Jurnal Pembelajaran Dan Biologi Nukleus p-ISSN: 2442-9481
Vol 11 (3): 1015 - 1032, September 2025 e-ISSN: 2685-7332

Shrimp Shell and Head Flour Formulation in Wet Noodle Products as Source of Protein and Calcium

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Submitted June 15 Th 2025, and Accepted August 29 Th 2025

Abstract

Background: *This study is the first to formulate wet noodles with combined shrimp shell and head flour of Metapenaeus monoceros, an area that has been rarely explored. These by-products were chosen for their high protein and calcium content, aiming to enhance nutrition and create value-added functional food. This study aims to investigate the impact of incorporating Penaeid shrimp skin and head flour on the protein content, calcium, and physical and organoleptic properties of wet noodles.* **Methodolgy:** *The study used a Completely Randomised Design (CRD) with four treatments: F1 (0%), F2 (5%), F3 (8%), and F4 (10%). Organoleptic tests were conducted by 60 untrained panellists. Data were analysed using parametric (ANOVA) and non-parametric (Kruskal-Wallis) tests using the SPSS software.* **Findings:** *The results of the physical quality analysis revealed that the addition of flour had no significant effect on cooking loss ($P > 0.05$). However, they had a substantial impact on cooking time and elasticity ($P < 0.05$). Organoleptic tests showed a significant effect ($P<0.05$) on the colour, aroma, taste, and texture of wet noodles. The best formulation (F2) compared to the control formulation (F1) showed an increase in protein content from 9.44% to 10% and calcium from 305.54 mg/kg to 1281.29 mg/kg, or almost four times.* **Contribution:** *This research presents a significant innovation by demonstrating that shrimp heads and shells are not merely industrial waste but can be utilized as a functional food ingredient. Fortifying noodles with this ingredient offers the dual benefit of improving nutritional quality while supporting environmental digestion.*

Keywords: *Calcium; Organoleptic; Protein; Shrimp Shell and Head; Wet Noodles*

https://doi.org/10.36987/jpbn.v11i3.7764

INTRODUCTION

Wet noodles have become a dietary staple in Indonesia, with the country ranking as the world's second-largest consumer of noodles, with an impressive 14.54 billion servings consumed annually (World Instant Noodles Association, 2024). Among adolescents aged 10 to 24 years, 64.8% to 68.3% consume noodles 1 to 6 times a week, which highlights their role as a complementary source of carbohydrates (Riskesdas, 2018). However, conventional wet noodles are nutritionally inadequate, containing only 9.44 % protein and less than 305 mg/kg of calcium, both of which fall far below the recommended daily intake for this age group. As a result, 30.8% of adolescents experience protein deficiency, and 45.4 % suffer from calcium insufficiency (Permenkes RI No. 28, 2019; Riskesdas, 2018). Deficiencies in protein and minerals such as calcium during this critical growth period can lead to impaired bone, muscle, and cognitive development, potentially reducing quality of life and future productivity. Therefore, the development of functional foods enriched with protein, calcium, and other bioactive components is crucial as a strategic nutritional intervention for this age group. Various studies in Indonesia have documented the successful creation of functional foods based on local ingredients, which have demonstrated good consumer acceptance sand suitable nutritional profiles. Integrating functional ingredients into widely consumed wet noodles can serve as an effective public health strategy to improve nutritional status and health outcomes of Indonesian adolescents comprehensively.

The utilization of seafood waste as a source of functional food ingredients is a rapidly growing trend in East Asia, particularly in Japan and South Korea. Seafood by-products such as fish heads, skins, and shells are intensively processed to extract high-value bioactive compounds like collagen, protein, astaxanthin, and peptides, which have well-documented health benefits including antioxidant and anti-inflammatory activities. Surimi-based products stand as successful examples of functional foods derived from fishery by-products in this region. Advanced extraction technologies combined with circular economy principles support waste reduction while enhancing product value (Ahn et al., 2021; Yin & Park, 2023).

