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Development and evaluation of different value-added products from the different varieties of moringa leaves (*Moringa oleifera*)

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Abstract
In India's vast agricultural tapestry, the drumstick tree (*Moringa oleifera*) emerges as a resilient asset, its leaves brimming with vitamins, minerals, and antioxidants that could revolutionize nutrition amid widespread deficiencies affecting over 50% of the population (National Family Health Survey, 2023). Despite annual production of 1.2 million tonnes from 380 km², moringa remains underutilized in processed foods, prompting this study to develop value-added products using powder from varieties PKM-1, PKM-2, ODC, and Prayagraj Local. Conducted at Naini Agricultural Institute, Prayagraj, during the 2025 season, the research employed a randomized block design with three replications, incorporating 10% moringa into sweet cookies, salty cookies, instant soup premix, and energy bars against a control, evaluating physico-chemical, nutritional, sensory, and economic attributes. Physico-chemical analysis revealed moisture of 5.22-11.90% and hardness increase of 179.78% (178-498 g) in incorporated treatments (ANOVA $p<0.0001$). Nutritional gains included iron up to 17.56 mg/100 g (PKM-2), protein 18.66 g/100 g, calcium 649.47 mg/100 g, vitamin C 6 mg/100 g, and beta-carotene 740 mcg ($p<0.00001$). Sensory scores reached 8.50 on a 9-point scale (p = 0.014-0.070). Economic viability showed costs Rs. 0.096-0.612 per unit and B:C ratios 1.56-4.20. PKM-2 excelled in iron enhancement. These findings advance postharvest technology by offering scalable, nutrient-dense products for malnutrition alleviation and rural economies.

Keywords: *Moringa oleifera*, value-added products, nutritional enhancement, sensory evaluation, economic feasibility, ANOVA

Introduction
In the heart of India's diverse agricultural landscape, where ancient traditions meet modern nutritional challenges, the humble drumstick tree (*Moringa oleifera*) stands as a beacon of untapped potential. Often called the "miracle tree" for its extraordinary resilience in arid conditions and its leaves packed with life-sustaining nutrients, moringa has been a staple in rural diets for centuries. Yet, in a nation grappling with micronutrient deficiencies affecting over 50% of its population-leading to widespread anemia, stunted growth, and weakened immunity (National Family Health Survey, 2023) [3] this nutrient powerhouse remains largely underutilized in everyday processed foods. With India's annual moringa production exceeding 1.2 million tonnes from just 380 km² of land, the opportunity to transform this abundant resource into accessible, value-added products is not just promising but urgent, especially as global food security demands innovative solutions to blend tradition with technology.

Moringa leaves are a nutritional treasure trove, boasting high levels of vitamins (A, B-complex, C, E), minerals (iron, calcium, potassium), proteins, and antioxidants such as flavonoids and phenolics, which surpass those in common vegetables like spinach or carrots (Gopalakrishnan *et al*., 2016) [1]. These compounds offer anti-inflammatory, antidiabetic, and anticancer properties, making moringa a natural ally against chronic diseases prevalent in developing regions (Stohs & Hartman, 2015) [2]. However, traditional consumption—often as fresh leaves or simple powders—limits bioavailability and shelf-life, resulting in postharvest losses and restricted market reach. Previous studies have explored moringa in limited formats, such as value-added biscuits or soups, but variety-specific evaluations and comprehensive assessments spanning physico-chemical, nutritional, sensory, and economic aspects are scarce, particularly in subtropical contexts like Uttar Pradesh.

This gap is particularly stark given moringa's varietal diversity—PKM-1, PKM-2, ODC, and Prayagraj Local each exhibit unique nutrient profiles, with PKM-2 known for elevated iron and ODC for calcium (Dhakar *et al*., 2011) [4]. By incorporating 10% moringa powder into everyday products like cookies, soup premix, and energy bars, this study not only aims to boost nutrient density but also to create economically viable options for small-scale farmers and urban consumers. The research addresses a critical need in postharvest technology: developing functional foods that retain moringa's benefits while ensuring palatability and affordability. Through a randomized block design with three replications, the investigation evaluated these products for moisture (5.22-11.90%), texture hardness (178-498 g), iron (0.20-17.56 mg/100 g), sensory scores (7.30-8.50), and B:C ratios (1.56-4.20), revealing PKM-2's superiority. These findings could revolutionize how moringa is viewed—from a backyard crop to a cornerstone of India's nutritional security, inviting readers to discover how simple innovation can combat complex global challenges.

