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Development, nutritional evaluation and sensory analysis of moringa (*Moringa oleifera*) drumstick soup as a functional dietary supplement for elderly nutrition

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Abstract
The present study was to develop and evaluate the Nutritional, Sensory and microbiological properties of Moringa (drumstick) soup as a functional food aimed at enhancing dietary quality, particularly for vulnerable populations. Three formulations (T1, T2 and T3) were prepared by varying Moringa content and were subjected to proximate analysis, micronutrient profiling, sensory evaluation and microbial testing. Among the variants, the T2 formulation (medium Moringa content) demonstrated optimal balance in terms of nutrient density and consumer acceptability. It exhibited substantial levels of essential nutrients, including 4.03 g protein, 2.5 g fiber, 217 mg calcium, 1346 mg vitamin A, and 19.6 mg vitamin C per 100 g. Sensory evaluation using a 7-point hedonic scale revealed T2 to be the most palatable, with high scores for aroma, taste, and overall acceptability. Microbial analysis confirmed the soup's safety with minimal aerobic plate counts and no pathogenic contamination. These findings support the potential of Moringa drumstick soup as a nutritionally rich, safe and culturally acceptable dietary intervention for promoting health and combating micronutrient deficiencies, particularly among the elderly and nutritionally at-risk groups.

Keywords: *Moringa oleifera*, drumstick soup, elderly nutrition, antioxidant activity, sensory evaluation

1. Introduction
Malnutrition and micronutrient deficiencies among elderly populations remain a global concern, especially in developing countries where access to nutrient-dense food sources is limited. Aging often results in reduced food intake, diminished nutrient absorption, and compromised immune function, increasing the need for easily digestible, nutrient-rich dietary options. Traditional dietary interventions using locally available, plant-based ingredients provide a sustainable strategy to enhance the nutritional status of vulnerable populations. In this context, *Moringa oleifera*, commonly referred to as the drumstick tree, has gained scientific attention due to its exceptional nutritional composition and therapeutic potential.

Moringa oleifera is indigenous to South Asia but is now cultivated across tropical and subtropical regions. The plant's leaves and pods (drumsticks) are particularly valued for their high content of essential vitamins, minerals, antioxidants and bioactive compounds (Anwar *et al*., 2007; Gopalakrishnan *et al*., 2016) [1, 8]. Moringa leaves are rich in protein, calcium, iron, vitamin A (as beta-carotene) and vitamin C, while the drumsticks provide fiber, amino acids and phenolic compounds that contribute to immune function, metabolic regulation and anti-inflammatory responses (Leone *et al*., 2015; Nambiar & Seshadri, 2001) [11, 12]. The World Health Organization and several public health researchers have recognized *M. oleifera* as a sustainable solution to combat malnutrition and food insecurity due to its nutrient density and adaptability (Fuglie, 2001) [6].

Soups are an ideal food delivery system for elderly individuals due to their soft texture, easy digestibility and capacity to incorporate multiple nutrients. Despite the growing evidence supporting moringa's health benefits, limited research has been conducted on its application in soup formulations, particularly for aging populations. Previous studies have primarily focused on moringa powders, teas, or capsules, but the incorporation of whole drumsticks and leaves into traditional food matrices like soup has the potential to enhance palatability and acceptance while preserving bioactive compounds (Verma *et al*., 2009; Chaudhary & Chourasia, 2017) [15, 4].

This study proposes the development and evaluation of a *Moringa oleifera*-based soup designed to address dietary inadequacies in the elderly. By exploiting both nutritional science and traditional culinary practices, this research aims to validate the nutritional efficacy, sensory acceptability and antioxidant potential of moringa drumstick soup, using standardized analytical methods and statistical techniques. The soup was developed in three formulations with varying moringa content and assessed for macro and micronutrient composition, microbial safety and consumer acceptability through sensory evaluation. This study aimed to develop a moringa-based drumstick soup by incorporating varying levels of moringa content and evaluating its potential as a functional food for elderly nutrition. The formulated soup variants were analyzed for their proximate composition, Micronutrient and Sensory evaluation was conducted using a 7-point hedonic scale to determine consumer acceptability.

2. Material and Methods

2.1 Ingredients procurement

All ingredients used in the formulation of Moringa drumstick soup were procured fresh from local markets in Hyderabad, Telangana. Core ingredients included fresh *Moringa oleifera* pods (drumsticks), moong dal (*Vigna radiata*), tomatoes, onions, garlic, cumin powder, black pepper, mint leaves and iodized salt. All raw materials were selected based on freshness and quality, washed thoroughly with potable water and stored under hygienic conditions before use.

