in millets. Finger millet helps in reducing the appetite, because of tryptophan content. Vitamin C helps in the absorption of iron and helps in treating anaemic patients (Chavan and Patil, 2016). Millets help in reducing plasma non-HDL and liver cholesteryl ester concentration and found to increase the faecal concentration (Hoi *et al.*, 2009).

The protein hydrolysates from foxtail millet lowered blood pressure significantly and decrease angiotensin-converting enzyme activity (Chen *et al.*, 2016). Extracts from various millets had shown inhibition against the proliferation of human colon cancer cells (HT-29) and radical-induced supercoiled DNA scission by 28-100% (Chandrasekaran and Shahid, 2011). Phenolic extracts exhibited inhibition of human breast cancer cells proliferation and against human liver cancer cells in a dose-dependent manner (Zhang *et al.*, 2014). Pradeep and Sreerama (2015) had found the greater inhibitory activity of acidified methanol phenolic extracts against α-glucosidase than α-amylase. Murtaza *et al.* (2014) found that whole grain finger millet and bran had increased levels of GSH (reduced glutathione) and catalase in the liver and decreased the levels of lipid peroxide, nitrite and superoxide dismutase.

Snack bars

Irrational eating habits cause several nutrition-related problems like consuming low ingestion of fiber leads to several gut-related problems among youth and adults. Therefore, regular consumption of dietary fiber, which has a high indigestible factor, is recommended among youth and adults to maintain a healthy gut. This in turn contributes to a significant modification in the prevention of several chronic diseases (Santos *et al.*, 2011). Formulating snack bars using regional raw materials will be sensational from a nutritional as well as in sensory perspective, as these can be considered as an option in the menu of the particular region. This kind of food earns profit in the global market as an innovative food (Prazeres *et al.*, 2017).

Energy bars are dietary supplements and are mostly consumed by people who want to maintain calorific needs. It also provides protein, fat and a high concentration of carbohydrates (Norajit *et al.*, 2011). Whole grain-based diets are increasing day by day because of their good source of dietary fiber, antioxidants, vitamins, *etc.*, but protein quality is poor as it is deficient in essential amino acids, especially lysine. Cereal bars can be incorporated with different ingredients, such as whole cereals, almonds, chestnuts,

nuts, dehydrated or crystallized fruits, chocolates, sugar, candies, *etc.* along with other processed cereals (Ferreira, 2004). The ingredients that are used should be added appropriately to assure common physical characteristics, flavor and texture as concerned, principally the balance point of water activity. The nutritious bars have earned importance and popularity in the market today. Energy bars provide most of their food energy (calories) in carbohydrate form (Tiwari *et al.*, 2017).

In general, protein bars are lower in carbohydrates, vitamins and dietary minerals than meal replacement bars and significantly higher in protein. Protein bars are mainly used by exercise enthusiasts for muscle building or athletes (Tiwari *et al.*, 2017). Body requirement for protein is higher and can be easily supplemented with protein bars. Oats, peanuts, soybean flour, amaranth, protein isolates and concentrates, *etc.*, are generally used ingredients in making protein bars. Some of the processing techniques reduce the bioavailability of the protein compounds. Therefore, the processing of the ingredients used acts as an important criterion during the selection of ingredients to make nutrition bars. The protein-rich nutribars should be appealing and satisfying to the consumers. Apart from being nutritious, they should have appreciable flavor and texture (das Neves, 2016).

A high fiber bar provides a fiber content of nearly 8-10 g/50 g of bar. Irrespective of being rich in fiber, it also contains an energy value of about 100 kcal per unit (Sharma *et al.,* 2014). Fibre has many beneficial effects on one's health, especially for cardiovascular and diabetes patients. Major attributes of fiber that contribute to better health are its ability to decrease total cholesterol, reduce the accumulation of LDL cholesterol and triglyceride level as well. It was revealed that people with diabetes who consumed a high fiber diet had lower serum glucose levels compared to those who had a low fiber diet (Possinger *et al.,* 2014).

The nutrient, snack, or cereal bars can also be classified into three main categories, according to a report in the USA regarding snack food consumption. They are health and wellness snacks, energy and nutrient bars and organic snack bars. When the focus is on consumer behavior, it can be classified as a replacement for a meal, or as a part of a meal (as food eaten between two main meals, or as a part of breakfast, lunch or dinner), or as a dessert (after a meal) (Constantin and Istrati, 2018). Constantin and Istrati (2018) have categorized snack bar types as a fruit-based snack bar, wheat or soy-based snack bar, cereal-based snack bar, vegetable-based snack bar and high protein snack bar.

