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Development and Evaluation of Noodles Incorporated with Lotus Seeds Flour

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Abstract
This study focuses on the development and evaluation of noodles incorporated with lotus seed flour (LSF) to enhance their nutritional profile. Lotus seeds (Nelumbo nucifera), known for their high protein, fiber, and mineral content, were processed into fine flour and blended with refined wheat flour in varying proportions (10%, 20%, and 30%). The formulated noodles were analyzed for sensory attributes, nutritional composition, textural properties, and microbial stability. Sensory evaluation revealed that noodles with 10% LSF had the highest overall acceptability in terms of taste, texture, and appearance. Nutritional analysis showed increased protein and fiber content with higher LSF incorporation, while textural analysis indicated a slight reduction in elasticity at higher substitution levels.
Microbial testing over a 30-day storage period confirmed the safety and shelf stability of the noodles. The findings suggest that lotus seed flour can be effectively used to develop nutritionally enriched noodles with acceptable sensory and safety parameters, especially at a 10–20% substitution level.

Keywords: Lotus seed flour, *Nelumbo nucifera*, value-added noodles, nutritional enrichment

Introduction
Noodles, a staple in many global cuisines, have transcended their origins to become a widely consumed food product due to their convenience, versatility, and adaptability to various flavor profiles. In recent years, the focus of consumers has shifted from merely satisfying hunger to seeking foods that contribute to health and well-being. This has led to a growing demand for functional and nutritionally enriched foods, including staple items like noodles. One such approach to enhancing the nutritional profile of noodles involves the incorporation of alternative flours derived from natural and health-promoting sources.
Lotus seeds (Nelumbo nucifera), also known as "makhana" in India, are an underutilized yet nutritionally rich ingredient that holds significant potential in functional food formulations. These seeds are a valuable source of protein, fiber, essential minerals such as magnesium, potassium, and calcium, and possess medicinal properties including antioxidant, anti-inflammatory, and anti- diabetic effects. Traditionally used in Ayurvedic and Chinese medicine, lotus seeds are now gaining attention as a sustainable and wholesome ingredient in modern food product development.
Incorporating lotus seed flour (LSF) into noodles not only enriches the product nutritionally but also adds a unique flavor and texture profile, aligning with the trend of clean- label and health-oriented food products.
However, the formulation process presents several challenges. Ensuring compatibility between LSF and refined flour, achieving desirable sensory attributes, and maintaining product stability are crucial aspects of product development. Moreover, lotus seed flour, being free from synthetic additives, requires careful attention to shelf life and moisture control during processing and storage.
The development of LSF-incorporated noodles represents an effort to bridge traditional nutritional wisdom with modern convenience foods. It responds to the growing consumer demand for innovative, health-conscious, and functional food products while promoting the use of indigenous and nutritionally superior ingredients. This study aims to formulate and evaluate noodles fortified with lotus seed flour in varying proportions, assess their sensory and nutritional properties, and determine the most acceptable blend that balances taste, texture, and health benefits.

Materials and Methods

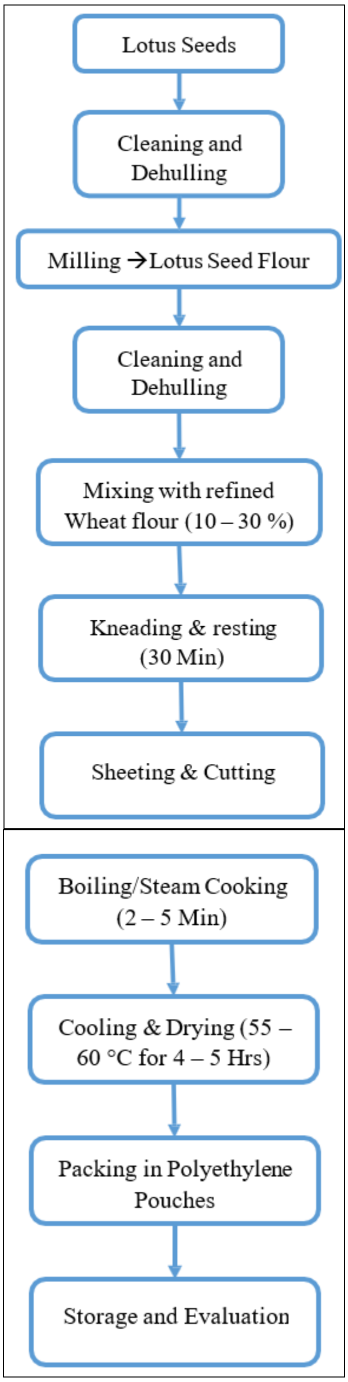
Materials

The materials used in the development of noodles incorporated with lotus seed flour (LSF) were selected based on their quality and suitability for achieving the desired nutritional and sensory attributes. The primary ingredients included:

