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Development of Functional Noodles Enriched with Moringa (Moringa oleifera) Leaf Powder: Effects on Nutritional Quality, Antioxidant Activity, and Consumer Acceptance

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Abstract

The increasing demand for functional foods has stimulated the development of innovative products enriched with bioactive plant ingredients. Moringa (Moringa oleifera) leaves are recognized as a valuable source of proteins, dietary fiber, vitamins, minerals, and antioxidant compounds. This study investigated the effects of incorporating moringa leaf powder (MLP) into wheat-based noodles on nutritional quality, antioxidant activity, physicochemical characteristics, cooking properties, and consumer acceptance. Four noodle formulations containing 0% (control), 2%, 4%, and 6% MLP were prepared and evaluated for proximate composition, total phenolic content (TPC), antioxidant activity, color parameters, texture profile, cooking loss, water absorption capacity, and sensory attributes. The results demonstrated that MLP significantly enhanced protein, dietary fiber, ash content, total phenolic content, and antioxidant activity of noodles ($p < 0.05$). Noodles containing 6% MLP exhibited the highest antioxidant activity (81.7% DPPH inhibition) and total phenolic content (136.8 mg GAE/100 g). However, excessive MLP incorporation negatively affected color acceptability and increased cooking loss. Sensory evaluation indicated that noodles containing 4% MLP achieved the highest overall acceptance score among consumers, recommended as the optimal formulation balancing nutritional enhancement and consumer acceptance.

Keywords: Functional noodles, moringa leaf powder, antioxidant activity, dietary fiber, consumer acceptance, functional food

1. Introduction

The growing prevalence of non-communicable diseases and increasing awareness of the relationship between diet and health have significantly influenced consumer food choices, and functional foods have emerged as one of the fastest-growing segments in the global food industry [1].

Among various functional food products, noodles represent a promising vehicle for nutritional enhancement because they are widely consumed across different age groups and socioeconomic levels, particularly in Asian countries including Indonesia, where they constitute a staple food for millions of consumers [2].

Moringa oleifera is a fast-growing tropical tree widely cultivated in Asia, Africa, and Latin America. Moringa leaves contain substantial amounts of proteins, essential amino acids, vitamins, minerals, phenolic compounds, flavonoids, and dietary fiber, and previous studies have reported that moringa leaves possess antioxidant, anti-inflammatory, antimicrobial, antihyperglycemic, and antihypertensive activities [4, 5].

The antioxidant properties of moringa leaves are largely attributed to phenolic compounds such as quercetin, kaempferol, chlorogenic acid, and various flavonoids capable of neutralizing free radicals and reducing oxidative stress implicated in chronic disease development [7].

Therefore, the objective of this study was to evaluate the effects of moringa leaf powder incorporation on the nutritional quality, antioxidant activity, physicochemical characteristics, cooking properties, and sensory acceptance of functional noodles, and to identify the optimal level of moringa leaf powder that provides maximum nutritional benefits while maintaining desirable consumer acceptance.

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2. Literature Review

2.1. Nutritional Profile of Moringa oleifera Leaves

Dried moringa leaf powder typically contains protein levels ranging from 25% to 35%, alongside significant concentrations of calcium, iron, potassium, magnesium, and vitamins A, C, and E, contributing to its reputation as a nutrient-dense superfood [6].

2.2. Antioxidant and Phenolic Compounds in Moringa

Quercetin, kaempferol, chlorogenic acid, ferulic acid, and caffeic acid are among the principal phenolic compounds identified in moringa leaves, functioning through free radical scavenging, metal chelation, and modulation of antioxidant defense systems [13, 14].

2.3. Fortification of Cereal-Based Products with Plant Powders

Previous research on fortifying bread, biscuits, cakes, and noodles with plant-derived powders has generally reported improved nutritional quality and antioxidant activity, although such fortification frequently introduces technological and sensory trade-offs related to color, texture, and flavor [8, 15].

3. Methodology

3.1. Experimental Design

This study employed a Completely Randomized Design (CRD) consisting of four treatments with different levels of moringa leaf powder (MLP): M0 (0%, control), M1 (2%), M2 (4%), and M3 (6%). Each treatment was prepared in triplicate, resulting in twelve experimental units.

3.2. Raw Materials and Preparation of Moringa Leaf Powder

Fresh moringa leaves were collected from local farms in West Sumatra, Indonesia, sorted, washed, and dried using a hot-air dryer at 50°C for 12 hours until the moisture content was below 8%. The dried leaves were milled and sieved through a 60-mesh screen.

