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RESEARCH ARTICLE

Development of Fresh Pasta Enriched with Dietary Fiber and Nutrients from Navy Bean Flour: Effects on Quality and Chemical Composition Toward Health Promotion and Agricultural Sustainability in Thailand

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ABSTRACT

The goal of the research was to prepare a dietary-enriched fresh pasta product using dietary fiber, nutrients, and partially replacing wheat flour with navy bean flour in contents of 10, 20, 30, and 40 percent. This was mainly to improve the nutritional attributes of pasta by the addition of protein, fiber, and health-promoting ingredients, retaining good sensory attributes. Navy beans (Phaseolus vulgaris) are characterized by high nutritional value, especially due to the presence of phaseolamin, which reduces alpha-amylase activity, thus maintaining the blood sugar level. Their health orientation makes them suitable for formulating pasta products and is in tandem with the current contemporary world trends of using foods as a pill, and since they are locally grown, it is in congruence with sustainable usage of local Thai crops. This research applied an experimental form of research through Randomized Complete Block Design (RCBD) to assess chemical parameters, physical dimensions, sensory acceptance, and safety. Using chemical analysis, it was found that, as the percentage of substitution rose, so did the protein and fiber content with the 40% formulation resulting in 15.94 percent protein, and 6.85 percent fiber. Nevertheless, both the physical and sensory tests showed that a 10 percent substitution level was the most balanced alternative between nutritional improvement and acceptance among consumers. The formula scored the highest in taste (4.06 +/- 1.04), texture (4.22 +/- 0.91), and overall liking (4.34 +/- 0.85) when a panel of 100 people was asked to score it against a set of other formulas. Testing in heavy metals established that lead levels and mercury of navy bean flour were less than 0.10mg/kg, which is within the safety standards mandated by the Thai Ministry of Public Health. Their results indicate that navy bean flour can be taken as a candidate to formulate health-oriented pasta. Besides, its utilization enhances sustainability in agriculture because it enhances the value of high-level crops and helps local farmers. This research is a basis on which any further research can commence in the glycemic index, mass production, and the creation of various pasta types based on certain consumer markets.

INTRODUCTION

With the modern concept of consumers being health and nutrition conscious, the food industry is moving along this path of creating food that not only tastes good but also encourages healthy characteristics, as well as sustainable well-being. This is particularly true in single-serving meals due to their convenience and popularity among urbanites, students, and work and college students. Pasta is one such product; it is an Italian origin pasta of noodle origin that has become acceptable and consumed in various parts of the world, including Thailand, where one consumed in both residential and restaurant and food service businesses.

Although pasta is so popular, it has limitations in nutritional value, especially since one of its most basic ingredients, which is wheat flour, is rich in carbohydrates made poor in dietary fiber. This composition may influence the level of sugar in the blood and does not fully satisfy the needs of healthy consumers. So, the production of a new product called the "fresh pasta enriched with dietary fiber and nutrients" has become the hot topic of discussion as one of the most promising alternatives meeting the demands of both health and the utilization of domestic products.

Navy bean (Phaseolus vulgaris) is a nutritious legume that is high in phaseolamin in the Thai context. As such, it halts the work of the alpha-amylase enzyme that is involved in digesting starch. This effect impedes sugar absorption in the digestive system, which is important in the regulation of blood sugar and general promotion of health. These beans are also a good source of protein, dietary fiber, and antioxidants, as they can become a raw material in the development of health-related foods.

In typical industrial production of pasta, durum wheat semolina is the primary ingredient based on its elasticity, firmness, and its ability to retain its shape after boiling or baking, which are critical characteristics to make pasta of the texture that is desired texture by the consumer. Nevertheless, wheat flour does not have the whole nutritional spectrum, like fiber, vitamins, and various minerals. Besides, people who are gluten-intolerant or diabetics can take high doses of wheat as a disadvantage.

By replacing wheat flour with navy bean flour in pasta products, a new and potentially successful solution is open, which not only helps consumers in solving their health problems, but also ensures that the country will increase its demand for the national agriculture production, especially food that can grow in highlands and may have economic constraints. New value chains of the food industry can be achieved through the use of raw materials in Royal Project zones.