Materials and Methods

The study was conducted during the 2025 agricultural season at the Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, India, employing a randomized block design with three replications to assess the performance of four *Moringa oleifera* varieties— PKM-1, PKM-2, ODC, and Prayagraj Local—against a control, with each experimental unit consisting of 100 g of product and moringa leaf powder incorporated at a 10% w/w ratio.

Fresh moringa leaves were harvested from mature plants grown under uniform conditions at the university farm, cleaned to remove impurities, and dehydrated using a food dehydrator at 50 °C for 8 hours to achieve a moisture content below 5%, followed by pulverization with a laboratory grinder and sieving through a 60-mesh sieve. Ingredients, sourced from Prayagraj markets in March 2025, included refined wheat flour, sugar, butter, rice flour, cornstarch, onion powder, garlic powder, tomato powder, salt, baking powder, cumin seeds, milk powder, oats, peanut butter, honey, almonds, cashews, sunflower seeds, flax seeds, dried cranberries, and vanilla essence. Four products—sweet cookies, salty cookies, instant soup premix, and energy bars—were formulated per 100 g as follows: sweet cookies with 41 g refined wheat flour, 22 g sugar, 24 g butter, 10 g moringa powder, 1 g vanilla essence, and 2 g milk; salty cookies with 44 g refined wheat flour, 18 g butter, 4 g rice flour, 7 g sugar, 1.5 g salt, 1 g baking powder, 2.3 g cumin seeds, 10 g moringa powder, and 2 g milk; instant soup premix with 2.3 g cornstarch, 1.1 g milk powder, 0.8 g onion powder, 0.6 g garlic powder, 0.4 g tomato powder, 0.8 g salt, 0.4 g sugar, 0.05 g black pepper, 0.15 g mixed herbs, 0.3 g monosodium glutamate, and 10 g moringa powder; and energy bars with 10 g oats, 11 g peanut butter, 20 g honey, 10 g almonds, 6 g cashews, 10 g sunflower seeds, 6 g flax seeds, 14 g dried cranberries, 1 g vanilla essence, and 10 g moringa powder, with ingredients mixed using a planetary mixer (Model: KM-300, 200W) at 120 rpm for 5 minutes, shaped (cookies 5 g each, bars 20 g each), baked at 180 °C for 12-15 minutes (cookies) or cooled and pressed (bars), and soup premix blended and packed in 10 g airtight sachets. Five treatments were applied—T_0 (control with no moringa), T_1 (PKM-1), T_2 (PKM-2), T_3 (ODC), and T_4 (Prayagraj Local)—each replicated thrice, with randomization across blocks to minimize environmental variability. Physico-chemical properties were evaluated by determining moisture content via the AOAC (2005) oven-drying method at 105 °C for 24 hours, texture analysis with a TA-XT_2 Texture Analyzer using a 5mm probe at 1 mm/s to measure hardness, cohesiveness, and fracturability, and nutritional analysis of iron, protein, calcium, vitamin C, and beta-carotene using standard laboratory methods (AOAC, 2005) cross-verified with Indian Food Composition Tables (IFCT, 2017); sensory evaluation involved 6 semi-trained judges (age 20-40, balanced gender) using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely) for color, appearance, aroma, taste, texture, and overall acceptability, with coded samples presented randomly in a controlled sensory lab. Economic feasibility was assessed using local Prayagraj market prices (March 2025): moringa powder Rs. 400/kg, refined wheat flour Rs. 30/kg, etc., calculating cost of preparation per unit by summing ingredient costs and labor (Rs. 50/hour for 2 hours/100 units), estimating gross income from selling prices (sweet cookies Rs. 10/unit, salty cookies Rs. 10/unit, soup premix Rs. 1.5/sachet, energy bars Rs. 16/unit) and deriving net income and benefit-cost (B:C) ratio as Net Income = Gross Income-Total Cost and B:C = Gross Income/Total Cost for 100-unit batches. Data were analyzed using R software (version 4.3.0) with ANOVA to find significant differences ($p<0.05$), and Least Significant Difference (LSD) tests were applied for mean separation where applicable.

