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Nikita Shinde
M.Tech Research Scholar, Department of Food Process Technology, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Vijaya Pawar
Professor, Department of Food Process Technology, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Sakshi Jiwtode
M.Tech Research Scholar, Department of Food Process Technology, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Monali Joshi
Ph.D. Research Scholar, Department of Food Process Technology, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Ahmed Rayyan
M.Tech Research Scholar, Department of Food Process Technology, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Corresponding Author:
Nikita Shinde
M.Tech Research Scholar, Department of Food Process Technology, College of Food Technology, VNMKV, Parbhani, Maharashtra, India

Development and quality evaluation of finger millet-based nutribar enriched with banana powder

Nikita Shinde, Vijaya Pawar, Sakshi Jiwtode, Monali Joshi and Ahmed Rayyan

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Abstract
The increasing demand for convenient and nutrient-dense foods has driven research into developing functional snack products that offer health benefits while being palatable. This study focused on the development and quality evaluation of a finger millet-based nutribar enriched with banana powder, dates, jaggery, and milk powder. Four formulations (T_0 to T_3) were prepared by varying ingredient proportions. Physical characteristics, proximate composition, mineral content, and textural profile were assessed to identify the optimal formulation. The selected sample (T_2) demonstrated superior nutritional quality, with enhanced mineral content (Calcium: 274.71 mg/100 g, Potassium: 482.83 mg/100 g, Iron: 2.754 mg/100 g), higher protein and crude fiber levels, and a balanced texture (Hardness: 4.42 Kg) that is suitable for diverse consumer groups. The study confirms that the integration of natural ingredients such as banana and milk powder contributes to nutritional enrichment, improved textural properties, and enhanced acceptability, aligning with current trends toward clean-label, functional foods. The developed nutribar represents a sustainable and health-oriented alternative for modern snacking.

Keywords: Finger millet, nutribar, functional food, mineral composition, proximate analysis, textural profile, plant-based nutrition

Introduction

The increasing global prevalence of diabetes and obesity has sparked a growing interest in nutrient-dense foods that offer complex carbohydrates, dietary fiber, and beneficial phytochemicals (Shobana *et al.*, 2007) [29]. Diets rich in phenolic acids have been associated with positive health effects, including antioxidant activity, protection against genetic mutations, and better blood glucose regulation, making them important components in the formulation of functional foods (Friedman, 1997) [14]. Wholegrain cereals are being more widely used in food products around the world, largely due to their high fiber content and abundance of bioactive compounds known to support overall health (Jones & Engleson, 2010) [16].

Among whole grains, millets stand out for their adaptability to dry and tropical climates, resistance to pests and diseases, and ability to grow in challenging environments where other cereals may not thrive. Despite these advantages, millets remain underutilized in many developed countries, although they offer significant potential for value-added food production, especially in developing regions. Moreover, millets are naturally gluten-free, making them an ideal choice for individuals with celiac disease or gluten sensitivity (Chandrasekara & Shahidi, 2010) [8].

Millets, a diverse group of small-seeded cereal crops, are globally recognized as essential staples for both human consumption and livestock feed. This category includes species such as little millet, foxtail millet, Kodo millet, common millet, barnyard millet, pearl millet, and various finger millets belonging to the Poaceae family (Saleh *et al.*, 2013) [26]. In regions facing water scarcity and unpredictable weather patterns, millets serve as a sustainable alternative, requiring minimal water while demonstrating strong resistance to environmental stress (Chapke *et al.*, 2018) [9]. Rich in macro and micronutrients, millets are regarded as having nutritional characteristics equal or superior to commonly consumed grains such as rice and wheat. Historically, they have been essential grains in India and are especially advised for youngsters, pregnant women, and nursing mothers due to their high nutritional