Indonesia's shrimp industry is the third-largest in the world (FAO, 2023) and generates approximately 350,000 tonnes of processing waste annually, primarily consisting of heads and shells. These by-products are rich in high-quality nutrients; shrimp heads contain 21 % protein, while shells provide 25 – 40 % protein and 45 – 50 % calcium carbonate (Dianiswara et al., 2023). The protein and calcium content in shrimp waste are highly competitive compared to other commonly consumed sources of protein and calcium. For example, anchovies contain 16 grams of protein per 100 grams and approximately 500 mg of calcium per 100 grams (Sukmawati et al., 2022) clams contain 7-15 grams of protein per 100 grams and 28.97-39.55% calcium carbonate depending on the species (Birhi et al., 2025); and cow's milk contains 3.2–3.5 grams of protein and 122-143 mg of calcium per 100 grams (Fadila, 2024). Thus, shrimp head and shell waste possess nutritional values that are not only comparable but excel in calcium content, making them a promising ingredient for functional food fortification based on wet noodles, which are typically low in protein and calcium.

Additionally, shrimp shells are a source of astaxanthin, an antioxidant that is 500 times more potent than vitamin E, as well as chitin (20 – 30%), which offers various health benefits (Hermanto & Nengseh, 2020). Despite their potential, these resources are often underutilized and discarded as waste. By transforming them into flour for food fortification, we could tackle nutritional deficiencies and improve waste management.

Previous studies have examined the use of shrimp heads and shells separately (Halimah & Maghfiroh, 2022; Sary, 2024), but none have optimized their combined application to enhance both protein and calcium content in wet noodles simultaneously. This study proposes an innovative approach by integrating these two waste streams, in line with circular economy principles. However, technical challenges must be addressed, such as sensory trade-offs, which include texture reduction due to the interaction between chitin and gluten, as well as odor issues caused by trimethylamine (Maulina et al., 2024). Furthermore, the bioavailability of calcium carbonate from shrimp shells and its stability during processing need careful evaluation (Lestari et al., 2021).

This research is focused on creating innovative wet noodle formulations that incorporate 0–10% shrimp head and shell flour. The study aims to measure the synergistic effects of protein and calcium, evaluate sensory properties, and determine the optimal inclusion level to maximize both nutrient retention and consumer appeal. By successfully implementing this approach, we have the potential to reduce shrimp waste by 15% while providing 1200 mg/day of their recommended daily calcium intake for adolescents aged 10-18 years (FAO, 2023). This research effectively bridges nutrition science with sustainable waste management, offering a promising, scalable solution that can enhance public health and contribute to Indonesia's food security objectives.

METHOD

This study undertakes an experimental research approach to uncover the truths within culinary science through a series of carefully conducted experiments. At its core is the creation of wet noodles, enriched with the innovative incorporation of Dogol's shrimp (*Metapenaeus monoceros*) shells and head flour in precisely measured ratios. This study employed a Completely Randomized Design (CRD) with four treatments and three replications each, utilizing shrimp shell to head flour 1:1 ratio on a dry weight basis. The research examined four distinct treatments that varied the proportions of shrimp shell, head and wheat flour as follows. The detailed formulations of each treatment are presented below:

- F1: 100% wheat flour
- F2: 95% wheat flour and 5% shrimp shell and head flour
- F3: 92% wheat flour and 8% shrimp shell and head flour
- F4: 90% wheat flour and 10% shrimp shell and head flour

After crafting the noodles, the products will undergo rigorous physical quality testing and organoleptic evaluations, focusing on essential attributes such as color, taste, aroma, and texture. Following these assessments, the most promising product will be evaluated for its nutritional content, with particular attention to protein and calcium levels, providing insights into both taste and health benefits.

Research Subject

The participants in this study were students from Teuku Umar University who consented to complete the Organoleptic Test questionnaire. The organoleptic evaluation was carried out using a sample of 60 untrained panelists who had no history of allergic shrimps, ensuring a diverse representation of opinions and perceptions related to the sensory characteristics being assessed.

Location and Time of Research

The study was conducted across three distinct locations to ensure a comprehensive analysis. Organoleptic and sensory evaluations were performed at the Biomedical Laboratory, while physical property assessments took place at the Agricultural Product Technology Laboratory of Teuku Umar University. Additionally, the determination of protein and calcium content was executed at the Banda Aceh Center for Food and Agricultural Product Testing (BSPJI). This research was carried out over a specified timeframe from September 10, 2024, to March 18, 2025.