2.2 Preparation of moringa drumstick soup

The soup was prepared in three different formulations were T1 (low moringa content), T2 (medium moringa content) and T3 (high moringa content) by varying the quantity of moringa drumsticks and complementary ingredients. For each variant, moringa pods were cut into 2-inch pieces and other vegetables including tomatoes, onions and garlic were coarsely chopped. Moong dal was washed and added to the mixture. All ingredients were placed in a pressure cooker with 120 mL of water and cooked for four whistles. The mixture was allowed to cool, then passed through a sieve to extract the pulp. This was followed by the addition of cumin powder, black pepper, and salt. The soup was simmered for 3-5 minutes, garnished with fresh mint leaves and served hot. the preparation was standardized for consistency across all three formulations (AOAC, 2016) [2].

Table 1: Composition of T1, T2 and T3 moringa drumstick soup

Ingredients	Quantity	T1 sample	T2 sample	T3 sample
Drumstick	Gram	110gm	120gm	130gm
Tomato	Gram	50gm	60gm	70m
Onion	Gram	40 g	50gm	60gm
Moong dal	Gram	10 g	20 g	30 g
Cumin powder	Gram	1 g	2 g	3g
Black pepper powder	Gram	1 g	2 g	3g
Garlic	Gram	2 g	3 g	4g
Mint leaves	Gram	3 g	4 g	5g
Pinch of salt	Gram	1 g	1g	1g
Water	ml	120 ml	120 ml	120 ml

2.3 Sensory evaluation of T1, T2 and T3 formulations

Sensory evaluation was conducted using a 9-point hedonic scale by a panel of 15 semi-trained individuals aged 25-45 years. Panelists were selected based on their sensory acuity and familiarity with traditional South Indian cuisine. Each sample (T1, T2, and T3) was coded and presented randomly to minimize bias. Attributes assessed included color, aroma, taste, texture, and overall acceptability. The evaluation was performed under controlled conditions using white light in a sensory lab, in accordance with the guidelines outlined by Stone and Sidel, (2004) [14]. The panelists rinsed their mouths with water between samples to avoid flavor carryover. Results were recorded and subjected to statistical analysis using one-way ANOVA to determine significance ($p<0.05$).

2.4 Nutritional analysis of moringa drumstick soup

Proximate composition, including moisture, ash, protein, fat, carbohydrate, and dietary fiber, was analyzed using standard procedures recommended by the Association of Official Analytical Chemists (AOAC, 2016) [2]. Protein was quantified using the Kjeldahl method, fat by Soxhlet extraction, fiber by enzymatic-gravimetric method, and carbohydrates by difference. Energy content was calculated using the Atwater conversion factors. Samples from all three formulations (T1, T2, and T3) were tested in triplicate to ensure reproducibility and accuracy. These analyses were carried out at a certified food testing laboratory using calibrated instrumentation.

2.5 Mineral and vitamin analysis of moringa drumstick soup

Micronutrient content was determined with a focus on calcium, iron, magnesium, potassium, zinc, vitamin C, vitamin A (as beta-carotene), and vitamin E. Mineral analysis was conducted using Atomic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) as per FAO/WHO protocols (2019). Vitamin C was estimated by titration using 2,6-Dichlorophenolindophenol (DCPIP) as an indicator, while vitamin A and E were quantified using High-Performance Liquid Chromatography (HPLC) following methods described by Ogunlesi *et al*., (2010) and Singleton & Rossi (1965). All tests were run in triplicate, and values were expressed as mg per 100 g of soup.

2.6 Microbial analysis of moringa drumstick soup

Microbial safety analysis was performed to assess the hygienic quality and shelf-stability of the soup formulations. Standard Plate Count (SPC) was conducted to determine the total aerobic microbial load, while specific tests for *Enterobacteriaceae*, *Staphylococcus aureus*, and yeast & mold counts were also carried out. The analyses followed procedures laid out by the International Commission on Microbiological Specifications for Foods (ICMSF, 2002) [9]. Samples were serially diluted and cultured on selective agar media under appropriate incubation conditions. Results were reported as colony-forming units per milliliter (CFU/mL). All samples met acceptable microbiological safety limits, indicating the soup's suitability for consumption.

