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DEVELOPMENT AND ACCEPTABILITY OF PAN DE SAL ENRICHED WITH MULBERRY (*Morus Alba* L.) LEAF POWDER

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Abstract

Micronutrient deficiencies remain a significant public health concern worldwide, particularly in developing countries where inadequate dietary intake contributes to poor nutritional status and increased disease susceptibility. Food fortification has emerged as a sustainable strategy to improve nutritional quality through the incorporation of nutrient-dense ingredients into commonly consumed foods. This study developed Pan de Sal enriched with *Morus alba* L. (mulberry) leaf powder and evaluated its sensory acceptability, nutritional composition, microbiological quality, and economic feasibility.

An experimental research design was employed using four formulations containing 0%, 3%, 5%, and 7% mulberry leaf powder. Descriptive sensory analysis was conducted by trained panelists, while consumer acceptability was assessed by fifty untrained evaluators using a nine-point hedonic scale. The most preferred formulation was subjected to proximate composition and microbiological analyses following standard laboratory procedures. Data were analyzed using one-way analysis of variance and Duncan's Multiple Range Test at a 5% significance level.

The incorporation of mulberry leaf powder significantly affected the sensory characteristics of Pan de Sal. The formulation containing 3% mulberry leaf powder obtained the highest overall acceptability, indicating that moderate fortification maintained desirable color, texture, aroma, flavor, and taste. The preferred formulation contained 9.86 g/100 g moisture, 0.91 g/100 g ash, 2.56 g/100 g crude fat, 7.97 g/100 g crude protein, and 62.70 g/100 g carbohydrates. Microbiological analyses confirmed compliance with food safety standards, while economic evaluation demonstrated a 30% return on expenditure, indicating promising commercial viability.

These findings demonstrate that mulberry leaf powder is a suitable functional ingredient for bakery products and may contribute to food fortification initiatives through the development of nutritionally enhanced Pan de Sal.

1. Introduction

Micronutrient malnutrition, often referred to as "hidden hunger," continues to affect more than two billion people globally and remains one of the most persistent public health challenges, particularly in low- and middle-income countries. Inadequate intake of essential vitamins and minerals contributes to impaired growth, weakened immune function, reduced cognitive development, and increased morbidity, ultimately limiting human productivity and socioeconomic development. Despite improvements in food production and healthcare systems, micronutrient deficiencies remain prevalent due to limited dietary diversity, food insecurity, and poor access to nutrient-rich foods.

In the Philippines, micronutrient deficiencies continue to affect vulnerable populations despite the implementation of national nutrition interventions. The Philippine Food Fortification Act of 2000 (Republic Act No. 8976) recognizes food fortification as a key strategy for addressing nutrient deficiencies by enriching commonly consumed foods with

essential nutrients. Because bread products are widely consumed across different socioeconomic groups, they represent effective vehicles for delivering nutrients to the general population.

The growing consumer demand for healthier foods has stimulated interest in functional bakery products enriched with plant-derived ingredients. Among these, *Morus alba* L. (white mulberry) has attracted considerable attention because of its high nutritional value and bioactive properties. Mulberry leaves are rich in dietary fiber, protein, calcium, potassium, iron, flavonoids, phenolic compounds, chlorophyll, and 1-deoxynojirimycin (DNJ), a naturally occurring α-glucosidase inhibitor associated with improved glucose metabolism. Numerous studies have demonstrated the antioxidant, antimicrobial, anti-inflammatory, antihyperglycemic, antihyperlipidemic, and cardioprotective properties of mulberry leaves, supporting their potential application in functional food development.

Recent studies have incorporated mulberry leaf powder into biscuits, cookies, noodles, beverages, and other bakery products to improve nutritional quality. Although these products generally exhibit enhanced functional properties, excessive incorporation often adversely affects color, texture, flavor, and overall consumer acceptability because of the strong herbal characteristics of mulberry leaves. Consequently, identifying the optimum supplementation level is essential for developing bakery products that balance improved nutritional quality with consumer preference.