According to Global Sweetener Development Group, New Jersey (2015), classified snack bars into high protein bars, protein bars, balanced carbohydrate/protein/fat and high carbohydrate bars. High protein bars are usually used in high protein programs as supplementary food or used by bodybuilders as a protein supplement. It contains 130-230 calories, 16-20 g of protein, 5-10 g of fat and 15-25 g of carbohydrates per 50 g of the product. Protein bars contain a slightly lesser amount of protein in comparison with high protein bars and provide 180-240 calories, 10-15 g of protein, 5-15 g of fat and 15-25 g of carbohydrates per 50 g. Li *et al.* (2008); Dan and Labuza (2010) have indicated the proportion of ingredients for protein-based snack bars as soy/dairy proteins (20-40%), fats (10-15%) and carbohydrates as sugar syrups (10-50%). Flavorants and stabilizers are added to basic ingredients for protein bars. A balanced carbohydrate/protein/fat bar is designed to provide balanced nutrients. Bars that contribute approximately 5-10 g of protein, 5-20 g of fat, 20-30 g of carbohydrates and 200-275 calories per 50 g of bar fall under this category. A high carbohydrate bar is developed to provide sustained energy or provide immediate energy. It provides nearly 160-230 calories, 30-40 g of carbohydrate, 2-9 g of protein and 5-15 g of fat per 50 g of the product.

According to Burrington and Boutin (2007), the bars are classified into high-protein bars, balanced nutrition bars, low carbohydrate bars and grain-based bars. A balanced nutrition bar is also called 40-30-30, as it is formulated to provide 40%, 30%, 30% of energy from carbohydrates, protein and fat respectively. It approximately contributes 5-10 g of protein, 20-30 g of carbohydrates, 5-20 g of fat and 200-275 calories per 50 g of the bar. High protein bars contain the highest level of protein than any other bar. Low carbohydrate bars are formulated to minimize carbohydrates and maximize protein. This bar should contain a protein content of balanced nutrition and a high-protein bar. These kinds of bars are formed using high levels of sugar alcohols, fiber and non-nutritive sweeteners to achieve the net carbohydrate. Grain-based bars contain whole grain as their main ingredient and will have low protein content. A typical cereal bar contains a fruit filling and an outer coating made up of cereals. It often contains 8% fat, 2.5% protein, 2.5% fibre and 73% carbohydrate.

A variety of ingredients have been used in the preparation of snack bars. This aids in catering to the diet requirements of a varied number of people, who look forward to a healthier lifestyle. As there is a growing demand for food with more health benefits, bars are developed with ingredients that are nutritional as well as functional. Cereal bars are also called portable nutrition as it provides a good quantity of carbohydrate and promotes energy recovery after strenuous exercise (Silva *et al.*, 2013).

Snack bar processing

Snack bars are made in two ways: the hot/oven process and the cold process. In the hot/oven process, the dry ingredients are mixed with a binder by heating the syrup to 85-90°C and maintaining the Brix at 85-90°Brix and baked at 120-140°C for 3-15 min and cooled to room temperature, packed and stored (Fig 1). In the cold process, the processing involves mixing of dry ingredients and binder, laminating and molding, followed by refrigeration, packaging and storage (Fig 2) (Sharma *et al.,* 2014). Constantin and Istrati (2018) also proposed a process of preparation by

baking and non-baking process and a method for filling inside nutribars or snack bars (Fig 3).

Technological constraints

There are certain opportunities and challenges in using millets due to nutrient composition like dietary fiber, health-promoting phytochemicals, resistant starch, vitamins and minerals and have additional anti-nutrients which makes it a challenge to utilize in making varied snack products (Collar, 2014; Taylor *et al.*, 2006). Tannin is an anti-nutritional compound, inhibits the fermentation process by binding to protein and condensed tannins alter the color, texture and taste of the end product (Yetneberk *et al.*, 2005). Grains, that are processed either into small-sized grains or into flours, affect the end product by giving low volume or by causing rancidity (Nantanga *et al.*, 2008). Gluten protein helps in forming the cohesive viscoelastic dough, wherein the absence of this protein does not provide a proper structure to the product. Proteins present in millets do not contribute to the texture of the product in comparison to wheat protein. Owing to higher dietary fiber content, millets affect the crumb structure, color and texture of the product.