Research Materials and Tools

Research Materials

The ingredients used in making wet noodles with the addition of shrimp shells and heads are high-protein wheat flour (Cakra Bertembar, Indorasa), shrimp head and shell flour, chicken eggs, shallots, garlic, salt, cooking oil, and pepper. To test the protein content, materials are needed in the form of wet noodle samples, 50% NaOH solution (Merck), Zn (Merck), H_2SO_4 (Merck), K_2SO_4 (Merck), $CuSO_4$ (Merck), standard hydrochloric acid solution (HCL 0.1 N Merck), phenolphthalein indicator, and distilled water. Testing the calcium content requires wet noodle sample materials, distilled water, and HNO_3 solution.

Research Tools

The equipment used in this study consisted of wet noodle making tools, namely a blender (Philips HR2221, Netherlands), a stainless steel basin (Maspion, Indonesia), a measuring cup (Pyrex, United States), Ampia (Marcato Atlas 150, Italy), a plastic scale (Camry, China), and an electric stove (Maspion S-301, Indonesia). For cooking loss testing, tools are needed in the form of measuring cups (Pyrex, United States), beakers (Pyrex, United States), test tube clamps (DLAB, China), stirring rods (IWAKI, Japan, filter paper (Whatman, England), analytical balance (Pioneer PA214, United States), desiccator (Normax, Portugal), porcelain cup (Assistant, Germany), electric stove (Maspion S-301, Indonesia) Oven (Memmert, Germany), mechanical thermometer (Zeal, England). For testing the cooking time of wet noodles, tools are needed in the form of analytical scales Analytical Balance (Pioneer PA214, United States), digital stopwatch (Casio, Japan), electric stove (Maspion S-301, Indonesia), Beaker Glass (Pyrex, United States), Thermometer (Hanna, Italy), Stainless Tweezers (DLAB, China) stainless sieve (Bel-Art). For elasticity testing, a ruler (Joyko) and a UTM machine are used (MCT-2150, Japan). Next, an acceptance test was conducted

p-ISSN: 2442-9481
e-ISSN: 2685-7332

in the form of an organoleptic test on the color, taste, aroma, texture, and wet noodle product.

For testing protein levels using the Kjeldahl method (AOAC 960.52), the following tools were used: Analytical Balance (Pioneer PA214), United States), Spatula (Pyrex, United States), Dropper Pipette (Pyrex, United States), Burette (Pyrex, United States), 300 ml Kjeldahl Flask (Pyrex, United States), 500 ml Boiling Flask (Pyrex, United States), 100 mm Diameter Watch Glass (Pyrex, United States), Beaker (Pyrex, United States), 75 mm Diameter Glass Funnel (IWAKI, Japan), 250 ml Erlenmeyer Flask (Pyrex, United States), 25 ml and 50 ml Measuring Cups (Pyrex, United States), Electric Stove (Maspion S-301, Indonesia), Acid Tank (Biobase, China), and Distillation Circuit (GASTEC model KJ-101, Japan). Calcium content test using Atomic Absorption Spectrophotometer (AAS) method (AOAC 984.27) using 30 ml Porcelain Crucible (Pyrex, United States), Desiccator (Nalgene, United States), Analytical Balance (Pioneer PA214, United States), Muffle Furnace (Nabertherm, Germany), Filter Paper (Whatman, England), 100 ml Measuring Flask (Pyrex, United States), 75 ml Pyrex Glass Funnel (United States), 100 and 200 ml Glass Beaker (Pyrex, United States), Measuring Pipette (Pyrex, United States), and Atomic Absorption Spectrophotometer (AAS) Machine (Shimadzu, Japan).

Research Procedures

This research consists of 4 main stages, including preparation of raw materials, formulation of wet noodle product production, identification of physical quality and acceptability, and identification of protein and calcium content in wet noodles.

Raw Material Preparation

The raw materials used in this study are the ingredients for making wet noodles, namely Cakra Kembar wheat flour, shrimp skin and head flour, chicken eggs, shallots, garlic, salt, cooking oil, and pepper.

