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FOOD INNOVATION: POPPED PEARL MILLET AND BOERHAVIA DIFFUSA LINN BLENDED NUTRI BAR

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ABSTRACT: Boerhavia diffusa Linn, known as Punarnava and as Mookirattai in regional language, is a leafy herb traditionally used for its health benefits due to its rich content of bioactive compounds, antioxidants, and nutrients. This study explores the potential of adding powdered Mookirattai leaves to the developed nutri bar using popped pearl millet aimed to improve its nutritional value and functional qualities. Different variations were made by incorporating varying amounts of Boerhavia diffusa leaf powder to the overall accepted nutri bar variation formulated. The enriched nutri bar showed favorable sensory evaluation for the variation which had 19.5 percent Boerhavia diffusa Linn leaf powder, confirming that adding Mookirattai leaves was acceptable in terms of color, flavor, taste, texture and overall acceptability. Overall, incorporating Boerhavia diffusa into millet-based nutri bars show promise for creating a healthy, nutrient-rich snack. Further studies could focus on maximizing the health benefits and maintaining the bioactive components during processing and storage.

Keywords: Pearl millet, Popped, Mookirattai leaves, Nutri bar, Sensory evaluation.

I. INTRODUCTION

Pearl millet (Pennisetum glaucum) is one of the most important cereal crops, grown in the tropics (Jindal, P & Nikhanj, P. 2023). Pearl millets are a rich source of antioxidants; the consumption offers a great deal of protection against free radical mediated disease such as arthritis, cancer, cardio vascular disease, diabetes mellitus and Alzheimer's disease (Samuel, 2020). Pearl millet is an essential source of iron and zinc and provides a low - cost solution for combating micronutrient deficiencies in millet consuming regions and could be exploited for the preparation of nutrient dense foods (FAO 2016). To enhance iron and zinc bio accessibility in pearl millet, a proper understanding of the effect of various processing technologies on the reduction of inhibitory factor is required. Popped pearl millet enhances digestibility, reduce antinutritional

factors, and improve sensory qualities. Popping involves rapid heating, which gelatinizes starch, increases puffing, and makes the grains easier to grind into a fine powder (Jindal, P & Nikhanj, P, 2023).

Studies have demonstrated that popping not only improves the palatability and crispness of millet products but also preserves most of the nutrients, including proteins, dietary fiber, and minerals (Kumari, Singh, Jha, Singh, Sarkar, & Bhatia, 2018; Garud, Lamdande, Tavanandi, Mohite, & Nidoni, 2022). Furthermore, the process reduces moisture content and microbial load, thereby increasing the shelf life of the flour (Chauhan, Jha, Sharma, Satyavathi, & Kumari, 2015).

Boerhavia diffusa Linn commonly known as Punarnava, and known as mookirattai leaves in regional language is one of the underutilized perennial herbs widely distributed in tropical and subtropical regions, including India. It has been extensively used in traditional medicine systems like Ayurveda for its therapeutic properties (Patel et al., 2025; Bhalerao, 2012).

The present study aimed to develop a popped pearl millet nutri bar incorporating Boerhavia diffusa Linn and to evaluate its sensory acceptability in order to determine its suitability as a functional millet based nutri bar.

II. METHODOLOGY

2.1 Processing of raw materials

Pearl millet (Pennisetum glaucum) procured from the local market was cleaned and was sundried for two hours in order to ease the popping process of millets using a thick bottomed pan on medium to high flame. In a hot pan, small batch of grains are added with quick stirring. The heat causes the grains to puff up and pop with a few seconds. The popped millet was whisked once for obtaining uniform coarse powder (Taylor et al., 2016).

Green gram (Vigna radiata), rich in iron and potassium and commonly recommended in dietetics, was procured from the local market, cleaned. Green gram was roasted until golden brown, cooled, and ground into a coarse powder (Hou et al., 2019). Pumpkin seeds (Cucurbita maxima Duchesne) were sautéed, and ground into coarse powder for increasing the healthy fats, magnesium, and zinc content (Kulczynski & Gramza-Michalowski, 2019). Dry amla (Phyllanthus emblica) without added sugar or salt was purchased and used for its high antioxidant value (Baliga & Dsouza, 2011). Turmeric (Curcuma longa L.) (Hewlings & Kalman, 2017) powder and dry ginger powder (Zingiber officinale roscoe) (Mao et al., 2019)., known for the anti-inflammatory and medicinal properties, were procured from the local market. Palm jaggery (Borassus flabellifer L.) syrup was prepared by boiling 100 g of powdered palm jaggery with 50 ml of water in a thick-bottomed pan until it reached a soft ball consistency. Mookirattai leaves Powder (Boerhavia diffusa Linn) was procured from local siddha medical shop of Puducherry.