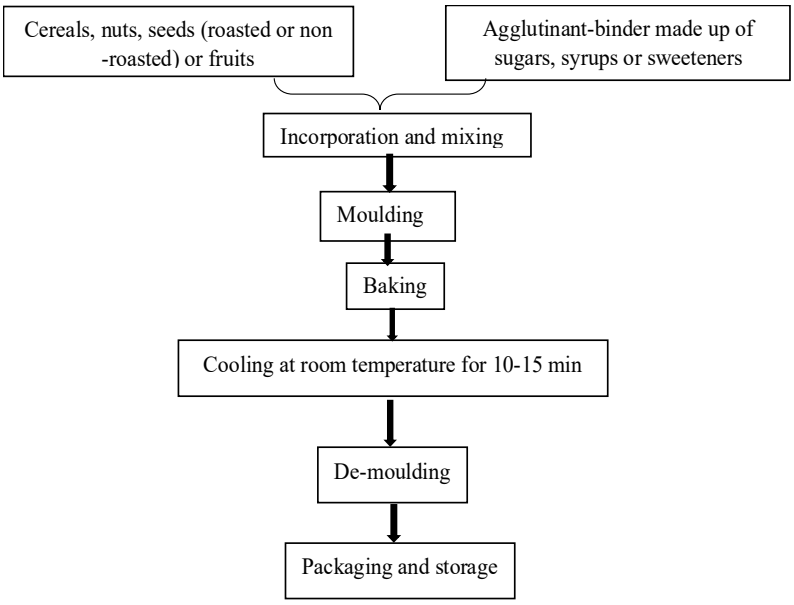

Fig 1: Flow chart for hot process. Source: Sharma *et al.,* 2014.

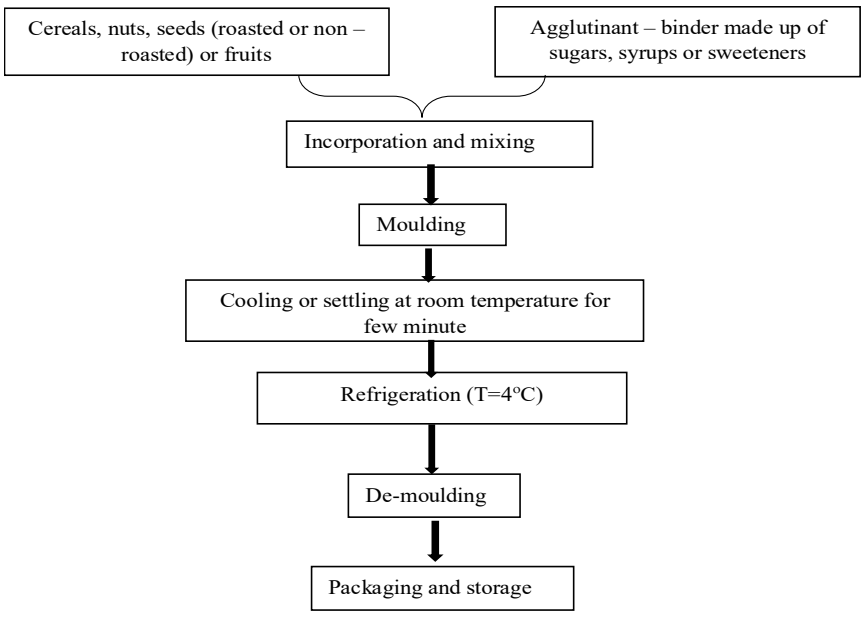

Fig 2: Flow chart for the cold process. Source: Sharma *et al.* (2014).