3. Results and Discursions

3.1 Sensory evaluation of moringa drumstick soup (T1, T2, T3)

The sensory evaluation of Moringa drumstick soup formulations (T1, T2, and T3) using a 7-point hedonic scale revealed notable differences in sensory perception among the three treatments (Table 2). T2, which incorporated a moderate concentration of moringa drumsticks, consistently scored highest across all sensory attributes, including color

(6.3 ± 0.18), aroma (6.5 ± 0.22), taste (6.7 ± 0.21), texture (6.4 ± 0.24), and overall acceptability (6.6 ± 0.20). These findings indicate that T2 achieved the most favorable balance between nutritional enrichment and sensory palatability. In contrast, T1 (low moringa content) and T3 (high moringa content) received comparatively lower scores, with T1 showing the lowest in taste (4.7 ± 0.30) and aroma (4.9 ± 0.31), possibly due to a diluted flavor profile. Although T3 exhibited a superior nutritional composition in previous analyses, its slightly reduced palatability particularly in taste (5.5 ± 0.33) and aroma (5.8 ± 0.29) may be attributed to the intense, slightly bitter flavor of moringa at higher concentrations, as reported in earlier studies (Gopalakrishnan *et al*., 2016; Verma *et al*., 2009) [8, 15]. The sensory results align with the findings of Stone and Sidel, (2004) [14], emphasizing that moderate incorporation of bioactive-rich ingredients like *Moringa oleifera* can enhance the organoleptic quality without compromising consumer acceptance. Therefore, T2 emerged as the most suitable formulation in terms of both nutritional benefit and sensory appeal, making it a promising dietary addition for elderly populations or health-conscious consumers.

Table 2: Sensory evaluation of moringa drumstick soup (T1, T2, T3)

Sensory attribute	T1 (Low moringa)	T2 (Medium moringa)	T3 (High moringa)
Color	5.1 ± 0.23	6.3 ± 0.18	5.9 ± 0.25
Aroma	4.9 ± 0.31	6.5 ± 0.22	5.8 ± 0.29
Taste	4.7 ± 0.30	6.7 ± 0.21	5.5 ± 0.33
Texture	5.0 ± 0.27	6.4 ± 0.24	5.6 ± 0.26
Overall acceptability	5.0 ± 0.22	6.6 ± 0.20	5.7 ± 0.28

Note: Values are mean ± standard deviation (n = 15); scale: 1 = dislike extremely, 7 = like extremely

3.2 Proximate analysis of moringa drumstick soup (T2 sample)

The proximate composition of the T2 moringa drumstick soup formulation indicates a well-balanced nutritional profile suitable for dietary enhancement, particularly in vulnerable populations such as the elderly (Table 3). The soup contained 74.35 g/100g of carbohydrates, contributing significantly to its energy value of 340.92 kcal/100g, thus offering a moderate caloric density appropriate for individuals with reduced appetites or increased energy needs. Protein content was recorded at 4.03 g/100g, which aligns with the protein values reported in prior studies utilizing legume-based soups enhanced with moringa (Gopalakrishnan *et al*., 2016) [8]. The inclusion of moong dal in the formulation likely contributed to this value, offering plant-based protein essential for muscle maintenance and tissue repair in aging individuals (Biesalski & Koletzko, 2004) [3]. Dietary fiber content stood at 2.5 g/100g, which supports gastrointestinal health and is particularly beneficial in managing age-related constipation and metabolic health (Slavin, 2013) [13]. The fat content (3.2 g/100g) remained within healthy limits, minimizing the risk of excess caloric load while still supporting fat-soluble vitamin absorption. Moisture content (17.62 g/100g) reflects the soup's semi-liquid nature, contributing to palatability and ease of digestion, while ash content (0.6 g/100g) suggests an appreciable mineral presence. The balanced macronutrient composition demonstrates the potential of moringa-based soup as a functional food with both nutritional and therapeutic benefits, supporting findings by Anwar *et al*., (2007) [1] regarding moringa's value in combating micronutrient malnutrition and promoting general health.

Table 3: Nutritional analysis of moringa (Drumstick) soup

Test parameter	Result	Unit
Carbohydrates	74.35	g/l00g
Protein	4.03	g/l00g
Fat	3.2	g/l00g
Fibre	2.5	g/l00g
Moisture	17.62	g/l00g
Ash	0.6	g/l00g
Energy	340.92	k.cal

3.3 Mineral and vitamin analysis of moringa drumstick soup (T2 sample)

The Mineral and Vitamin profile of the T2 moringa drumstick soup formulation demonstrates its significant potential as a functional dietary supplement, especially for Nutritionally at-risk populations such as the elderly (Table 4). The soup contained 217 mg/100g of calcium, an essential micronutrient for skeletal health and prevention of osteoporosis, particularly important for post-menopausal women and older adults (Biesalski & Koletzko, 2004) [3]. Potassium levels (153 mg/100g) support cardiovascular health by aiding blood pressure regulation and electrolyte balance, while iron content (2.6 mg/100g) provides a plant-based source critical for hemoglobin synthesis and combating iron-deficiency anemia (Nambiar & Seshadri, 2001) [12]. The presence of 43.1 mg/100g of magnesium and 0.7 mg/100g of zinc further contributes to enzymatic activity, immune modulation, and neuromuscular function, aligning with the mineral density reported in earlier studies of *Moringa oleifera* products (Gopalakrishnan *et al*., 2016; Anwar *et al*., 2007) [8, 1].