Wet Noodle Product Manufacturing Formulation

The formulation of making wet noodles uses a composition of shrimp skin and head flour of 0%, 5%, 8%, and 10% which is mixed into one dough with other raw materials, namely Cakra Kembar wheat flour, chicken eggs, shallots, garlic, salt, cooking oil, and pepper. The shrimp by-product flour was prepared from a mixture of shells and heads in a 1:1 ratio on a dry weight basis, meaning that 50% of the flour originated from shrimp shells and 50% from shrimp heads. Then the mixed dough will be kneaded, then the noodle dough is formed, the noodles that have been formed lengthwise will be boiled for ± 1 minute at a temperature of 100oC, finally the noodles are cooled and wet noodles are produced with four different treatments, namely F1 (0%), F2 (5%), F3 (8%), and F4 (10%).

Identification of Wet Noodle Products

Wet noodle products will undergo physical quality analysis, including cooking time, cooking loss, and elasticity. Sensory or organoleptic acceptance analysis, including color, taste, aroma, and texture of wet noodles, using a hedonic test, which is a test conducted to see the level of preference for a product, in this case, a wet noodle product. Then, the best formulation will be selected from the results of physical and organoleptic quality tests to conduct protein and calcium content tests.

Identification of Protein and Calcium Content

The final stage is to identify the protein and calcium levels in the selected wet noodle products. Protein levels are identified using the Kjeldahl method, and calcium levels are determined using the Atomic Absorption Spectrophotometer (AAS) method with the DF-AAS01 tool.

Physical Quality Analysis

Physical quality analysis aims to see the physical condition of wet noodles. Physical quality analysis in this study includes cooking time, cooking loss, and elasticity.

Cooking Time

Cooking time analysis was carried out to determine the optimal cooking time for noodles. The procedure for determining the optimum cooking time in this study is a modified method from Rasper and de Man. The process begins with weighing raw noodles, which can weigh as much as 5 grams. The noodles are then cut into 5 cm lengths and cooked in 150 ml of boiling water for 3 minutes in a beaker. Then, the stopwatch is activated. Every minute, a strand of noodles is taken and then pressed with two sheets of glass. The optimum cooking time is achieved when a white line is formed when pressed with two sheets of glass (Situngkir et al., 2019).

Cooking Loss

Cooking loss is the amount of substance that dissolves and is lost with water during the noodle cooking process. In this test, 75 mL of water is heated in a glass beaker to a temperature of around 100 °C, then 5 grams of wet noodle sample is put into it and cooked for approximately 3 minutes. After that, the noodles are drained for approximately 2 minutes. The remaining water from the cooking process is then dried using an oven at a temperature of 105 °C for 36 hours for analysis. The calculation of cooking loss is based on the weight of the residue left behind with the following equation (Kusumawati et al., 2022).

$$Cooking\ Loss\ (\%) = \frac{Remaining\ weight\ of\ dry\ residue}{/Sample\ weight\ before\ cooking}\ x\ 100\ \ldots\ldots\ (1)$$

Elasticity

The elasticity of wet noodles is the elasticity of noodles, which is influenced by the gluten content in the noodle dough. The higher the wheat flour content in the dough, the higher the gluten content, so that the noodles become more elastic or chewy

p-ISSN: 2442-9481
e-ISSN: 2685-7332

(Afriliyanti et al., 2023). The elasticity of wet noodles refers to how far the noodles can be stretched before breaking. The measurement of the elasticity of wet noodles in this study was carried out using the UTM MCT-2150 Machine. The elasticity of wet noodles is measured by applying a tensile force to the noodles and measuring how far the noodles stretch before breaking.

Acceptance Analysis (Organoleptic)

Analysis of the acceptability of wet noodle products using sensory tests or organoleptic tests, namely a test to evaluate the quality of a product based on human sensory perception, namely sight, smell, touch, taste, and hearing (Adawiyah et al., 2024). The organoleptic test used in this study was hedonic. The parameters tested were color, aroma, and taste. The hedonic test on wet noodles uses a 5-level scale starting from a scale of 1 very dislike to a scale of 5 very like which refers to Sucianti (2020), including: 1 = Very Dislike; 2 = Dislike; 3 = Somewhat Dislike; 4 = Like; and 5 = Very Like. For the assessment of texture parameters, it refers to Rohmalia & Dainy (2023), namely using a scale of 1-5 levels starting from 1 very not chewy to 5 very chewy, including 1 = Very Not Chewy; 2 = Not Chewy; 3 = Less Chewy; 4 = Chewy; and 5 = Very Chewy.