The design of more nutritious pasta is a multidisciplinary combination of food science and nutrition expertise, and expertise in production technology. It involves identifying the right ratio of substitution, managing textural consistency, coloration, and taste, and also striking a balance between food product nutritional value and consumer satisfaction. This research is based on experimental research aimed at formulating new pasta recipes by enhancing fiber and nutrients gained by navy bean flour, with quality determination in the following aspects:

• Chemical configuration analysis: protein, fiber, fat, ash, and sugars

• Physical analysis: firmness, color, swelling, and cooking loss

• Sensory evaluation for consumer acceptance

• Safety assessment for heavy metals (lead and mercury)

Objectives of the Study

1. To develop a fresh pasta product enriched with dietary fiber and nutrients by partially substituting wheat flour with navy bean flour.

2. To investigate the effects of varying substitution levels of navy bean flour on the chemical composition, physical properties, and consumer acceptance of the pasta product.

3. To evaluate the safety of the product in terms of heavy metal contamination and its suitability for consumption.

RESEARCH METHODOLOGY

Research Design

This study employed an experimental approach aimed at comparing the effects of substituting wheat flour with navy bean flour in fresh pasta formulations. The research focused on evaluating physical, chemical, and sensory qualities. The experimental design followed a Randomized Complete Block Design (RCBD) to control confounding variables and enhance analytical accuracy. The research was divided into three key phases:

1. Selection of the optimal standard pasta formula

2. Development of pasta formulas with varying levels of navy bean flour substitution

3. Analysis and evaluation of product quality

Materials, Equipment, and Sample Groups

Food Ingredients

- High-protein wheat flour (Goose Brand)
- Navy beans from the Royal Project (roasted and finely milled)
- Grade 2 chicken eggs
- Extra virgin olive oil (Bertolli brand)
- Table salt (Prungthip brand)
- Boiled water

Production and Analytical Equipment

- Pasta roller machine
- Convection oven
- 80-mesh sieve
- Digital scale
- Colorimeter (HunterLab, ColorQuest XE, USA)
- Texture analyzer (Stable Micro Systems, TA.XT Plus model)
- Sensory evaluation tools (paper plates, forks, drinking water)

Research Procedures

1. Selection of Standard Pasta Formula

The researcher compiled three fresh pasta recipes from textbooks and instructional materials used in the Culinary Arts and Technology Program at Rangsit University. These recipes were produced and subjected to sensory evaluation by a test group of 50 participants, including instructors, culinary students, and general consumers. The evaluation used a 5-point Hedonic Scale to determine the most preferred formula, which was selected as the base for further modification using navy bean flour.

2. Development of Pasta Formulas with Navy Bean Flour

The selected base formula was modified by substituting wheat flour with roasted, finely milled navy bean flour at levels of 10%, 20%, 30%, and 40% by weight. The total flour content was maintained at 225 grams, with other ingredients (eggs, olive oil, water, salt) kept constant. Pasta production followed standard procedures.

3. Product Quality Analysis and Evaluation

3.1 Chemical Composition Analysis

Cooked pasta samples were analyzed according to AOAC standards for the following components:

- Moisture
- Protein
- Fat
- Dietary fiber
- Ash
- Carbohydrates (calculated by difference)

3.2 Physical Property Analysis

- Color values (L*, a*, b*)

- Cooking loss (%)
- Cooking yield (%)
- Swelling index (%)
- Pasta strand firmness (g)
- Break distance (mm)

3.3 Sensory Evaluation

A sample group of 100 participants, comprising 50 students and 50 general consumers aged 18–50, evaluated the pasta products based on color, aroma, taste, texture, and overall liking using a 5-point Hedonic Scale.

3.4 Heavy Metal Contamination Analysis

Navy bean flour used in production was tested for lead and mercury content using standard methods outlined in the Thai Ministry of Public Health Notification No. 98 (1986), which stipulates maximum limits of 1 mg/kg for lead and 0.2 mg/kg for mercury.

RESULTS OF THE STUDY

1. Selection of the Standard Pasta Formula

Three fresh pasta recipes were tested by a group of 50 participants, including culinary experts and general consumers, using a 5-point Hedonic Scale. The first formula—comprising egg yolks, olive oil, and water in optimal proportions—received the highest overall acceptance scores, particularly in taste (4.06 ± 1.04), texture (4.22 ± 0.91), and overall liking (4.34 ± 0.85). This formula was selected as the base for further modification using navy bean flour.