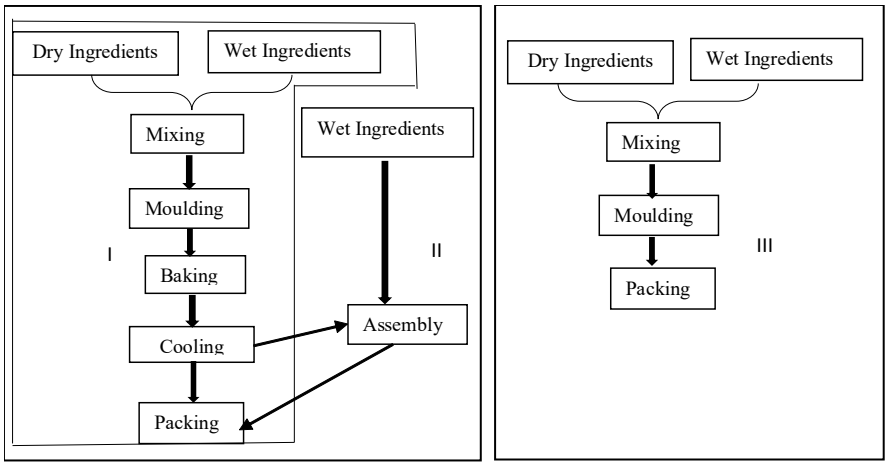

Fig 3: Snack bar processing. I. Baked bars II. Baked with filling III. Cold formed bar
Source: Constantin and Istrati, (2018).

Opportunities of utilizing millets in snack bars

The main challenge is making a nutrition or snack bar is getting an appropriate texture of the bar apart from meeting the required nutrient content. Several physicochemical, thermo-dynamical and process-related factors affect the texture of the bar (Das Neves, 2016). Zhou *et al.* (2008) reported that insoluble aggregates that are formed during interchange reactions between thiol-disulfide result in bar hardening. It was also reported that an increase in the water activity of the product does not soften the bar alone, sometimes it also hardens the bar. This is due to the reduction in water available for the plasticity of the protein particles (Li *et al.*, 2008). A challenge in making a high protein bar is to maintain its taste and texture along with its bioavailable protein.

Millets can be combined with legumes and certain oilseeds in the preparation of snack bars by using appropriate processing techniques (Pathak *et al.*, 2000). Several strategies are proposed to utilize these millets in the production of gluten-free products that are mostly dough-based. The strategies involve either reformulation of the product using hydrocolloids, enzymes, additives, pre-gelatinized and native starches and flours, geminated flours and by adding other non-cereal gluten-free ingredients or by altering the processing technique or by breeding or genetic engineering.

Using hydrocolloids like xanthan gum or cellulose derivatives increased gas retention, improved texture, delayed staling of bread, low resistance to deformation, increased viscosity of batters and improved crumb texture (Hart *et al.*, 1970 and Schober *et al.*, 2007). Emulsifiers help in higher elastic recovery, staling rate has been reduced and spread ratio of cookies has been improved by adding wheat flour lipids (Onyango *et al.*, 2009 and Badi *et al.*, 1976). The use of pre-gelatinized starches increases the viscosity of the batter with an increase in starch concentration, cohesiveness and elasticity of the crumb but also increases crumb damage (Onyango *et al.*, 2011). Therefore, an appropriate proportion of the ingredients is essential in product formulation. Germinated millet flours can also be used as it was found to decrease hardness and increase cohesiveness and help in designing new food products (Phattanakulkaemorie *et al.*, 2011).

Fermentation of millet flour improves the nutrient composition, reduces anti-nutrient content and improves cooking property along with protein degradation and synthesis of oligosaccharides (Galle *et al.*, 2012 and Osman 2011). Precooking the dough before the extrusion changes the properties of the dough and yields a good quality product. Hydrothermal processing also results in enhanced carbohydrate and protein digestibility of the flour. Fermentation and heat-moisture treatment improve starches that digest the slow and resistant starch content of the flour (Amadou *et al.*, 2014).

Biofortification of sorghum using genetic engineering led to starch with high protein and starch digestibility (Jampala *et al.*, 2012); Da Silva *et al.* (2011) by introducing genetically modified sorghum improved lysine content and protein digestibility.

The above-mentioned technologies could be adopted to utilize millets as a functional ingredient in snack bar manufacturing. The taste and the physicochemical characteristics of millets are based on the pre-processing technique used in product design. Therefore, it is necessary to optimize the pre-processing technology of millets to determine their optimum utility in snack bar development.