Results and Discussion

The development of value-added products from *Moringa oleifera* powder, utilizing varieties PKM-1, PKM-2, ODC, and Prayagraj Local in contrast to a control (T_0), resulted in products showing a uniform green tint, a visual enhancement noted during sample preparation (Plates not shown). Physico-chemical attributes, as detailed in Table 1, revealed a significant upsurge in moisture content, escalating from 5.22% in T_0 soup premix to 11.90% in T_0 sweet cookies, marking a 127.97% increase attributable to the high fiber content of moringa leaves (ANOVA, F = 19.44, p = 0.0001). This pattern was consistent across all products: sweet cookies averaged 11.28% for T_1-T_4, salty cookies 10.66%, instant soup premix 6.23%, and energy bars 9.41%, showing a progressive enhancement in water retention capacity, with sweet cookies showing the most pronounced effect. Texture analysis further proved a remarkable improvement, with hardness rising from 178 g in T_0 salty cookies to 498 g in T_2 energy bars, a 179.78% increment, alongside cohesiveness increasing from 0.041 to 0.091 and fracturability from 4985 g to 5685 g (F = 20.00, p = 0.00008). This suggests a value-added, cohesive structure, particularly clear in energy bars, which aligns with findings by Gopalakrishnan *et al*. (2016) [1] on the textural benefits of fiber enrichment.

Nutritional profiling, also presented in Table 1, underscored substantial enhancements, with iron content soaring from 0.20 mg/100 g in T_0 soup premix to 17.56 mg/100 g in T_2 energy bars, a 8678% leap that fulfills 50-100% of the Recommended Dietary Allowance (RDA). Protein levels

climbed from 0.80 g/100 g to 18.66 g/100 g, calcium from 10.00 mg/100 g to
649.47 mg/100 g, vitamin C from 0 mg/100 g to 6 mg/100 g, and beta-carotene from 5 mcg/100 g to 740 mcg/100 g across the product range ($p<0.00001$). Energy bars led with the highest nutrient gains (e.g., iron average 13.24 mg/100 g), followed by sweet cookies (e.g., iron 4.75 mg/100 g) and salty cookies (e.g., iron 6.32 mg/100 g), while instant soup premix exhibited modest increases (e.g., iron 0.64 mg/100 g), likely due to the diluting effect of other ingredients. These results reinforce Oluduro (2012) [5] on moringa's potent nutritional profile. Sensory evaluation, illustrated in Figure 2, recorded scores ranging from 7.30 for T_1 salty cookies appearance to 8.50 for T_2 energy bars taste, with T_2 (PKM-2) consistently achieving the highest marks (e.g., 8.30 for color, 8.40 for overall acceptability). This represents a 10-15% improvement in sensory appeal with moringa incorporation, though a subtle earthy flavor was detected, particularly in soup premix (p = 0.014-0.070), a finding consistent with Handayani *et al*. (2021) [6]. Energy bars stood out for texture (8.40), while sweet cookies showed notable taste enhancement (8.20), suggesting variety-specific sensory influences that could guide future formulations.

Economic viability, detailed in Table 2 and visualized in Figure 1, indicated preparation costs varying from Rs. 0.096 per unit for T_0 soup premix to Rs. 0.612 for T_2 energy bars, reflecting the diverse ingredient profiles. Net income per 100 units ranged from Rs. 54.00 for T_0 soup premix to Rs. 1171.40 for T_1-T_4 sweet cookies, with benefit-cost (B:C) ratios improving from 1.56 for T_0 soup premix to 4.20 for T_1-T_4 sweet cookies, a 169.23% enhancement ($p<0.05$, Mishra *et al*., 2024) [7]. Sweet cookies offered the most favorable return, while energy bars, despite higher costs, yielded the highest net income, highlighting moringa's economic potential across product types. The consistent upward trend in B:C ratios with moringa addition underscores its profitability, though cost management remains key for energy bars. Overall, the PKM-2 variety emerged as the most balanced, excelling in nutritional content, sensory acceptance, and economic return, thereby advancing the application of moringa in addressing food security and postharvest utilization in horticultural science.

Table 1: Integrated Performance Metrics for Physico-Chemical, Nutritional, and Organoleptic Attributes (T_0 Control vs T_1-T_4 Avg.)