Protein Content Analysis

Identification of protein content in wet noodles will be carried out using the Kjeldahl method (AOAC 960.52). The Kjeldahl method is a method of analyzing protein content by determining the total amount of nitrogen, where, by multiplying the resulting nitrogen content by a conversion factor of 6.25, the protein content will be obtained. The Kjeldahl method test is divided into three stages, namely Destruction, Distillation, and Titration (Sylvia et al., 2021).

In the destruction stage, 1 gram of the sample was ground. The mixture was placed in a Kjeldahl flask, followed by the addition of 7.5 grams of K_2SO_4, 0.35 grams of $CuSO_4$, and 15 mL of concentrated H_2SO_4. The flask was then shaken until homogeneous and heated in a fume hood until the liquid became clear. The heating process was continued for 30 minutes, after which the flask was cooled. Furthermore, the results of the destruction were transferred to the distillation flask (distillation stage), and 50 mL of 50 % NaOH, 200 mg Zn, and 100 mL of distilled water were added, then heated until boiling. The distillate was collected in an Erlenmeyer flask containing 50 mL of 0.1 N HCl and 3–5 drops of phenolphthalein indicator, and the distillation process was stopped when the distillate was no longer basic.

The final stage of the distillate was titrated with 0.1 N NaOH until a constant pink color as the endpoint, with duplicate repetitions and blank determination for calculating nitrogen content. To calculate the amount of nitrogen content, the following equation 2 is used (Sylvia et al., 2021):

$$N = \frac{(ml\ NaOH\ blank - ml\ NaOH\ Sample)\ x\ N\ NaOH\ x\ 14{,}008}{Sample\ Grams\ x\ 1000} \text{ x } 100\% \ldots\ldots\ldots\ (2)$$

Once the nitrogen content is known, the protein content is then calculated by multiplying the conversion factor (6.25) as follows equation 3 refers to Sylvia et al., (2021):

$$Protein\ (\%) = N\ x\ 6{,}25 \quad \text{...} \quad (3)$$

Calcium Content Analysis

Identification of calcium content in wet noodles will be carried out using the Atomic Absorption Spectrophotometer (AAS) method or Atomic Absorption Spectrophotometry (AOAC 984.27). The AAS method is an analysis method used to measure the Concentration of metal elements in a sample based on the absorption of radiation by free atoms in the gas phase. The AAS method test is divided into two stages, namely the sample ashing stage and the sample destruction stage (Trisna et al., 2023).

The first stage of the porcelain cup was heated at 105 °C for 1 hour, then cooled in a desiccator for 15 minutes and weighed. After that, 10 grams of sample was put into the cup and burned in a furnace at 550 °C for 4 hours, then cooled again in a desiccator for 15 minutes. The second stage of the sample ash was then placed in a beaker, followed by the addition of 30 mL of distilled water and 10 mL of nitric acid. The mixture was boiled for 10 minutes and then cooled. The solution was filtered and collected in a 50 mL measuring flask as the stock solution. Add 2.5 mL of distilled water, then the solution is ready to be analyzed using AAS to determine the calcium concentration. The calculation of calcium levels is carried out using the following formula (Sufiani et al., 2022):

$$Kalsium\ (\%) = \frac{C\ x\ I\ x\ P}{W\ \ x\ 10000} \quad \text{...} \quad (4)$$

description :
C = Concentration of reading results of AAS (ppm)
I = Stock solution (ml)
P = Diluent
W = Sample Weight

Data Analysis

The data in this study were analyzed using SPSS 22.0 software (Chicago, IL, USA). The data obtained in this study will be subjected to statistical tests using ANOVA (Analysis of Variance) analysis with a significance level of 5% ($P < 0.05$). This is done to test the acceptance or rejection of the hypothesis. If the significance value or p value (probability) <0.05, then it can be concluded that there is a real effect on the treatment, and if the significance value or p value (probability)> 0.05, then it can be concluded that there is no real effect on the treatment. If there is a real difference between the treatments, a further test will be carried out, namely the Tukey Test, to see which treatment has a more specific difference (Rahim et al., 2021).