2.2. Formulation of Nutri Bars & sensory analysis

2.2.1. Variations

Nutri bar using popped pearl millet, green gram and palm jaggery was developed as control samples in three variations coded as PPNB1, PPNB2, and PPNB3 denoting popped pearl millet nutri bar. The most accepted variation by the selected panelists was chosen for developing experimental nutri bar. The experimental nutri bar developed in three different variations was subjected to sensory analysis using 9- point hedonic rating. It was coded as PPGNB1, PPGNB2, PPGNB3 denoting the ingredient Popped pearl millet, green gram and contains other ingredients pumpkin seeds, dry amla, dry ginger powder and turmeric powder. To the most accepted variation Boerhavia diffusa linn leaf powder was incorporated at 13.5 per cent, 16.5 per cent, 19.5 percent and was coded as PPMENB1, PPMENB2 and PPMENB3 denoting enriched nutri bar- and was evaluated for its sensory attributes.

2.2.2. Sensory analysis

Sensory evaluation was conducted by 30 semi-trained and trained panelists. Panelists were selected based on their familiarity with sensory evaluation and absence of food allergies or sensitivities to the ingredients. The different variations of nutri bar were evaluated for colour, flavour, taste, texture, appearance and overall acceptability using a 9-point hedonic rating scale (1= dislike extremely, 9= like extremely).

2.2.3. Statistical analysis

The results were expressed as mean ± standard deviation (Mean ± SD). A One-way analysis of variance (ANOVA) was performed separately for each sensory attribute to determine whether there were statistically significant differences among the five formulations. The treatments included the control, PPGNB3, PPMENB1, PPMENB2 and PPMENB3. The level of statistical significance was set at $p < 0.05$.

When the ANOVA indicated a significant difference among the treatments, post-hoc multiple comparison analysis was performed to identify the specific treatment means that differed significantly from one another. The results of the post-hoc comparison were represented by superscript lowercase letters. Means sharing the same superscript letter were considered statistically non-significant, whereas means with different superscript letters were considered significantly different at $p < 0.05$.

The statistical analysis was used to determine the effect of incorporation of different levels of Boerhavia diffusa Linn leaf powder on the sensory characteristics and overall acceptability of the developed nutri bar.

III. RESULTS AND DISCUSSION

3.1. Popped Pearl millet nutri bar incorporated with Boerhavia diffusa Linn

The table gives the nutri bar incorporated with Boerhavia diffusa linn leaf powder in three different variations

TABLE 3.1 - Popped pearl millet nutri bar incorporated with Boerhavia diffusa Linn leaf powder

	Variations in g		
Ingredients	**PPMENB 1**	**PPMENB 2**	**PPMENB 3**
Popped pearl millet (g)	63.75	63.75	63.75
Green gram (g)	21.25	21.25	21.25
Pumpkin seeds (g)	5	5	5
Dry amla (g)	5	5	5
Dry ginger powder (g)	1	1	1
Turmeric (g)	1	1	1
Mookirattai keerai leaf powder (g)	13.5	16.5	19.5
Palm jaggery (g)	100	100	100

Three variations were developed by gradually increasing the quantity of Boerhavia diffusa leaf powder from 13.5 g to 19.5 g, while the quantities of the remaining ingredients were kept constant. The different levels of Boerhavia diffusa leaf powder were incorporated to identify the optimum level that would improve the functional properties of the nutri bar without affecting its sensory acceptability.

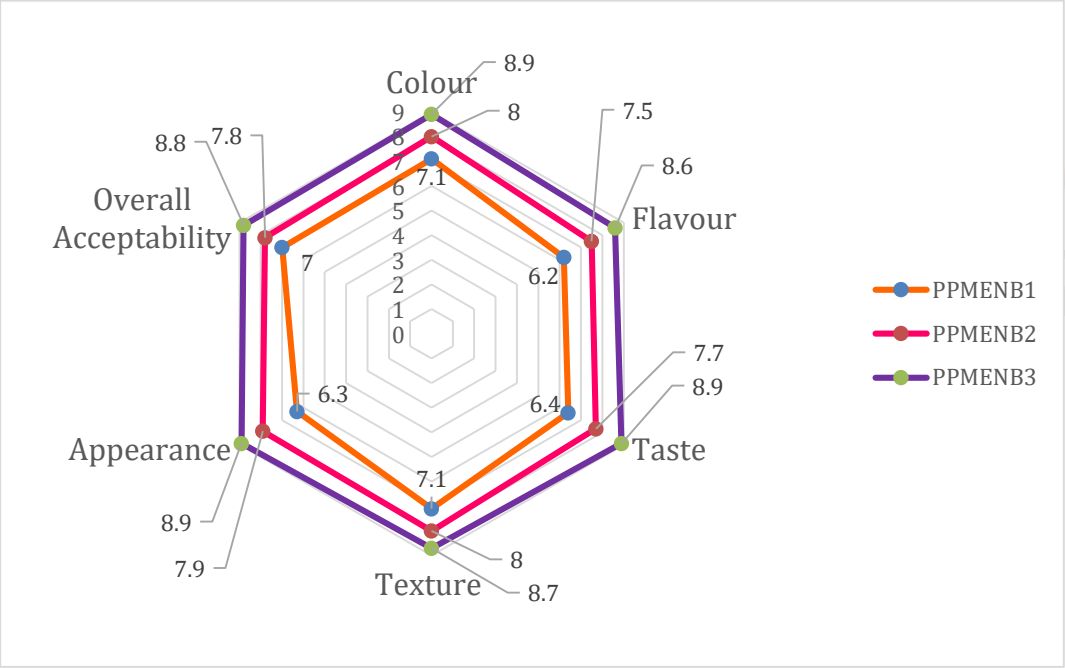
The enriched popped pearl millet nutri bar formulation had a total weight of 200g, The formulation yielded four servings of 50 g each. The cost per serving was Rs. 30, indicating that the developed nutri bar is economical and affordable.