content and easy digestibility (Amadou *et al.*, 2013) [6]
Finger millet (*Eleusine coracana* L.), also known as ragi or nachni, is one of the most valuable millets in India, contributing significantly to millet production worldwide. It accounts for approximately 85% of minor millet cultivation in India, with Karnataka as the leading producing state (FAO, 2010; Upadhyaya *et al.*, 2007) [13, 36]. Finger millet is rich in polyphenols, dietary fiber, minerals, and amino acids, offering potential health benefits such as improved glycemic control and reduced risk of chronic diseases (Dida *et al.*, 2008; McKeown *et al.*, 2002) [12, 18].
Banana (Musa spp.) is another significant component used in functional food formulations. It is a rich source of potassium, dietary fiber, and bioactive compounds, with both ripe and green bananas offering important nutritional benefits (Simmonds & Shepherd, 1955; Kumar *et al.*, 2012) [31, 17]. Green banana flour is particularly valuable due to its high starch and dietary fiber content, supporting cholesterol-lowering effects and promoting cardiovascular health (Ovando-Martínez *et al.*, 2009; Zhang *et al.*, 2005) [22, 38].
Dates (Phoenix dactylifera L.) are a nutritious fruit extensively cultivated in the Middle East and North Africa. Rich in sugars, vitamins, minerals, and antioxidants, dates are widely used as natural sweeteners and functional ingredients (Al-Shahib *et al.*, 2003; Tang *et al.*, 2013) [5, 34]. Their inclusion in functional food products offers both energy-dense nutrition and potential therapeutic effects, such as anti-diabetic and anti-inflammatory benefits.
Jaggery, a traditional unrefined sugar, provides more nutrients compared to refined sugar, including calcium, magnesium, iron, and antioxidants (Singh & Rao, 2021) [25]. It releases energy gradually, supports digestive health, and serves as a rich source of essential minerals.
Milk powder, particularly skimmed milk powder, is widely used in food formulations for its high protein and mineral content along with extended shelf life (Walstra *et al.*, 2006) [37]. It adds valuable nutrients to functional foods while enhancing texture and mouth feel.
Nutribars are convenient, nutrient-dense products designed to provide a rapid energy source through macronutrients such as carbohydrates, proteins, and fats (Tiwari, 2017) [35]. The combination of finger millet, banana powder, dates, jaggery, and milk powder provides a balanced mixture of nutrition and flavor, offering essential elements like protein, dietary fiber, and minerals without artificial additives. This aligns with the modern dietary focus on clean labels, plant-based nutrition,

Materials

Raw Materials

The ingredients such as finger millet, milk powder, Jaggery, Dates and glucose syrup were purchased from the local market of Parbhani. The Grand Nain variety of Banana was procured from Agri photovoltaic plant of Manvat.

Chemicals and Glassware

Analytical grade chemicals and laboratory glassware were sourced from specialized laboratories within the College of Food Technology, VNMKV.

Processing and Analytical Equipment

The key equipment used in the study included a mixer grinder for grinding and mixing raw ingredients, a stainless steel vessel for preparation of binder syrup and mixing of components, and a hand moulder for shaping the nutribar samples. Drying was carried out using a cabinet dryer, while a hot air oven was used for moisture removal during proximate analysis. Ashing of samples was performed in a muffle furnace. A digital weighing balance provided precise measurement of raw materials and samples during analysis. The Soxhlet apparatus was employed for fat extraction, and a micro-Kjeldahl assembly was used to determine protein content through nitrogen estimation. Texture Profile Analysis (TPA) was conducted using a Stable Micro System *TAXT2* Plus Texture Analyzer to measure hardness and other textural properties of the nutribar. Finally, the mineral composition of samples was quantified using an Atomic Absorption Spectrophotometer (AAS), ensuring accurate detection of calcium, iron, zinc, and other micronutrients.

Packaging Materials

Packaging materials such as low-density polyethylene (LDPE), Aluminium foil, butter paper and high-density polyethylene (HDPE) standing pouches were procured from the local market in Parbhani.

Chemical Analysis of nutribar

Estimation of moisture content

5 g sample subjected to oven drying at 105º For 4-5 hours it was again weighed after cooling and repeated until a constant weight was obtained. The Resultant loss in weight was calculated as moisture content (AOAC, 2000) [3]

% Moisture = loss in weight of sample after drying/Weight of Sample × 100

Fat Content: Total fat content was determined by using Soxhlet apparatus as per the procedure of AACC (1990) [1] Method No. 30-25.

Protein Content: Protein content in sample was determined by using convectional Mirco-Kjeldhal digestion and distillation by using procedure as given in AOAC (1992) [7].