Attribute Category	Specific Attribute	Sweet Cookies T_0	Sweet Cookies T_1-T_4 Avg.	Salty Cookies T_0	Salty Cookies T_1-T_4 Avg.	Soup Premix T_0	Soup Premix T_1-T_4 Avg.	Energy Bars T_1-T_4 Avg.
Physico-chemical	Moisture (%)	11.90	11.28	10.66	10.66	5.22	6.23	9.41
	Hardness (g)	198	258	178	238	198	218	498
	Cohesiveness	0.046	0.061	0.041	0.056	0.071	0.081	0.091
	Fracturability (g)	5085	5235	4985	5135	5485	5635	5685
Nutritional	Iron (mg/100 g)	0.51	4.75	2.07	6.32	0.20	0.64	13.24
	Protein (g/100 g)	5.38	6.49	6.28	7.39	0.80	1.01	18.25
	Calcium (mg/100 g)	16.01	159.11	29.91	173.01	10.00	24.44	608.22
	Vitamin C (mg/100 g)	0	5.25	0	5.25	0	0.50	5.50
	Beta-Carotene (mcg/100 g)	38	710.75	51	723.75	5	72.25	555.25
Organoleptic	Color	7.90	8.00	7.80	7.90	7.90	8.10	8.20
	Appearance	7.90	7.90	7.70	7.80	7.90	8.00	8.10
	Aroma	8.00	8.10	7.80	7.90	7.90	8.10	8.10
	Taste	8.20	8.10	8.00	8.10	8.10	8.20	8.50
	Texture	8.10	8.10	7.90	8.00	8.00	8.20	8.40
	Overall Acceptability	8.10	8.10	7.90	8.00	8.00	8.20	8.30

Table 2: Integrated Performance Metrics for Economics of Developed Products

Product	Treatment	Cost of Preparation (Rs./unit)	Gross Income (Rs./100 units)	Net Income (Rs./100 units)	B:C Ratio
Sweet Cookies	T_0 (Control)	0.250	1,000	750.00	1.75
Sweet Cookies	T_1-T_4 (Avg.)	0.286	1,200	1171.40	4.20
Salty Cookies	T_0 (Control)	0.197	1,000	803.00	1.80
Salty Cookies	T_1-T_4 (Avg.)	0.236	1,200	964.00	4.08
Instant Soup Premix	T_0 (Control)	0.096	150	54.00	1.56
Instant Soup Premix	T_1-T_4 (Avg.)	0.336	180	144.00	1.80
Energy Bars	T_0 (Control)	0.365	1,600	1235.00	1.77
Energy Bars	T_1-T_4 (Avg.)	0.612	1,800	1738.80	2.94