3.2. MEAN SENSORY SCORE OF ENRICHED NUTRI BAR

TABLE 3.2- Mean sensory score of enriched nutri bar incorporated with Boerhavia diffusa Linn leaf powder

Variations	Mean sensory score					
	Colour	Flavour	Taste	Texture	Appearance	Overall Acceptability
PPMENB1	7.1 ± 0.8	6.2 ± 1.1	6.4 ± 0.8	7.1 ± 0.9	6.3 ± 0.7	7.0 ± 0.9
PPMENB2	8.0 ± 0.7	7.5 ± 0.9	7.7 ± 0.7	8.0 ± 0.8	7.9 ± 0.8	7.8 ± 0.9
PPMENB3	8.9 ± 0.1	8.6 ± 0.5	8.9 ± 0.2	8.7 ± 0.4	8.9 ± 0.2	8.8 ± 0.3

Figure 1 - Mean sensory score of enriched nutri bar incorporated with Boerhavia diffusa Linn leaf powder



A highest mean score of 8.9 ± 0.2 was obtained for appearance, taste and colour for the third variation PPMENB3, followed by PPMENB2 and PPMENB1. The consistently higher scores obtained by PPMENB3 across all sensory attributes and overall acceptability indicate that it was the most preferred and acceptable formulation among the three enriched Nutri bar variations.

3.3. ONE WAY ANOVA BETWEEN CONTROL VS ACCEPTED VARIATION AND ENRICHED NUTRI BAR

TABLE 3.3 - One way ANOVA between Control vs Accepted Variation and enriched Nutri bar

Attributes	Control	PPMNB 3	PPMENB 1	PPMENB 2	PPMENB 3
Colour	7.5 ± 0.9^{a}	7.4 ± 0.4^{a}	7.1 ± 0.8^{b}	8.0 ± 0.7^{c}	8.9 ± 0.1^{d}
Flavour	8.0 ± 0.8^{a}	7.1 ± 0.6^{b}	6.2 ± 1.1^{c}	7.5 ± 0.9^{b}	8.6 ± 0.5^{d}
Taste	7.6 ± 1.1^{a}	7.4 ± 0.5^{a}	6.4 ± 0.8^{b}	7.7 ± 0.7^{a}	8.9 ± 0.2^{c}
Texture	7.4 ± 1.4^{a}	7.3 ± 0.4^{a}	7.1 ± 0.9^{a}	8.0 ± 0.8^{b}	8.7 ± 0.4^{c}
Appearance	7.2 ± 1.2^{a}	7.0 ± 0.6^{a}	6.3 ± 0.7^{b}	7.9 ± 0.8^{c}	8.9 ± 0.2^{d}
Overall acceptability	8.9 ± 0.1^{a}	8.6 ± 0.5^{ab}	8.9 ± 0.2^{a}	7.8 ± 0.9^{b}	8.8 ± 0.3^{c}

Note: Values are expressed as mean ± standard deviation (Mean ± SD) (n = 30). One way ANOVA showed significant differences among the treatments for all sensory attributes ($p<0.001$).

The sensory evaluation data were statistically analysed using one-way analysis of variance (ANOVA) to determine whether significant differences existed among the control nutri bar, PPNB3 and the enriched nutri bar variations (PPMENB1, PPMENB2 and PPMENB3).

One – way ANOVA revealed significant differences ($p<0.05$) among the Nutri bar formulations for colour, flavour, taste, texture, appearance and overall acceptability. PPMENB3 recorded significantly higher scores for the most sensory attributes, particularly colour (8.9±0.1) taste (8.9±0.2), texture (8.7±0.4) and appearance (8.9±0.2), indicating superior sensory acceptance. However, overall acceptability was highest for the control and PPENB1 (8.9±0.1 and 8.9±0.2 respectively), while PPMENB2 showed comparatively lower acceptance (7.8±0.9)

Conclusion

Popping of pearl millet proved to be a suitable processing method for improving the grain's suitability in ready-to-eat snack formulations. Sensory analysis showed that the various incorporation levels of Boerhavia diffusa leaf powder were well accepted, with one formulation achieving significantly higher scores for texture and overall acceptability. The findings highlight the potential of incorporating traditional leafy resources into convenient food formats to enhance dietary diversity and promote the utilization of indigenous plant ingredients.

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