Lotus Seed Flour (LSF): Lotus seeds (Nelumbo nucifera) were sourced from a certified supplier specializing in high-quality, sustainably harvested lotus seeds.
The seeds were cleaned, dehulled, and milled to produce a fine, smooth flour, ensuring retention of their nutritional properties.

- **Refined Wheat Flour**: High-quality refined
- wheat flour was used as the base flour for noodle preparation.
- **Water**: Clean, potable water was used for dough preparation and hydration.
- **Salt**: Food-grade salt was added to enhance flavor and improve dough consistency.
- **Optional Additives**: A combination of emulsifiers or stabilizers was used as necessary to improve the texture and shelf life of the noodles.

Flowchart



Methods

Preparation of Lotus Seed Flour

1. **Selection and Cleaning**: Fresh lotus seeds were selected and thoroughly cleaned to remove any impurities.
2. **Dehulling**: The outer shells of the lotus seeds were

removed using a mechanical dehulling process, ensuring only the inner seeds remained.
3. **Milling**: The dehulled lotus seeds were ground using a laboratory-scale grinder to obtain a fine powder, which was then stored in airtight containers to prevent moisture absorption.

Noodle Preparation

1. **Formulation of Dough**: Refined wheat flour and lotus seed flour were weighed in varying proportions (5%, 10%, 15%, 20%, 25% and 30% LSF) based on the experimental design. The ingredients were mixed in a planetary mixer to form a homogeneous dough.
2. **Kneading and Resting**: The dough was kneaded with water until a smooth,elastic consistency was achieved. The dough was allowed to rest for 30 minutes to facilitate gluten development and improve texture.
3. **Shaping**: The dough was passed through a noodle extruder to form uniform noodle strands, which were then cut to the desired length.
4. **Boiling**: The noodles were boiled in water at 100°C for 2–3 minutes to assess the cooking properties and texture of the product.

Evaluation of Noodles

1. **Sensory Evaluation**: A trained sensory panel of 10 members evaluated the noodles for color, texture, aroma, and taste using a 9-point hedonic scale. The sensory evaluation was conducted after the noodles were cooked and cooled.
2. **Nutritional Analysis**: The nutritional composition of the noodles, including moisture content, protein, fiber, and carbohydrate levels, was determined using standard laboratory methods. Proximate analysis was performed following AOAC (Association of Official Analytical Chemists) guidelines.
3. **Texture Profile Analysis**: A texture analyzer was used to measure the firmness, elasticity, and chewiness of the noodles. A standard texture profile analysis (TPA) was conducted to assess the textural attributes of the noodles.
4. **Shelf-Life Evaluation**: The shelf life of the noodles was evaluated by storing them under different conditions (ambient and refrigerated) and testing for changes in sensory attributes, microbial contamination, and nutritional content over a period of 30 days. Sensory evaluations were conducted at 0, 7, 14, and 30 days.

Proximate Analysis

To evaluate the nutritional composition and overall quality of the lotus seed flour–incorporated noodles, proximate analysis was carried out. This assessment focused on determining key parameters such as moisture, ash, protein, fat, fibre, and carbohydrate content. These measurements help in understanding the product's nutritional profile and ensure consistency, stability, and suitability for consumption throughout its shelf life. Sample Preparation:
Noodle samples were prepared in various batches with different
proportions of lotus seed flour (5%, 10%, 15%, 20%, 25% and 30%) and stored under ambient for a period of 30 days.