Fiber Content

The fiber content of the sample was determined by the procedure as described in AOAC (1992) [7].

Ash Content

The ash content present in the sample was determined according to the procedure given in AOAC (1992) [7] using Muffle furnace.

Carbohydrate Content

Total Carbohydrate content of sample was calculated by difference method as follows. (Merrill and Watt, 1973) [24].

Carbohydrate (%) = [100-(Moisture + Fat + Protein + Ash + Fiber)]

Mineral Analysis

Titration and spectrophotometric method were used to determine the presence of minerals including zinc, iron, manganese and copper (Atomic absorption spectrophotometer).

Nutribar Formulation

Based on preliminary trials and sensory evaluation, four nutribar formulations were finalized, designated as T_0, T_1, T_2, and T_3. The standardized recipe for the development of the nutribar consisted of 30 g of finger millet flour, 10 g of banana powder, 30 g of dates, 10 g of jaggery, 10 g of milk powder, and 10 g of glucose syrup. These ingredients were selected to provide a balanced nutritional profile with functional benefits, while also ensuring good taste and texture.

Table 1: Formulations of raw material used for preparation of nutribar

Sample	Quantity (g)					
	Finger millet	Banana powder	Dates	Jaggery	Milk powder	Glucose syrup
T_0	40	-	30	10	10	10
T_1	35	5	30	10	10	10
T_2	30	10	30	10	10	10
T_3	25	15	30	10	10	10

T_0: 40% finger millet flour + 30% Dates + 10 jaggery + 10% milk powder + 10 glucose syrup
T_1: 35% finger millet flour + 5% banana Powder + 30% Dates + 10 jaggery + 10% milk powder + 10 glucose syrup
T_2: 30% finger millet flour + 10% banana Powder + 30% Dates + 10 jaggery + 10% milk powder + 10 glucose syrup
T_3: 25% finger millet flour + 15% banana Powder + 30% Dates + 10 jaggery + 10% milk powder + 10 glucose syrup

Methodology for preparation of nutribar

The preparation procedure began with the roasting of finger millet grains to enhance flavor and reduce moisture content, followed by milling to obtain fine millet flour. Dry ingredients including finger millet flour, banana powder, dates, jaggery, and milk powder were thoroughly mixed. Separately, the binder syrup was prepared by heating jaggery, dates, and glucose syrup in a stainless steel vessel until a homogeneous viscous mixture was formed. The dry mix was then combined with the binder syrup and thoroughly blended to form a uniform dough. The mixture was shaped into bars using a hand moulder, followed by cooling to stabilize the shape. Subsequently, a chocolate coating was applied to enhance sensory appeal. The nutribars were packaged in LDPE or HDPE pouches to ensure proper preservation and storage stability. Finally, the bars were stored under controlled conditions until further analysis.

Selection &weighing of raw material
↓
Roasting of finger millet
↓
Milling/grinding into flour
↓
Mixing of dry ingredients
↓
(Finger millet flour, banana powder, milk powder)
↓
Preparation of binder syrup (jaggery, dates & glucose syrup)
↓
Addition of dry ingredient into syrup
↓
Moulding and pressing
↓
Cooling & cutting
↓
Chocolate coating
↓
Refrigeration
↓
Packaging
↓
Storage

Sensory Analysis

Conducted using a 9-point Hedonic Scale (Meilgaard *et al.*, 1999) [20] assessing appearance, colour, taste, flavour, texture, and overall acceptability.

Statistical Analysis

A Completely Randomized Design (CRD) was used.
ANOVA was performed following Panse and Sukhatme (1967) [25] with S.E. and C.D. calculated at 5% significance (p<0.05).

Results and Discussion

Physical Properties of Nutribar

The physical characteristics of different nutribar formulations are presented in Table 1. All formulations exhibited a uniform rectangular shape with consistent length (5.5 cm) and width (3.4 cm). The height varied slightly across formulations, ranging from 2.0 cm (T_1) to 2.4 cm (T_3). The weight of the nutribars increased from 13.32 g in the control sample (T_0) to 14.26 g in T_3, indicating that the addition of functional ingredients contributed to increased product mass. The selected sample (T_2) showed a weight of 14.03 g, suggesting a well-balanced formulation in terms of bulk and ingredient composition.