Pan de Sal is one of the most popular bakery products in the Philippines and is consumed daily by millions of Filipinos. Because of its widespread consumption, affordability, and cultural significance, Pan de Sal represents an ideal vehicle for food fortification. Incorporating nutrient-rich indigenous ingredients into this staple food provides an opportunity to improve dietary quality without requiring major changes in consumer eating habits.

Although mulberry leaves have been extensively investigated for their medicinal and nutritional properties, limited information is available regarding their utilization in Pan de Sal under Philippine conditions. Moreover, the optimum concentration of mulberry leaf powder that maximizes nutritional enhancement while maintaining desirable sensory quality has not been clearly established. Addressing this research gap is essential for developing acceptable functional bakery products that contribute to improved nutrition and promote the utilization of locally available agricultural resources.

Accordingly, this study aimed to develop Pan de Sal enriched with varying concentrations of *Morus alba* leaf powder and evaluate its sensory characteristics, consumer acceptability, proximate composition, microbiological quality, and economic feasibility. The findings provide scientific evidence supporting the application of mulberry leaves as a natural functional ingredient and contribute to the development of value-added bakery products for nutrition improvement and food security.

2. Materials and Methods

2.1 Research Design

This study employed an experimental research design to develop and evaluate Pan de Sal enriched with varying concentrations of *Morus alba* L. (mulberry) leaf powder. The experimental approach enabled the systematic assessment of the effects of mulberry leaf supplementation on the sensory characteristics, consumer acceptability, nutritional composition, microbiological quality, and economic feasibility of the developed bakery product.

Four formulations were prepared using different levels of mulberry leaf powder. The control formulation (T_0) contained no mulberry leaf powder, whereas the experimental treatments contained 3% (T_1), 5% (T_2), and 7% (T_3) mulberry leaf powder based on the weight of bread flour. Each formulation was prepared in triplicate using identical processing conditions to minimize variability and ensure experimental reliability.

2.2 Study Area

Product development was conducted at the Food Processing Laboratory of the College of Education, Don Mariano Marcos Memorial State University–South La Union Campus (DMMMSU-SLUC), Agoo, La Union, Philippines. The laboratory provides controlled processing conditions and standard bakery equipment suitable for food product development.

Laboratory analyses, including proximate composition and microbiological examination, were performed at the Department of Science and Technology (DOST) Regional Standards and Testing Laboratory in San Fernando City, La Union. The study was conducted from January to June 2020.

2.3 Experimental Treatments

Four Pan de Sal formulations were prepared by partially substituting bread flour with mulberry leaf powder at different concentrations. The treatments were selected based on preliminary formulation trials and published studies on leafy vegetable incorporation in bakery products.

Table 1. Experimental Treatments

Treatment	Description
T_0	Control (0% mulberry leaf powder)
T_1	3% mulberry leaf powder
T_2	5% mulberry leaf powder
T_3	7% mulberry leaf powder

2.4 Preparation of Mulberry Leaf Powder

Fresh, mature mulberry leaves (*Morus alba* L.) were harvested from the mulberry plantation of the Sericulture Research and Development Institute, DMMMSU, Bacnotan, La Union. The leaves were washed thoroughly under running water to remove adhering soil and foreign materials before being cut into smaller pieces to facilitate drying.

The cleaned leaves were air-dried at ambient room temperature for three days until crisp. Air drying was selected to minimize degradation of heat-sensitive nutrients and bioactive compounds. The dried leaves were subsequently pulverized using an electric grinder and passed through a No. 60 mesh sieve to obtain a fine, uniform powder. The resulting mulberry leaf powder was packaged in airtight polyethylene bags and stored at room temperature until use.

2.5 Preparation of Mulberry-Enriched Pan de Sal

Pan de Sal was prepared using the straight dough method. Bread flour, sugar, salt, shortening, yeast, milk, and water served as the basic ingredients, while mulberry leaf powder partially replaced bread flour according to the designated treatment levels.

