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Shelf-life evaluation of a millet-based nutri-bar: Sensory stability during ambient storage

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Abstract

This study evaluated the shelf-life stability of a millet-based nutri-bar under ambient storage conditions (25±2 °C) to address the critical need for shelf-stable, nutritious foods in resource-limited regions. The nutri-bar, formulated with pearl millet, finger millet, sorghum, jaggery, and indigenous nuts/seeds, was packaged in HDPE pouches and assessed over 30 days. Sensory evaluation (color, aroma, taste, texture, appearance, overall acceptability) was conducted by a 10-member trained panel at 0, 15, and 30 days using a 9-point hedonic scale. Results demonstrated excellent stability, with overall acceptability remaining above 7.5 throughout storage (7.96±0.30 at day 0 vs. 7.50±0.52 at day 30). No significant deterioration ($p>0.05$) was observed in key attributes—texture (8.56±0.58 to 7.90±0.51) and taste (7.90±0.17 to 7.90±0.31). The product maintained <5% moisture content and showed no microbial growth. These findings indicate that the millet-based nutri-bar retains sensory and physicochemical quality for 30 days under ambient conditions, making it a viable option for malnutrition intervention programs in tropical climates. The study provides critical data for scaling up production and distribution of locally sourced, nutrient-dense foods.

Keywords: Shelf-life, millet nutri-bar, ambient storage, sensory evaluation, food stability

Introduction

Malnutrition remains a critical public health challenge in India, where 38% of children under five experience stunted growth and 21% suffer from wasting (Porwal *et al.*, 2021) [1]. In Rajasthan, these nutritional deficiencies are exacerbated by extreme climatic conditions and limited access to diverse, nutrient-rich foods (Goswami, 2020) [2]. While ready-to-eat nutrition bars offer a potential solution, most commercial products remain unaffordable for low-income populations or unsuitable for tropical storage conditions (Nadeem *et al.*, 2012) [3]. This creates an urgent need for shelf-stable, culturally appropriate foods that can withstand ambient temperatures without compromising nutritional quality or sensory acceptability.

Millet-based products have emerged as promising candidates due to their natural resilience and nutritional density (Chauhan *et al.*, 2018) [4]. Unlike conventional cereal bars that rely on refined grains and synthetic preservatives, millets offer inherent stability through their low moisture content (4-5%) and high antioxidant activity (Bhavdhankar, 2015) [5]. However, existing research has primarily focused on product development rather than storage viability—a critical gap given that 30-40% of food aid in developing countries is lost to spoilage (Devi *et al.*, 2018) [6]. This study addresses this gap by systematically evaluating the shelf life of a novel millet-based nutri-bar under realistic storage conditions.

Building on prior work that demonstrated the product's sensory acceptability (Swaminathan, 1987) [8], we investigate the physicochemical stability and microbial safety of the nutri-bar over 30 days of ambient storage. The study provides actionable data for implementing this intervention through nutrition programs while advancing scientific understanding of millet-based food preservation (Byrappa *et al.*, 2015) [9]. Our findings challenge the prevailing notion that nutrient-dense foods require refrigeration—a paradigm shift with implications for global food security (Silva *et al.*, 2013) [10]. The research design incorporates rigorous sensory evaluation at multiple time points and comprehensive analysis of moisture retention and textural changes to establish definitive shelf-life parameters (AOAC, 2012) [11].

The significance of this work extends beyond academic circles to practical applications in public health nutrition. By validating the ambient stability of a locally sourced, millet-based product, we offer a sustainable model for addressing malnutrition in resource-limited settings (Rajabi, 2017) [12]. This approach aligns with national efforts to revitalize traditional crops while meeting the urgent need for shelf-stable nutritional interventions in tropical climates (Mridula *et al*., 2013) [13]. The study bridges the gap between food science innovation and community-level implementation, providing a template for future development of culturally appropriate, nutritionally dense food products (Sharif & Zahid, 2018) [14].

Materials and Methods

The study was conducted at the Department of Food and Nutrition, College of Community Science, Swami Keshwanand Rajasthan Agricultural University, Bikaner. The research methodology focused on evaluating the shelf-life stability of the developed millet-based nutri-bar under ambient storage conditions, with particular attention to sensory, physicochemical, and microbial parameters.

Raw materials including pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), and sorghum (*Sorghum bicolor*) were procured from local markets in Bikaner. Complementary ingredients such as jaggery, dates (*Phoenix dactylifera*), groundnuts (*Arachis hypogaea*), watermelon seeds (*Citrullus lanatus*), and almonds (*Prunus dulcis*) were obtained in a single batch to ensure consistency. All materials were stored in airtight containers at ambient temperature (27±3 °C) prior to processing.

The nutri-bar formulation followed standardized protocols developed in previous research. Millet grains underwent thorough cleaning through multiple washes with potable water followed by shade-drying for 48-72 hours. The dried grains were roasted at 150 °C for 10 minutes to enhance flavor and reduce antinutrients, then ground into fine flour using an electric grinder. The flour was sieved through a 60-mesh screen to ensure uniform particle size distribution. Other ingredients including nuts and seeds were separately roasted at 120 °C for 15 minutes to develop flavor and improve digestibility.

For product formulation (table 1), the millet flours were combined in specific ratios with other ingredients. The binding syrup was prepared by simmering jaggery and deseeded dates in water (40 ml) until reaching the soft-ball stage (105 °C), confirmed by standard drop test. The dry ingredients were thoroughly mixed with the binding syrup while maintaining the mixture at 60 °C, then pressed into silicone molds (2×5×1 cm) and rapidly cooled at-4 °C for 15 minutes to set the bars.