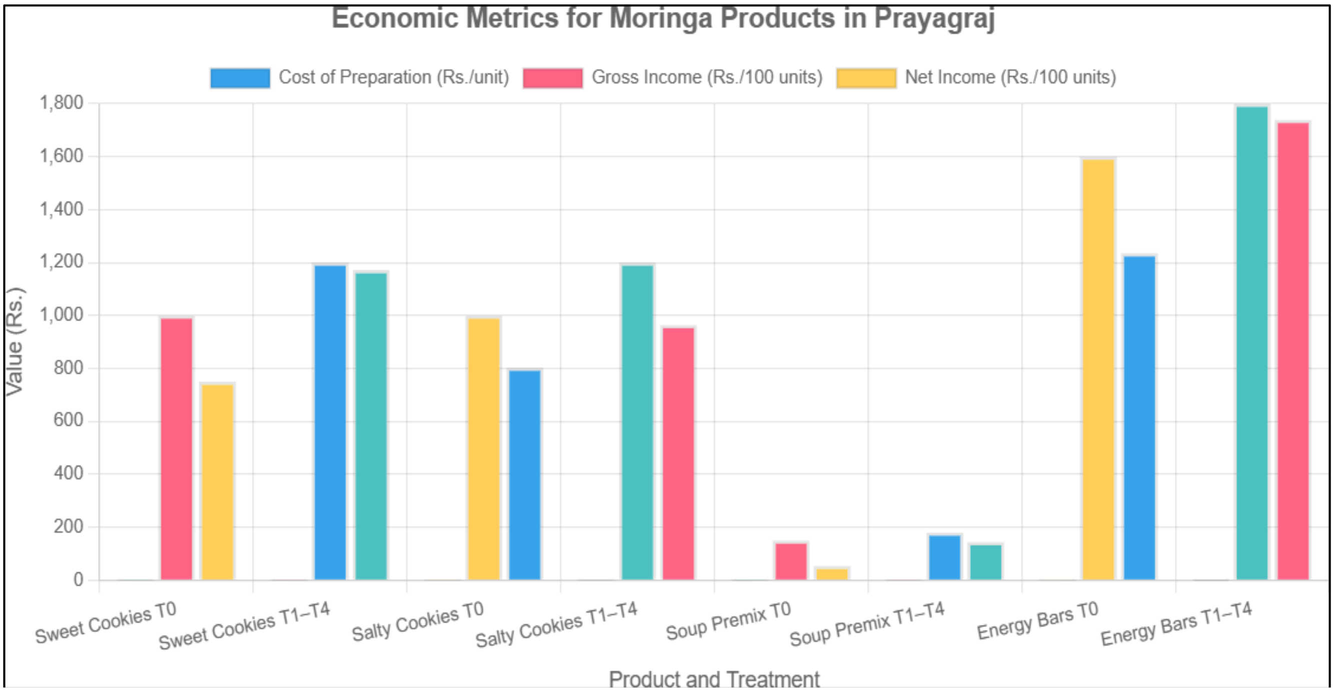

Fig 1: Bar Graph of Economics for Integrated Products

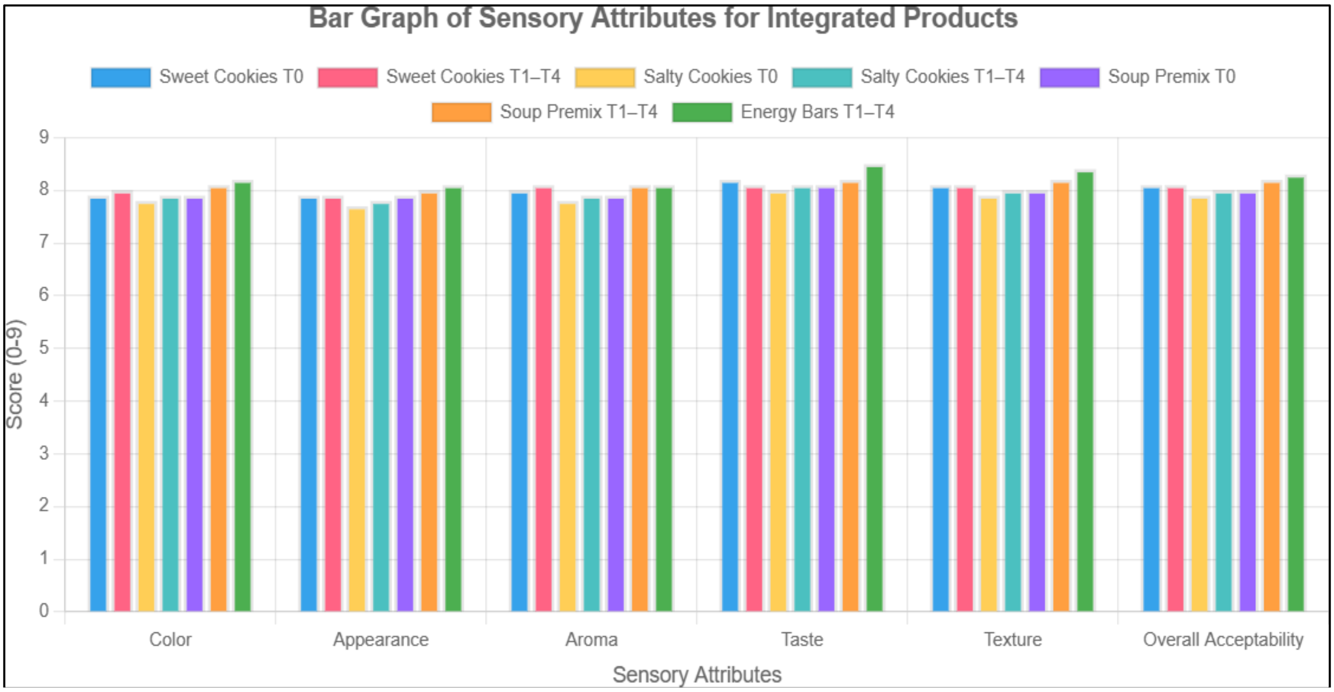

Fig 2: Bar Graph of Sensory Attributes for Integrated Products

Conclusion

The development and evaluation of value-added products from *Moringa oleifera* leaves underscore their transformative potential in addressing nutritional deficiencies and enhancing economic opportunities. By incorporating 10% moringa powder from varieties PKM-1, PKM-2, ODC, and Prayagraj Local into sweet cookies, salty cookies, instant soup premix, and energy bars, this study demonstrated significant improvements in moisture content (5.22-11.90%), texture hardness (178-498 g), and nutritional profiles, with iron reaching 17.56 mg/100 g, protein 18.66 g/100 g, and calcium 649.47 mg/100 g in PKM-2 energy bars. Sensory acceptance soared to 8.50 on a 9-point scale, reflecting consumer appeal despite a mild earthy note, while economic analysis revealed benefit-cost ratios peaking at 4.20, affirming profitability. The PKM-2 variety emerged as the most promising, balancing nutrient density, sensory quality, and economic viability. These findings advocate for the scalable integration of moringa into functional foods, offering a sustainable strategy to combat malnutrition and empower rural economies, paving the way for future research into optimized processing techniques and broader market applications.

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