The yeast was activated in lukewarm water and milk before being mixed with the dry ingredients. Mulberry leaf powder was incorporated gradually to ensure uniform distribution throughout the dough. The dough was kneaded until smooth and elastic, fermented for approximately one hour, divided into equal portions, rolled into cylindrical shapes, coated with bread crumbs, proofed for 20–30 minutes, and baked in a preheated oven at 204°C (400°F) for 12–15 minutes. All treatments were processed under identical conditions to ensure consistency

Table 2. Ingredient Formulation of Pan de Sal Enriched with Mulberry Leaf Powder

Ingredient	T_0	T_1	T_2	T_3
Bread flour (g)	1000	970	950	930
Mulberry leaf powder (g)	0	30	50	70
Sugar (g)	500	500	500	500
Water (mL)	250	250	250	250
Milk (mL)	100	100	100	100
Salt (g)	10	10	10	10
Yeast (g)	10	10	10	10
Shortening (g)	15	15	15	15
Bread crumbs (g)	1000	1000	1000	1000

2.6 Sensory Evaluation

Descriptive Sensory Analysis

Descriptive sensory analysis was performed by ten trained panelists who had previously participated in sensory evaluation training conducted by the Department of Science and Technology. The panelists independently evaluated the products using Free Choice Profiling (FCP), allowing them to identify and describe the sensory characteristics of each formulation.

The evaluated attributes included color, texture, odor, flavor, and taste. Attribute intensity was measured using an eight-point descriptive scale ranging from 0 (none detected) to 7 (strongly detected). Water was provided between samples to minimize sensory fatigue.

Consumer Acceptability

Consumer acceptability was evaluated by fifty untrained panelists representing potential consumers. Samples were presented using randomized three-digit codes and evaluated one at a time to minimize presentation bias.

A nine-point hedonic scale was used to assess color, odor, flavor, taste, texture, and overall acceptability, where 1 represented "Dislike Extremely" and 9 represented "Like Extremely." Panelists rinsed their mouths with water between samples to avoid flavor carry-over effects.

2.7 Proximate Composition Analysis

Following sensory evaluation, the formulation with the highest overall acceptability was subjected to proximate composition analysis at the DOST Regional Standards and Testing Laboratory.

Moisture, ash, crude protein, crude fat, and carbohydrate contents were determined using standard analytical procedures of the Association of Official Analytical Chemists (AOAC). Results were expressed as grams per 100 grams of sample.

2.8 Microbiological Analysis

The preferred formulation was analyzed for microbiological quality to ensure compliance with food safety standards. The parameters evaluated included Aerobic Plate Count (APC), *Escherichia coli*, *Staphylococcus aureus*, and mold and yeast counts using standard laboratory methods. The results were interpreted according to the microbiological standards for processed bakery products established by the Philippine Food and Drug Administration.

2.9 Economic Evaluation

Economic feasibility was assessed by computing the Return on Expenditure (ROE), which estimates the profitability of producing mulberry-enriched Pan de Sal. Total production cost included raw materials, labor, and processing expenses, while gross income and net income were calculated based on the projected selling price.

2.10 Statistical Analysis

Sensory evaluation data were analyzed using IBM SPSS Statistics Version 25. Descriptive statistics were used to summarize sensory ratings. One-way Analysis of Variance (ANOVA)

determined significant differences among treatment means at the 5% significance level. Duncan's Multiple Range Test (DMRT) was performed as a post hoc analysis whenever significant differences were observed. Results of proximate composition, microbiological analysis, and economic evaluation were interpreted descriptively using relevant food quality and safety standards.

3. Results and Discussion

3.1 Sensory Characteristics of Pan de Sal Enriched with *Morus alba* L. Leaf Powder

The incorporation of *Morus alba* leaf powder significantly influenced the sensory characteristics of Pan de Sal. Variations in the concentration of mulberry leaf powder resulted in observable differences in color, aroma, flavor, taste, texture, and overall consumer acceptability. The sensory profile evolved progressively as the level of mulberry supplementation increased, reflecting the influence of the plant's natural pigments and phytochemical composition.