RESULT AND DISCUSSION

Physical Quality Analysis Of Wet Noodles

The physical quality analysis of wet noodles in this study included cooking time, cooking loss, and elasticity. The results of the physical quality analysis are presented in Table 1. Based on Table 1, the cooking time analysis showed significant differences (P<0.05) among treatments. Specifically, significant variations were observed between F1 and F3, and between F1 and F4, with the longest average cooking time found in treatment F4 (10%) at 200.2 seconds. This was followed by F3 (176 seconds), F2 (150.6 seconds), and the shortest in F1 (0%) at 144.4 seconds. This was followed by treatment F3 (8%), with an average cooking time of 176 seconds, treatment F2 (5%) with 150.6 seconds, and the lowest average cooking time of treatment F1 (0%), which was 144.4 seconds. This trend aligns with the findings of Maemunah et al. (2022), who state that higher protein content in noodle dough leads to longer cooking times. This is attributed to the more complex and dense protein structure, which takes longer to absorb hot water and achieve complete denaturation.

In conclusion, the addition of shrimp skin and head flour significantly increases the cooking time of wet noodles, particularly at higher concentrations. According to Arinachaque et al., (2023), the typical cooking time for wet noodles ranges from 2 to 4 minutes (120 to 240 seconds). Therefore, the cooking times observed in this study, ranging from 144.4 seconds to 200.2 seconds, are within acceptable limits and should not disrupt consumer satisfaction when serving noodle products.

Table 1. Physical Quality Analysis of Wet Noodles with the Addition of Shrimp Skin and Head Flour

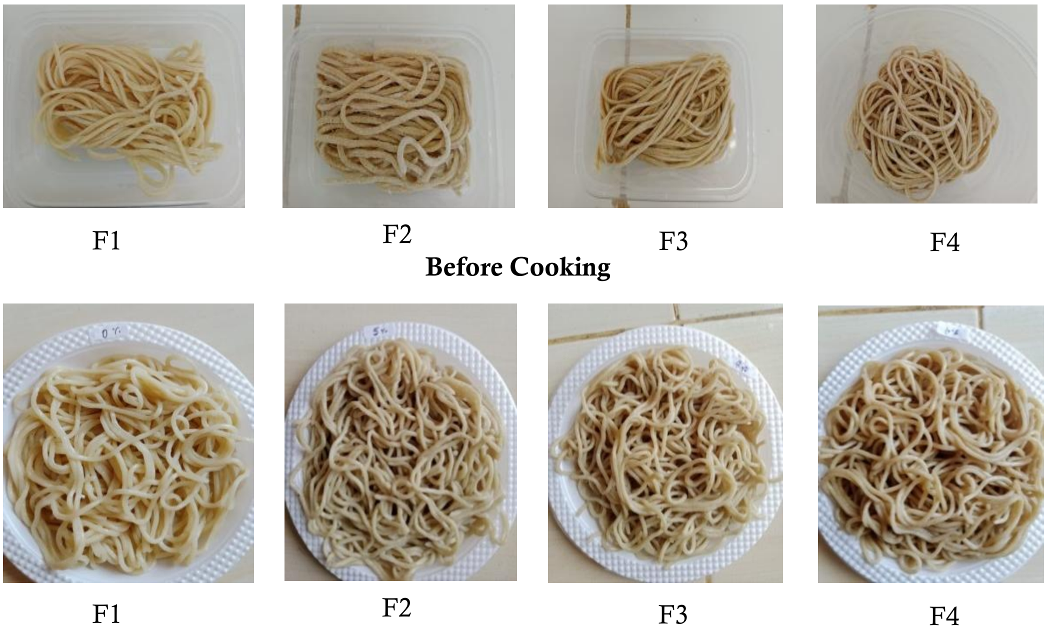
Parameters	**Treatment**				***P-Value***
	F1	F2	F3	F4	
Cooking Time (s)	144,4 ± 4,25^{a}	150,6 ± 5,78^{ab}	176 ± 18,04^{bac}	200,2 ± 5,10^{cb}	0,000
Cooking Loss (%)	5,66 ± 0,26^{a}	5,91 ± 1,01^{a}	5,77 ± 0.55^{a}	6,97 ± 0.42^{a}	0,111
Elasticity (mm)	33,54 ± 0,71^{cb}	31,25 ± 1,51^{bc}	27,38 ± 3,54^{b}	13,21 ± 0,79^{a}	0,000