Table 2: Physical Properties of Nutribar

Formulation	Shape	Length (cm)	Width (cm)	Height (cm)	Weight (g)
T_0	Rectangular	5.5	3.4	2.1	13.32
T_1	Rectangular	5.5	3.4	2.0	13.70
T_2	Rectangular	5.5	3.4	2.1	14.03
T_3	Rectangular	5.5	3.4	2.4	14.26

Proximate Composition of Nutribar

The proximate composition of the control (T_0) and selected optimized formulation (T_2) is shown in Table 2. Moisture content remained stable, with values of 11.40±0.25% and 11.39±0.21% for T_0 and T_2 respectively, indicating good shelf stability. Fat content was nearly unchanged, reflecting consistency in fat-contributing ingredients.
Protein content showed a slight increase in T_2 (6.34±0.30%) compared to T_0 (6.05±0.27%), likely due to the addition of banana powder.
Ash content slightly increased, indicating enhanced mineral content.
Carbohydrates content was slightly increased in T_2 (73.87±0.47) jsample compared to T_1 (73.40±0.40).Crude fiber increased from 2.31±0.20% to 2.62±0.16%, enhancing dietary fiber content. These Results are in close agreement with the findings reported by (Titus U. Nwabueze, 2019).

Table 3: Proximate Composition of Nutribar

Chemical Properties (%)	Control (T_0)	Selected Sample (T_2)
Moisture	11.40±0.25	11.35±0.21
Fat	4.17±0.16	4.18±0.15
Protein	6.05±0.27	6.34±0.30
Ash	2.2±0.24	2.32±0.12
Carbohydrates	73.40±0.40	73.87±0.49
Crude Fiber	2.31±0.20	2.62±0.16

*Each value is an average of three determinations.

Mineral Composition of Nutribar

Mineral content of the control and selected sample is shown in Table 4. The mineral composition analysis revealed significant improvements in several key minerals in the selected nutribar formulation (T_2) compared to the control (T_0). Calcium content increased from 266.1±0.61 mg/100 g to 274.71±0.60 mg/100 g, contributing to enhanced bone health potential. Potassium exhibited a significant rise from 425.23±0.32 mg/100 g to 482.83±0.43 mg/100 g, which is beneficial for maintaining electrolyte balance and supporting cardiovascular health. In contrast, magnesium content decreased from 343.36±0.36 mg/100 g to 281.41±0.30 mg/100 g, possibly due to ingredient dilution or processing factors such as thermal degradation or interaction with other components during preparation. Notably, iron concentration increased markedly from 1.36±0.06 mg/100 g to 2.754±0.05 mg/100 g, significantly enhancing the functional property of the nutribar by providing a potential source of dietary iron to combat anaemia. Zinc content remained stable between the control and selected sample, indicating that its retention was unaffected by the formulation changes. These findings suggest that the optimized formulation (T_2) improves the mineral profile, particularly calcium, potassium, and iron, making the nutribar a functional product with added nutritional benefits.

Table 4: Mineral composition of nutribar (mg/100 g)

Sample	Calcium (mg/100 g)	Potassium (mg/100 g)	Magnesium (mg/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)
Control (T_0)	266.1±0.61	425.23±0.32	343.36±0.36	1.36±0.06	25.45±0.27
Selected Sample (T_2)	274.7±0.60	482.83±0.43	281.41±0.30	2.754±0.05	25.30±0.16

*Each value is an average of three determinations.

Conclusion

This study successfully developed a finger millet-based nutribar fortified with banana powder, dates, jaggery, and milk powder, targeting the increasing consumer demand for nutritious and convenient functional foods. The selected formulation (T_2) exhibited significant improvements in mineral composition, including calcium, potassium, and iron, along with a balanced proximate profile enriched in dietary fiber and protein. Textural analysis revealed an optimal hardness level, ensuring consumer acceptability. The utilization of natural ingredients without artificial additives demonstrates the product's alignment with clean-label trends. These findings suggest that the developed nutribar holds great potential as a health-promoting snack, contributing to improved nutrition and addressing micronutrient deficiencies, especially in underprivileged populations. Future studies could focus on shelf-life stability, consumer sensory evaluation, and large-scale production optimization.

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