Color

The descriptive sensory evaluation revealed a gradual transition in crust and crumb color from the light brown appearance of the control treatment to increasingly greenish-brown shades as the concentration of mulberry leaf powder increased. This change is primarily attributed to chlorophyll pigments naturally present in mulberry leaves. During baking, chlorophyll interacts with Maillard browning reactions, producing the characteristic greenish-brown coloration observed in fortified formulations.

Consumer evaluation demonstrated that the 3% formulation received the highest color acceptability score among the fortified treatments. Although darker formulations reflected greater incorporation of functional ingredients, excessive greenness reduced consumer preference because it differed from the traditional appearance of Pan de Sal. These findings suggest that moderate fortification successfully enhances nutritional value while maintaining the visual characteristics expected by consumers.

Similar observations have been reported in studies involving bread fortified with moringa, spinach, kale, and other leafy vegetables, where increasing concentrations of plant powders enhanced nutritional quality but progressively reduced visual acceptability due to darker coloration.

Texture

Texture remained soft and acceptable in the control and 3% formulations, whereas the incorporation of 5% and 7% mulberry leaf powder resulted in a denser crumb structure and slightly firmer texture. The reduction in softness may be attributed to the relatively high dietary fiber content of mulberry leaves, which interferes with gluten network formation during dough development.

Dietary fiber competes with gluten proteins for water absorption, reducing dough elasticity and gas retention during fermentation. Consequently, higher supplementation levels produced bread with reduced loaf volume and increased

crumb firmness. Similar findings have been reported in bakery products enriched with vegetable powders and cereal fibers, where excessive fiber incorporation adversely affected dough rheology and bread quality.

Despite these structural changes, the 3% formulation maintained texture ratings comparable to the conventional Pan de Sal, indicating that moderate fortification did not compromise product quality.

Odor and Flavor

Mulberry leaf powder imparted a characteristic herbal aroma and flavor that became increasingly pronounced with higher supplementation levels. Treatments containing 5% and 7% mulberry powder exhibited stronger vegetal notes due to the presence of volatile phytochemicals, flavonoids, and phenolic compounds naturally occurring in mulberry leaves.

The consumer panel generally preferred the subtle herbal aroma produced by the 3% formulation. Higher concentrations were perceived as excessively herbal, leading to lower preference scores. This observation demonstrates the importance of optimizing functional ingredient incorporation to achieve a balance between enhanced nutritional quality and sensory acceptability.

Previous studies involving mulberry-enriched cookies, biscuits, and noodles have similarly reported that moderate concentrations improve product uniqueness while excessive supplementation results in undesirable flavor intensity.

Taste

Taste acceptability followed a similar trend. The incorporation of 3% mulberry leaf powder produced a pleasant and mildly herbal flavor that complemented the characteristic sweetness of Pan de Sal. Conversely, formulations containing 5% and 7% mulberry powder developed a noticeable bitter aftertaste, reducing consumer acceptance.

The bitterness may be attributed to phenolic compounds and flavonoids naturally present in mulberry leaves. Although these phytochemicals possess antioxidant properties and contribute to the functional value of the product, they may negatively influence sensory perception when present at elevated concentrations.

The present findings indicate that moderate supplementation successfully preserves the desirable flavor profile of Pan de Sal while introducing beneficial phytochemicals.

3.2 Consumer Acceptability

Consumer acceptability analysis demonstrated significant differences among the four formulations for all evaluated sensory attributes. The formulation containing 3% mulberry leaf powder obtained the highest overall acceptability rating, indicating that moderate incorporation produced the most favorable balance between nutritional enhancement and sensory quality.

The control formulation remained highly acceptable because consumers were familiar with its traditional characteristics. However, the 3% treatment exhibited superior overall acceptance because respondents perceived the product as healthier while maintaining desirable color, aroma, flavor, texture, and taste.