Methods

- **Moisture:** To determine the moisture content, a known quantity of the noodle sample was accurately weighed and subjected to drying in a hot-air oven at 105°C. The sample was heated at a constant temperature until it reached a stable weight. The difference between the initial and final weights was used to calculate the percentage of moisture present in the product.
- **Fat (Soxhlet apparatus):** To estimate the fat content, a measured amount of the sample was placed in a Soxhlet apparatus and extracted using an appropriate solvent. The extraction was continued until all the soluble lipids were removed. After evaporating the solvent, the remaining residue was weighed, and the fat percentage was calculated based on the mass of the extracted lipids.
- **Protein:** To determine the protein content, a precisely weighed portion of the sample was digested using a suitable catalyst and concentrated acid to convert the nitrogen present into ammonium ions. The digested solution was then neutralized and distilled, and the released ammonia was collected and quantified. The amount of nitrogen obtained was used to calculate the total protein content using an appropriate conversion factor.
- **Calcium:** To quantify the calcium content, the sample was digested with a suitable acid mixture to bring the mineral components into solution. The clear digest was then analysed using an atomic absorption spectrophotometer. The absorbance recorded at the calcium-specific wavelength was compared with a standard calibration curve, and the corresponding concentration of calcium in the sample was calculated.
- **Potassium:** To determine the potassium content, the sample was first digested to convert the mineral components into a measurable form. The digested solution was then filtered, diluted, and analysed using a flame photometer. The intensity of the emitted light at the potassium-specific wavelength was recorded and compared with a standard calibration curve. From this, the concentration of potassium in the sample was calculated.
- **Ash:** To estimate the ash content, a known quantity of the sample was placed in a pre-weighed crucible and heated in a muffle furnace at a high temperature until all organic matter was completely burned off. After cooling in a desiccator, the remaining inorganic residue was weighed. The ash percentage was calculated based on the weight of this residue relative to the initial sample mass.

Product development

The development of noodles incorporated with lotus seed flour involved a series of standardized processing steps aimed at enhancing the nutritional profile while maintaining the sensory and textural qualities expected of noodle products. The process began with the procurement of high-quality lotus seeds (commonly known as makhana), which were sourced from verified suppliers to ensure purity, uniformity, and compliance with food safety standards.
The lotus seeds were initially cleaned to remove extraneous matter such as husks, dust, or stones, followed bydrying under controlled conditions to preserve their natural properties. Once dried, the seeds were milled into a fine flour using a laboratory-grade grinder. The flour was passed

through a sieve (80-mesh) to ensure uniform particle size, essential for homogenous mixing during noodle dough preparation.

The noodle formulation was developed by replacing refined wheat flour(maida) with varying proportions of lotus seed flour — 10%, 20%, and 30%— to assess the functional and sensory impact. A control sample with 100% refined wheat flour was also prepared for comparison.

The dry ingredients were thoroughly mixed, and water was added gradually to form a cohesive dough. The dough was then kneaded mechanically to develop gluten structure (in control and low-replacement formulations), followed by a resting period to ensure uniform hydration. The dough was sheeted using a roller sheeter and cut into uniform strands using a noodle cutter.

The noodles were steam-cooked for 5 minutes, then cooled and dried using a tray dryer at 55–60°C for 4–5 hours until the desired moisture content (<10%) was achieved. Once dried, the noodles were packed in polyethylene pouches and stored in airtight containers for further analysis.

Special attention was given to the organoleptic properties, texture, and nutritional enhancement contributed by the lotus seed flour. Incorporation of lotus seed flour not only increased the protein and fiber content but also contributed to a mild nutty flavor, offering a functional food product with potential health benefits.

This systematic product development approach ensured that the lotus seed flour-enriched noodles maintained acceptable quality attributes, making them suitable for consumer acceptance and commercial scalability.

Table 1: Formulation of noodles incorporating lotus seed flow

Ingredients (in g)	Control	Sample 1 5%	Sample 2 10%	Sample 3 15%	Sample 4 20%	Sample 5 25%	Sample 6 30%
Refined flour	50	47.5	45	42.5	40	37.5	35
LSF	0	2.5	5	7.5	10	12.5	15
Salt	1	1	1	1	1	1	1
Water(ml)	25	25	25	25	25	25	25