Gap in study

Due to the technological constraints mentioned, millets are not utilized extensively in the snack food industry as well as in breakfast cereal production. In the recent past, the market has expanded itself with the large manufacturing of snack bars. The market has been segmented into granola bars, nutrition and health bars and specialized bars (IFF, 2020). The need for specialized bar increases as the consumer

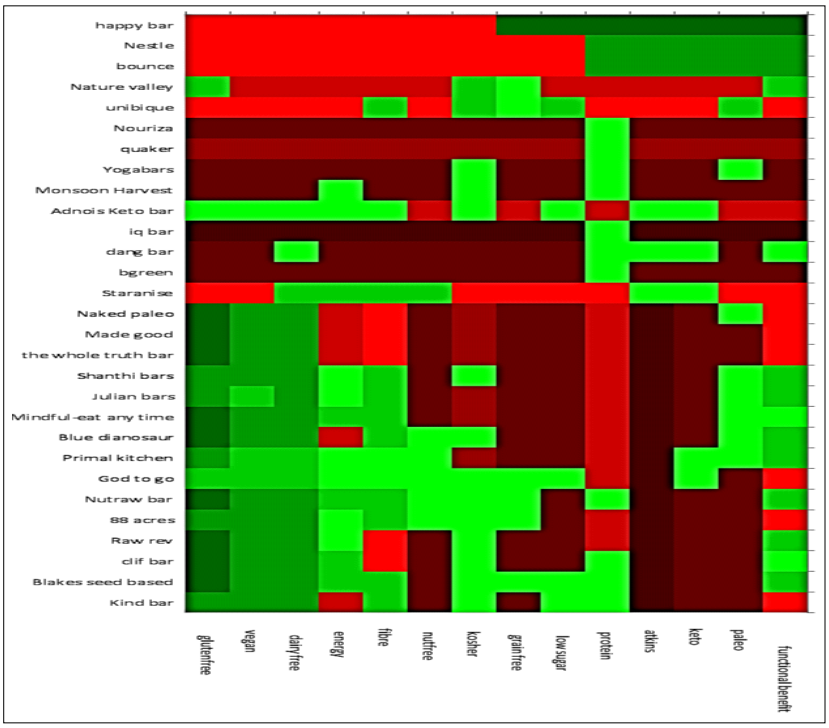

Fig 4: Heatmap analysis of snack bars in the market.

demand increases for a particular need. The market survey conducted in the current study revealed that millet-based bars are limited in the market and the percentage utilized summed up to 25% only. The heat map developed by using XLSTAT version 21.0 was based on the claims given on the packaging material of snack bars available in the consumer market (Fig 4). The heat map gives an overview of different brands of commercially available snack bars and their health/ nutrient claim. The study revealed that there is a dire need for the utilization of millets in designing and developing snack bars for specialized conditions and as ready-to-use therapeutic foods (RUTFs). However, in the recent past, several studies were observed for the utilization of millets in developing general granola bars. A necessity was felt for developing a range of wholesome nutrient-dense products, that meet the nutritional requirement of target consumers as per the physiological, clinical, economic and demographic conditions, globally. Samuel and Peerkhan (2020) had used pearl millet in the production of the snack bar, to raise the consumption of pearl millet-based foods in the household. The snack bar was composed of 25-30% pearl millet along with nuts and whey protein. The millet was steamed and oven dried before incorporation in bar formulation, which enhanced the protein digestibility and the available protein content. Sohan *et al.* (2021), formulated energy bars using flakes of foxtail and proso millet by incorporating 50% millet flakes along with other nuts and sweeteners for manufacturing at a large scale. These types of bars can be used as convenience foods for all age groups.

Sobana (2017) reported the utilization of millets in snack bar preparation for a targeted audience for sports nutrition. In this study, millets were subjected to roasting and germination and concluded that millet-based bars were found to be high calorie, easily digestible and a low-cost product for athletes. Himaja and Manikkavachakan (2020) have developed bars using sorghum and millets along with nuts to address the requirement of balanced nutrition bars for the larger segment of the population. The developed bars could be used as meal replacers for adults and adolescents.

The various studies on snack bars revealed the under-utilization of millets in snack bar preparation even though millets are nutri-dense and possess functional health benefits. Therefore, a need was felt to emphasize and reassert the importance of millet incorporation in therapeutic and specialized bars. However, savory bars can also be developed using millets as they can adapt to different flavors.

CONCLUSION

Millets are grains with high nutritive value. They can be used to make foods that are of therapeutic potential. When one's eating habit changes, it represents a change in one's health condition. Due to the lack of several technological opportunities and challenges, the millets are underutilized in several countries. Being a cost-effective crop, millets can be used in products that are cost-effective and highly nutritious. Snack bars are convenient, ready-to-eat, bite-sized, nutri-dense food products that can be eaten as a part of a meal or replacement for a meal. Therefore, emphasis could be given to developing novel and creative millet-based snack bars for additional health benefits by meeting the special nutritional requirement of different segments of the population.

Conflict of interest: None.

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