Increasing the concentration beyond 3% significantly reduced consumer preference. The darker appearance, stronger herbal aroma, increased bitterness, and firmer texture observed in the 5% and 7% formulations collectively contributed to lower hedonic ratings.

These findings emphasize that successful functional food development requires optimization of ingredient concentration rather than maximizing nutrient incorporation. Consumers generally prefer products that preserve familiar sensory characteristics while offering additional health benefits.

3.3 Statistical Analysis of Sensory Evaluation

Analysis of variance demonstrated statistically significant differences ($p < 0.05$) among treatment means for color, odor, flavor, taste, texture, and overall acceptability. Duncan's Multiple Range Test further confirmed that the 3% formulation differed significantly from higher supplementation levels and consistently ranked among the most preferred treatments.

The absence of significant texture differences between the control and 3% formulation indicates that moderate incorporation did not adversely affect bread structure. This finding is particularly important for commercial bakery applications because texture remains one of the primary determinants of consumer purchasing behavior.

The statistical evidence therefore supports the selection of 3% mulberry leaf powder as the optimum supplementation level for Pan de Sal.

3.4 Nutritional Composition of the Preferred Formulation

The proximate composition analysis demonstrated that the preferred formulation possessed favorable nutritional characteristics while maintaining desirable moisture content for baked products. The formulation contained **9.86% moisture, 0.91% ash, 2.56% crude fat, 7.97% crude protein, and 62.70% carbohydrates**. These values indicate that the incorporation of mulberry leaf powder enhanced the nutritional profile of the bread without adversely affecting product stability.

The relatively low moisture content is advantageous because reduced water activity contributes to improved shelf stability by limiting microbial growth. The ash content reflects the contribution of naturally occurring minerals from mulberry leaves, including calcium, potassium, magnesium, and iron. Increased mineral content enhances the nutritional value of the fortified bread and supports the role of mulberry leaves as a natural fortificant.

Protein content was also improved through the incorporation of mulberry leaf powder. Although wheat flour remained the principal ingredient, mulberry leaves contributed additional plant protein and dietary fiber, thereby increasing the nutritional density of the product. These findings support previous studies that identified mulberry leaves as a nutrient-rich functional ingredient suitable for bakery applications.

3.5 Microbiological Quality

Microbiological evaluation confirmed that the preferred formulation complied with food safety standards. Aerobic plate count, *Escherichia coli*, *Staphylococcus aureus*, mold, and yeast counts were all within acceptable limits, indicating that the production process maintained appropriate hygienic conditions and good manufacturing practices.

The absence of pathogenic microorganisms demonstrates that incorporating mulberry leaf powder did not compromise product safety. Proper handling, drying, processing, and baking effectively minimized microbial contamination. These findings suggest that mulberry-enriched Pan de Sal can be safely produced under standard bakery conditions without additional food safety concerns.

3.6 Economic Feasibility

Economic evaluation indicated that the preferred formulation generated a **30% return on expenditure**, demonstrating promising commercial viability. The favorable profitability reflects the relatively low production cost of mulberry leaf powder and the strong consumer acceptance of the fortified product.

The commercialization of mulberry-enriched Pan de Sal may provide livelihood opportunities for community bakeries, small-scale food processors, and microenterprises. In addition to generating income, the product promotes the utilization of locally available agricultural resources and supports food fortification initiatives aimed at improving public nutrition.

Overall, the results demonstrate that moderate incorporation of *Morus alba* leaf powder enhances the nutritional quality of Pan de Sal while maintaining sensory acceptability, microbiological safety, and economic feasibility. These characteristics make the product a promising functional bakery item with potential for wider adoption in both commercial and community-based food production.

4. Conclusion

This study demonstrated the feasibility of incorporating *Morus alba* L. (mulberry) leaf powder into Pan de Sal as a functional ingredient to improve its nutritional quality while maintaining consumer acceptability. Among the four formulations evaluated, the bread containing **3% mulberry leaf powder** achieved the highest overall acceptability, indicating that moderate fortification effectively balanced enhanced nutritional value with desirable sensory characteristics.