2. Development of Pasta Formulas Using Navy Bean Flour

The researcher substituted portions of wheat flour in the base formula with navy bean flour at levels of 10%, 20%, 30%, and 40% by weight. The total flour content was maintained at 225 grams, with other ingredients (egg, oil, water, salt) kept constant. The pasta was produced using standard procedures and analyzed for quality.

3. Chemical Composition Analysis

The substitution of navy bean flour affected the chemical composition of the cooked pasta as follows:

Substitution Level (%)	Protein (%)	Dietary Fiber (%)	Fat (%)	Moisture (%)	Ash (%)	Carbohydrate (%)
0	14.67	2.52	10.85	11.13	2.54	60.81
10	14.88	4.03	9.95	12.92	2.49	59.76
20	15.37	4.44	10.89	11.42	2.64	59.68
30	15.71	5.64	10.34	11.71	3.04	59.21
40	15.94	6.85	10.56	11.49	3.34	58.58

Higher substitution levels led to significant increases in protein and dietary fiber, reflecting improved nutritional values- especially fiber, which plays a key role in digestive health and blood sugar regulation.

4. Physical Property Analysis

4.1 Color Analysis

Color values of prepared pasta were restrained as follows:

Substitution Level (%)	L* (Lightness)	a* (Redness)	b* (Yellowness)
0	79.77	3.04	21.05
10	76.59	1.65	17.46
20	79.11	2.02	19.88
30	80.44	1.63	19.99
40	79.33	2.60	20.69

An increasing concentration of navy bean flour was inclined to decrease the lightness and yellowness, implying that the appearance could change, leading to the rejection of the flour by the consumer.

4.2 Firmness and Break Distance

Substitution Level (%)	Firmness (g)	Break Distance (mm)
0	52.9	77.4
10	49.6	65.5
20	49.8	56.5
30	36.5	31.9
40	30.4	20.8

The level was substantial as break distance was minimal in the presence of high substitution levels, potentially attributed to lower gluten levels, which influence the elasticity of pasta. Nonetheless, the 10 percent replacement was not so high as to make a consumer unsatisfied.

4.3 Swelling and Cooking Loss

Substitution Level (%)	Cooking Loss (%)	Swelling (%)
0	5.01	65.16
10	3.71	65.66
20	6.82	65.51
30	6.80	63.66
40	4.71	65.02

The cooking loss was lowest with the formula of navy bean flour through which 10% was placed, and thus strong structural integrity of the pasta strands was shown.

DISCUSSION OF THE FINDINGS

The findings of the last part reveal that replacing wheat flour with the navy bean flour in the formulations of fresh pasta has a major impact on nutrition content, customer value, and quality of the product. It is notable that, 10 percent substitution level produced the best results considering both nutriment addition and overall liking.

1. Changes in Chemical Composition

This analysis showed that the respective protein and dietary fiber levels went up as levels of navy bean flour went up in proportionality. This can be attributed to the structural characteristics of the flour containing navy beans, which is rich in amylose and non-digestible polysaccharides termed as resistant starch. The cells are vital in influencing blood sugar levels (Fuentes-Zaragoza et al., 2010). The nutritional prospect of navy bean flour was revealed in the 40 % substitution level that achieved the maximum protein content (15.94%), which surpassed the minimum requirement of the Thai Industrial Standard (TIS 475-2526) on the requirement of protein content in Macaroni products (14%).

2. Physical Properties and Nutritional Efficiency

The examination of cooking loss and pasta strand hardness displayed a close connection with the quantity of navy bean flour added. The 10 percent substitution level incurred less cooking loss (3.71 percent), hence fewer losses in nutrients and uniform maintenance of shape under boiling. However, higher substitution levels (30–40%) negatively affected texture and elasticity, with reduced firmness and shorter break distances. This is consistent with the reduction in gluten, which is essential for pasta structure. These findings suggest that while navy bean flour enhances nutritional value, excessive use may compromise consumer satisfaction.