Results & Discussion

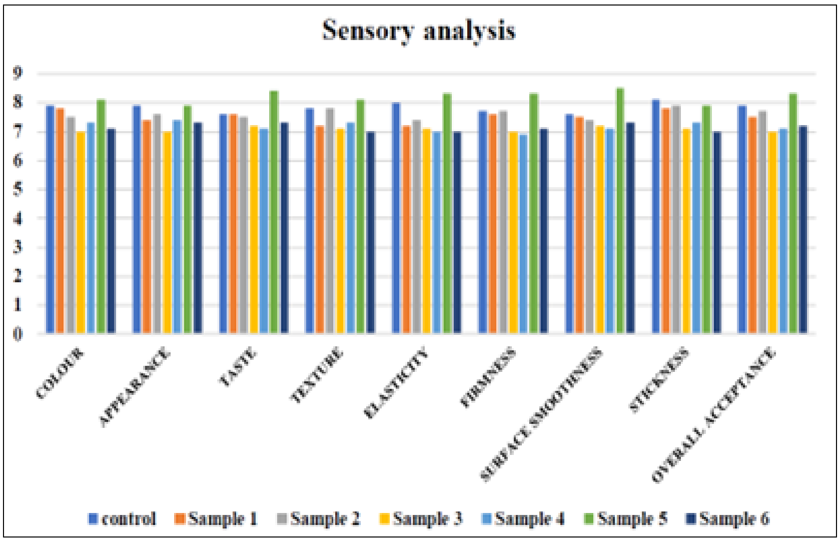


Fig 1: Sensory analysis in graphical representation

The present study focused on the development and evaluation of noodles incorporated with varying levels of lotus seed flour (5%,10%, 15%, 20%,25% and 30%) as a partial replacement for refined wheat flour. The objective was to enhance the nutritional quality of noodles while maintaining acceptable sensory and physicochemical properties.

Sensory Evaluation

Sensory analysis was conducted to evaluate the organoleptic attributes (Appearance, texture, taste, aroma, and overall acceptability) of the lotus seed flour-enriched noodles in comparison to control noodles (100% refined wheat flour). A semi-trained panel using a 9- point hedonic scale assessed the Products.

- Noodles with 25% lotus seed flour incorporation showed the highest Overall acceptability with favorable scores in terms of taste, texture, and appearance.
- As the incorporation level increased beyond 30%, panelists noted a slight change in flavor and firmness, attributed to the unique nutty taste and reduced gluten content.
- The 30% incorporation sample had a marginally reduced acceptability due to noticeable changes in texture (slightly brittle) and color (duller appearance).

Texture Analysis

Instrumental texture analysis revealed that:

- Control noodles had the highest elasticity and firmness due to the strong gluten network.
- Incorporation of lotus seed flour resulted in a gradual decrease in tensile strength and chewiness, particularly in the 30% formulation.
- However, 20% and 25% incorporation levels maintained acceptable texture, making them viable for consumer use.

Nutritional Evaluation

Proximate analysis indicated a significant improvement in the nutritional profile:

- Protein and dietary fiber content increased progressively with the inclusion of lotus seed flour.
- Fat and carbohydrate levels were

Marginally reduced in comparison to the control.

This demonstrated the functional value of lotus seed flour in improving the nutritional density of noodles, offering added health benefits such as improved satiety and better glycemic control.

4. Packaging and Shelf Life

Noodles were packed in food-grade Polyethylene bags and monitored over time. There was no visible spoilage, discoloration, or off-odor during the 3- month period, suggesting adequate shelf life for all formulations, particularly at 20% and 25% substitution levels.

Table 2: Proximate analysis for control and sample 5(25%)

Parameters	Control	Sample 5 (25%)
Moisture%	1.5	3.45
Fat%	0.2	1.42
Ash%	1.15	1.35
Calcium(mg)	3.9	6.9
Potassium(mg)	1.2	1.8
Magnesium(mg)	0.45	0.7
Protein(mg)	10.25	17.34

Conclusion

The study successfully demonstrated the potential of lotus seed flour as a functional ingredient in noodle production. The incorporation of 20% and 25% lotus seed flour yielded noodles with improved nutritional profiles while retaining acceptable sensory and textural characteristics.

Among the formulations tested, 25% lotus seed flour-enriched noodles emerged as the most preferred variant, balancing taste, texture, and nutritional enhancement. Microbial analysis confirmed the product's safety and stability, making it a promising option for commercial application in the health food sector. Future work can explore fortification with other functional ingredients, alternative drying methods, or gluten- free formulations to further expand product diversity.

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