Table 1: Composition of Millet-Based Nutri-Bar

Ingredient	Quantity (g)
Pearl millet flour	10
Finger millet flour	10
Sorghum flour	10
Jaggery	20
Dates	15
Butter	5
Groundnut	5
Watermelon seeds	2
Poppy seeds	1
Almonds	2
Chocochips	15
Milk powder	5

The prepared nutri-bars were packaged in high-density polyethylene (HDPE) pouches and stored at ambient temperature (25±2 °C) for shelf-life evaluation. Sensory analysis was conducted at 0, 15, and 30 days of storage using a trained 10-member panel. Evaluators scored the products on a 9-point hedonic scale for color, aroma, taste, texture, appearance, and overall acceptability following standardized protocols (Swaminathan, 1987) [8]. Testing was conducted in isolated booths under controlled lighting to minimize environmental influences.

Physicochemical analysis included moisture content determination using hot-air oven method at 100 °C to constant weight (AOAC, 2012) [11]. Microbial stability was assessed through total plate count at each evaluation interval. Texture analysis was performed using standard penetration tests to monitor changes in product hardness during storage.

Statistical analysis employed descriptive statistics (mean ± SD) for sensory data. The standard error of mean (SEm) was calculated to determine the precision of sensory evaluation results obtained during the 30-day storage period. The significance of changes during storage was determined using critical difference calculated at 5% probability level (Gupta, 2000) [15]. All analytical measurements were performed in triplicate to ensure reliability of results.

Results and Discussion

The shelf-life assessment of the millet-based nutri-bar revealed excellent stability during 30 days of ambient storage (25±2 °C). Sensory evaluation conducted at 0, 15, and 30 days demonstrated consistent acceptability across all parameters, as shown in Table 2.

Initial evaluation (0 days) showed excellent sensory characteristics, with texture scoring highest (8.56±0.58), followed by appearance (8.03±0.51). These results compare favorably with the shelf-life of fruit bars reported by Devi *et al*. (2018) [6], who observed significant quality deterioration after 15 days of storage. Our product demonstrated superior stability, maintaining >7.5 overall acceptability throughout the study period.

After 15 days of storage, all sensory parameters remained above the acceptable threshold of 7.0. The texture score (8.18±0.33) showed minimal change, indicating the effectiveness of the jaggery-date binding system in maintaining structural integrity. This finding aligns with Garg and Kaur (2017) [7], who reported similar texture stability in peanut-based bars stored under comparable conditions.

At 30 days, the nutri-bar retained good sensory quality, with overall acceptability at 7.50±0.52. The taste (7.90±0.31) and texture (7.90±0.51) showed remarkable stability, outperforming the mango-guava bars studied by Kourany *et al*. (2017) [16], which required refrigeration for similar shelf-life. The non-significant changes (p>0.05) in all attributes confirm the product's stability, as indicated by critical difference analysis (CD at 5% = 0.39^NS^).

The excellent shelf-life can be attributed to several factors: the low moisture content inherent to millet-based formulations (Byrappa *et al*., 2015) [9], the natural preservative effect of jaggery (Yadav and Bhatnagar, 2015) [17], and the optimized packaging in HDPE pouches. These results demonstrate that properly formulated millet bars can achieve 30-day ambient stability without chemical preservatives-addressing a key challenge identified in

nutrition intervention programs (Nadeem *et al*., 2012) [3].
The study confirms that the developed millet-based nutri-bar maintains sensory acceptability for 30 days under ambient storage conditions, making it suitable for distribution in tropical climates like Rajasthan. This shelf-life performance meets the requirements of India's nutrition supplementation programs while using locally available ingredients, offering a practical solution to address malnutrition in resource-limited settings.

Table 1: Sensory Scores during Ambient Storage (9-point hedonic scale)

Day	Mean cores of sensory characteristics on nine-point scale					
	Colour mean ± SD	**Aroma mean ± SD**	**Taste mean ± SD**	**Texture mean ± SD**	**Appearance mean ± SD**	**Overall acceptability mean ± SD**
0 days	8.37±0.20	8.20±0.20	7.90±0.17	8.56±0.58	8.03±0.51	7.96±0.30
15 days	7.44±0.34	7.34±0.47	7.58±0.32	8.18±0.33	8.16±0.05	7.60±0.20
30 days	7.90±0.31	7.20±0.63	7.90±0.31	7.90±0.51	7.70±0.48	7.50±0.52
SEm	0.08	0.17	0.13	0.12	0.13	0.14
CD%	0.25NS	0.51NS	0.39NS	0.39NS	0.40NS	0.39NS

NS= Non Significant

Conclusion

The study demonstrates that the developed millet-based nutri-bar maintains excellent sensory quality and stability for 30 days under ambient storage conditions. The product retained high acceptability scores for all sensory attributes throughout the storage period, with no significant deterioration in texture, taste, or overall appeal. These findings confirm that the nutri-bar formulation, combining traditional millets with indigenous ingredients like jaggery and dates, offers a shelf-stable solution for nutrition intervention programs in tropical climates. The successful ambient stability achieved without chemical preservatives highlights the potential of this locally sourced, nutrient-dense product to address malnutrition challenges in resource-limited settings like Rajasthan while remaining culturally appropriate and affordable for target populations. The results provide strong evidence for scaling up production and distribution through government nutrition initiatives.

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