3. Sensory Acceptance

Consumer evaluation showed that the 10% substitution formula received the highest overall liking score (4.36 ± 0.77). Minor changes in color, aroma, and texture were still acceptable to most consumers. However, increasing the proportion of navy bean flour intensified the bean aroma and altered the texture, which led to lower scores among general consumers—especially those

unfamiliar with the flavor profile of navy beans or who preferred the soft, elastic texture typical of wheat-based pasta. This highlights the importance of balancing nutrition and sensory appeal.

4. Safety Regarding Residual Contaminants

Heavy metal analysis of navy bean flour showed lead and mercury levels below 0.10 mg/kg, which is within the safety limits set by the Thai Ministry of Public Health (Notification No. 98, 1986). This confirms that navy bean flour is safe for use in food products and supports its potential for commercial development.

5. Comparison with Related Research

The findings of this study align with those of Celleno et al. (2007), who reported that navy beans can aid in weight reduction by inhibiting starch-digesting enzymes. Similarly, Raben et al. (1994) found that resistant starch helps reduce postprandial blood glucose levels. The results also correspond with the study by Kulaya et al. (2018), which developed pasta from rice flour and mung bean flour and achieved good consumer acceptance, though limitations in aroma and texture were noted—similar to the issues observed in the 30–40% navy bean flour formulas in this study.

6. Research Limitations and Considerations

Although navy bean flour significantly enhances nutritional value, changes in texture and aroma remain key limitations for marketability. It is recommended to adjust the formula by incorporating natural herbs or flavoring agents to mask the bean aroma. Additionally, this study did not assess the glycemic index (GI), which is a critical factor for diabetic and health-conscious consumers. Future research should include GI testing to strengthen the health claims of the product.

Recommendations

According to the results, high levels of nutritional properties and a positive consumer acceptance were observed with fresh pasta containing 10-per percent replacement of flour with navy beans. The practical application and development of further research are the following recommendations offered by the researcher:

1. Infrastructure and Education Suggestions:

- Curriculum Integration: Include the navy bean pasta formula in culinary and nutrition classes, specifically when learning about starch-based food and health-driven food development. This will enable the students to learn about the use of local ingredients in developing functional foods.
- Innovation in Food Thinking: Use this research as a case study to encourage thinking about bringing innovation into food product development with production technology and nutritional therapy together.

2. Commercial and Product Development Recommendation:

- Shelf-Stable Product Development Over boost the product to semi-cooked or dried pasta mode with the added benefits of extended shelf life and conveniently-seeking health consumers.
- Diversification in pasta shapes: Establish different varieties and shapes of pasta to address the consumer needs differently, like different age groups, such as children, the elderly, or persons who are on a special diet.
- Glycemic Index Testing: To validate that the product is suitable for diabetic and health-conscious consumers, carry out testing of the glycemic index (GI).
- Comparative Ingredient Research: Research on the possibilities of other flours, e.g., soybean flour, brown rice flour, or purple yam flour, as wheat flour substitutes, and compare their effectiveness with navy bean flour.

3. Recommendations, social and agricultural promotion

- Highland Agriculture: As much as possible, encourage agricultural uses of highland crops, such as the food industry utilization of native legumes, like navy beans, showing it is commercially viable.

- Value Chain Creation: Create value chains for the farmers by linking navy bean production grown in Royal Project areas to be linked to health-concept food products in the mainstream markets.
- Community Training: Hold trainings on navy bean processing for community entrepreneurs, which include food cooperatives, agricultural groups, etc.

4. Policy and Public Health Recommendations

- Nutritional Food Prototypes: The government agencies, such as the Food and Drug Administration (FDA), Department of Health, and health-based organizations can be encouraged to use the research findings to come up with prototypes in producing nutritionally fortified staple foods.
- Implementation in Education: Educate the inclusion of concepts of health-related foods into school and university meal plans, particularly in health development and nutrition departments.

5. Recommendations for Further Research

- Fine-Tuning Substitution Ratios: Investigate substitution levels below 10% and between 10–15% to identify the optimal balance between nutritional value and consumer satisfaction.
- Biochemical Impact Studies: Examine the effects of navy bean pasta consumption on blood glucose and lipid levels in test subjects to validate its health benefits at a clinical level.
- Industrial-Scale Production Testing: Conduct trials at the industrial level to assess nutrient stability after thermal processing and determine suitable drying methods for commercial production.

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