3.3. Noodle Preparation

Wheat flour was substituted with MLP at the designated levels, combined with salt, egg, and water. The dough was mixed for 15 minutes, rested for 30 minutes, sheeted, cut into strands approximately 2 mm wide, and dried at 45°C for 6 hours to a final moisture content below 12%.

3.4. Proximate, Phenolic, and Antioxidant Analyses

Proximate analyses followed AOAC methods [9], including moisture, crude protein (Kjeldahl), crude fat (Soxhlet), ash, and crude fiber. Total phenolic content was determined using the Folin–Ciocalteu method, and antioxidant activity was assessed using the DPPH assay: DPPH Inhibition (%) = $[(A0 - As) / A0] \times 100$.

3.5. Cooking Quality, Texture, and Sensory Evaluation

Cooking time, water absorption, and cooking loss were determined according to standard noodle testing procedures. Texture (hardness, tensile strength) was measured using a Texture Analyzer. Thirty semi-trained panelists evaluated color, aroma, texture, taste, and overall acceptability using a nine-point hedonic scale. Data were analyzed using one-way ANOVA and Duncan's Multiple Range Test (DMRT) at $p < 0.05$.

4. Results and Discussion

4.1. Proximate Composition

The incorporation of MLP significantly increased protein, ash, and dietary fiber contents ($p < 0.05$), with the highest nutritional enhancement observed in noodles containing 6% MLP.

Table 1. Proximate composition of moringa-enriched noodles (%).

Parameter	M0	M1	M2	M3
Moisture	10.82	10.67	10.54	10.48

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Protein	11.24	12.73	14.15	15.68
Fat	2.15	2.26	2.37	2.49
Ash	0.91	1.18	1.46	1.79
Crude Fiber	1.43	2.52	3.81	5.06

Values represent mean of triplicate determinations.

4.2. Total Phenolic Content and Antioxidant Activity

TPC and antioxidant activity increased significantly with increasing MLP concentration. A strong positive correlation was observed between TPC and antioxidant activity ($r = 0.96$; $p < 0.01$).

Table 2. Total phenolic content and DPPH radical scavenging activity.

Treatment	TPC (mg GAE/100 g)	DPPH Inhibition (%)
M0	31.5 ± 1.2	18.6 ± 0.9
M1	72.4 ± 2.1	47.3 ± 1.5
M2	105.7 ± 2.8	66.9 ± 1.8
M3	136.8 ± 3.4	81.7 ± 2.0

Values are means ± standard deviation of triplicate determinations.

4.3. Cooking Properties and Texture

Water absorption increased significantly with MLP addition, reflecting the high fiber content of moringa leaves, while cooking loss also increased at higher substitution levels, indicating some weakening of the gluten matrix. The incorporation of MLP significantly increased noodle firmness and tensile strength.

Table 3. Cooking quality and texture characteristics of noodles.

Parameter	M0	M1	M2	M3
Cooking Time (min)	5.2	5.5	5.8	6.1
Water Absorption (%)	136.5	142.7	149.3	156.4
Cooking Loss (%)	4.2	4.8	5.3	6.4
Hardness (N)	4.21	4.46	4.72	5.01

Source: Cooking quality and texture analysis of noodle samples.

4.4. Sensory Evaluation

The highest overall acceptability was achieved by M2 (4% MLP), indicating the best balance between nutritional enhancement and sensory quality. Increasing MLP concentration resulted in darker and greener noodles due to chlorophyll pigments, which were positively perceived at moderate levels but less favorably at the 6% inclusion.

Table 4. Sensory scores of noodle samples on a nine-point hedonic scale.

Attribute	M0	M1	M2	M3
Color	7.5	8.1	8.4	7.2
Aroma	7.2	7.8	8.3	7.5
Texture	7.4	8.0	8.5	7.8
Taste	7.3	8.1	8.6	7.1
Overall Acceptability	7.3	8.2	8.7	7.4

Values represent mean scores from 30 semi-trained panelists.

5. Conclution

The incorporation of Moringa oleifera leaf powder significantly improved the nutritional, functional, and sensory characteristics of wheat-based noodles. MLP enrichment increased protein, dietary fiber, ash content, total phenolic content, and antioxidant activity while influencing color, texture, and cooking properties. Noodles containing 6% MLP exhibited the highest nutritional and antioxidant values; however, the 4% formulation achieved the greatest overall consumer acceptance, representing the optimal formulation for commercial development.

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