Notably, the soup also showed a high concentration of vitamin A (1346 mg/100g as beta-carotene), reinforcing its role in vision health and immune defense. Vitamin C content (19.6 mg/100g) aids in enhancing non-heme iron absorption and contributes antioxidant protection against oxidative stress, a factor closely associated with aging and chronic disease (Ogunlesi *et al*., 2010). Vitamin K (321 mg/100g), often underrepresented in plant-based foods, plays a crucial role in blood clotting and bone metabolism, while vitamin E (3.8 mg/100g) supports cell membrane integrity through its antioxidant function (Leone *et al*., 2015) [11]. These values collectively confirm moringa's nature as a nutrient-dense food source with broad public health implications. As observed in related studies, the nutrient retention in this formulation emphasizes the benefit of minimal thermal processing in preserving vitamin content during soup preparation (Verma *et al*., 2009; Chaudhary & Chourasia, 2017) [15, 4].

Table 4: Mineral and vitamin analysis of moringa (Drumstick) soup

Test Parameter	Result	Unit
Calcium	217	mg/l00g
Potassium	153	mg/l00g
Iron	2.6	mg/l00g
Magnesium	43.1	mg/l00g
Zinc	0.7	mg/l00g
Vitamin C	19.6	mg/l00g
Vitamin K	321	mg/l00g
Vitamin E	3.8	mg/100g
Vitamin A	1346	mg/100g

3.4 Microbial analysis of moringa (drumstick) soup

The microbial quality assessment of the T2 Moringa drumstick soup revealed excellent microbiological safety, indicating its suitability for consumption and storage under hygienic conditions (Table 5). The aerobic plate count was recorded at <10 CFU/ml, which is well below the maximum acceptable limit of 10^4 CFU/ml set for ready-to-eat foods by the International Commission on Microbiological Specifications for Foods (ICMSF, 2002) [9]. This low microbial load confirms effective heat treatment during soup preparation and suggests minimal post-processing contamination. No growth of *Enterobacteriaceae* or *Staphylococcus aureus* was detected, reflecting strict adherence to sanitary protocols during ingredient handling and cooking. The absence of *S. aureus*, a common pathogen associated with foodborne illnesses, is particularly significant and complies with food safety standards outlined by the Food and Agriculture Organization (FAO/WHO, 2003) [5].

Furthermore, yeast and mold counts were also found to be <10 CFU/ml, indicating excellent fungal stability and low spoilage potential. This is critical in products containing high moisture content and plant-based components, which are generally prone to fungal contamination (Jay *et al*., 2005) [10]. The results confirm that the soup formulation, processing, and handling practices ensured microbial safety, which is essential for both home consumption and potential commercialization. These findings are consistent with previous studies on moringa-based preparations, which reported similarly low microbial loads when good manufacturing practices were followed (Fuglie, 2001; Gopalakrishnan *et al*., 2016) [7, 8].

Table 5: Microbial activity of moringa (drumstick) soup

S. No.	Test Parameter	Unit	Result
1.	Aerobic plate Count	CFU/ml	<10
3.	Enterobacteriaceae	CFU/ml	Absent
4.	S. aureus	CFU/ml	Absent
5.	Yeast & Mold	CFU/ml	<10

Conclusion

The Moringa Drumstick Soup (T2) demonstrates significant Nutritional highlighting its potential as a functional food. The sensory evaluation results indicate moderate to high consumer acceptability, with particular preference for the medium Moringa formulation (T2) in terms of taste, aroma, and overall acceptability. The nutritional analysis confirms the soup's rich content of essential macronutrients, including carbohydrates, protein and dietary fiber; it also exhibited impressive energy value of 340.92 kcal per 100 g. Furthermore, the mineral and vitamin profile emphasize the presence of critical micronutrients such as calcium, potassium, magnesium and vitamins A, C and K; which contribute to its health-promoting properties. The microbial analysis reveals an excellent safety profile with negligible microbial contamination, making the soup safe for consumption and storage. These findings collectively suggest that Moringa drumstick soup, particularly with moderate Moringa content, could serve as a valuable addition to functional food products aimed at improving public health, especially in regions where malnutrition and nutrient deficiencies are prevalent.

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