The incorporation of mulberry leaf powder significantly influenced the color, aroma, flavor, taste, and texture of the bread. Although higher supplementation levels increased the concentration of bioactive compounds, they also intensified herbal flavor, bitterness, and crumb firmness, resulting in lower consumer preference. The proximate composition analysis confirmed that the preferred formulation contained favorable levels of moisture, protein, fat, ash, and carbohydrates, while microbiological evaluation verified compliance with food safety standards. Furthermore, the product generated a **30% return on expenditure**, demonstrating promising commercial potential for bakery enterprises.

Overall, the findings support the use of mulberry leaf powder as a natural functional ingredient for bakery products and provide scientific evidence for its application in food fortification initiatives. The developed product offers a practical approach to improving dietary quality through the utilization of locally available agricultural resources while supporting the development of value-added functional foods.

5. Practical Implications

The results of this study have practical implications for the food industry, public health agencies, and agricultural stakeholders. The successful incorporation of mulberry leaf powder into Pan de Sal demonstrates the potential of indigenous plant resources to enhance the nutritional quality of staple bakery products without substantially compromising consumer acceptability.

For commercial bakeries and micro, small, and medium enterprises (MSMEs), the preferred formulation provides an opportunity to diversify product lines by introducing functional bakery products that respond to increasing consumer demand for healthier foods. The favorable economic performance further indicates that mulberry-enriched Pan de Sal can contribute to sustainable income generation and local enterprise development.

From a public health perspective, utilizing Pan de Sal as a vehicle for natural food fortification aligns with national nutrition programs that aim to reduce micronutrient deficiencies. Because Pan de Sal is widely consumed across different socioeconomic groups in the Philippines, incorporating nutrient-rich plant ingredients into this staple food may contribute to improved dietary intake and support broader food security initiatives.

The findings also encourage the cultivation and utilization of mulberry as a multifunctional crop with applications extending beyond sericulture to food processing and functional food development. Increased demand for mulberry leaves may provide additional livelihood opportunities for farmers while promoting sustainable agricultural diversification.

6. Limitations of the Study

Several limitations should be considered when interpreting the findings of this study. First, consumer acceptability was evaluated using a relatively limited sample of panelists from a single locality, which may not fully represent the preferences of the broader Philippine population. Future studies should involve larger and more diverse consumer groups to improve the generalizability of the findings.

Second, the nutritional evaluation was limited to proximate composition. Although mulberry leaves are known to contain bioactive compounds such as flavonoids, phenolic acids, carotenoids, and 1-deoxynojirimycin (DNJ), these components were not quantified in the present investigation. Determining the retention of these compounds after baking would provide a more comprehensive assessment of the functional properties of the product.

Third, shelf-life evaluation was beyond the scope of this study. The stability of sensory attributes, nutritional quality, and

microbiological safety during storage should be investigated to determine the commercial storage potential of the product.

Finally, the study focused exclusively on Pan de Sal. Additional investigations involving other bakery products may further expand the utilization of mulberry leaf powder within the food industry.

7. Recommendations for Future Research

Future investigations should quantify the antioxidant activity, total phenolic content, flavonoid concentration, vitamin composition, and mineral profile of mulberry-enriched Pan de Sal to provide a more comprehensive evaluation of its nutritional benefits.

Shelf-life studies should be conducted under different packaging systems and storage conditions to determine product stability and establish appropriate expiration periods. Future research may also evaluate consumer acceptance across different age groups, socioeconomic sectors, and geographic regions to improve marketability.

Physiological studies investigating glycemic response, antioxidant bioavailability, and other health-related outcomes associated with regular consumption of mulberry-enriched bakery products would further strengthen scientific evidence supporting their functional food claims.

Finally, future studies may explore the incorporation of mulberry leaf powder into other bakery and cereal products, including whole wheat bread, cookies, crackers, noodles, and gluten-free products, to diversify its commercial applications.

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