* The data presented consists of Mean ± Std. Deviation. Different notations in the same row and column indicate significant differences (P<0.05)

Furthermore, the cooking loss parameters in Table 1 show that the addition of shrimp skin and head flour to wet noodles did not provide a significant difference (P>0.05) in the cooking loss of wet noodles. The highest average cooking loss was in the F4 treatment (10%) which was 6.97%, followed by the F2 treatment (5%) which was 5.91%, the F3 treatment (8%) which was 5.77%, and the lowest average was in the F1 treatment (0%) which was 5.66%. According to Kusumawati (2022), high cooking loss values can cause the loss of food components that should contribute to the nutritional value of the product, such as protein, minerals, and vitamins. Therefore, noodles with low cooking loss values are more desirable because they exhibit good structural resistance and minimize the loss of nutrients needed by the body during the cooking process.

Finally, the results of the Elasticity parameter test in Table 1 show that the addition of shrimp skin and head flour to wet noodles gives a significant difference

(P <0.05) in the elasticity of wet noodles. Significant differences are found in treatments F1 and F3, F1 and F4, F2 and F4, and F3 and F4, while insignificant differences are found in treatments F1 and F2 and F2 and F3. The highest average value is found in treatment F1 (0%) which is 33.54 mm, then continued with F2 (5%) which is 31.25 mm, F3 (8%) which is 27.38 mm, and the lowest average is found in treatment F4 (10%), which is 13.21 mm. Based on the analysis results, it is evident that the higher the composition of shrimp skin and head flour, the lower the elasticity level of wet noodles, and vice versa. The decrease in elasticity in wet noodles can be explained by the reduction in the proportion of wheat flour, which is the main source of gluten that forms the elastic structure in noodle dough. When wheat flour is partially replaced by shrimp skin and head flour, the amount of gluten in the dough decreases so that the noodles become more brittle and less flexible.



After Cooking

Figure 2. Wet noodles F1 (0%), Wet noodles F2 (5%), Wet noodles F3 (8%), and Wet noodles F4 (10%)

This finding is consistent with the results of Pratiwi (2021), which states that noodle elasticity is highly dependent on the gluten content in the flour. The higher the gluten content in the dough, the better the tensile strength of the resulting noodle product. Conversely, additional ingredients that do not contain gluten, such as shrimp skin and head flour, are added; the proportion of gluten decreases, so that the ability of the tissue to withstand tensile forces and return to its original shape also decreases. This is also supported by research by Amalia et al., (2024), which states that the gluten content influences noodle elasticity in the ingredients. The main source of gluten in wet noodles in this study was wheat flour, so the lower the Concentration of wheat flour, the elasticity of the wet noodles will also decrease. This decrease in elasticity is also related to the increase in cooking loss values. In this study, although statistically not significantly different (P>0.05), when compared numerically, there was an increase in cooking loss in each treatment with the highest formulation, namely F4 (10%) of 6.97%, compared to F1 (0%) of 5.66%. In the research of Amalia et al., (2024), it is also explained that the decreasing amount of gluten makes the dough formed unstable, resulting in many particles of ingredients being released when cooked. When the elasticity and strength of the noodle structure decrease due to the reduction of gluten, the noodles tend to be more easily damaged or broken during the cooking process, which causes more nutrients to dissolve into the boiling water.

Acceptance Analysis of Wet Noodles (Organoleptic Test)

The acceptability analysis of wet noodles was conducted based on several parameters, including color, aroma, taste, and texture. The results of the analysis are presented in Table 2. Based on Table 2, there was a significant difference in the level of panelist preference for the color parameter (P<0,05). The level of preference that is significantly different among the panelists is in the treatments F1 and F2, F1 and F3, and F1 and F4. At the same time, the level of preference of the panelists that is not significantly different is in the treatments F2 and F3, F3 and F4, and F4 and F2. The results of the assessment of the color aspect by the researchers showed that the highest average level of preference of the panelists was in the F1 treatment (0%) which was 4.07, followed by the F2 treatment (5%) of 3.27, in the F3 treatment (8%) of 3.27, and the lowest average was in the F4 treatment (10%) which was 2.75. The higher percentage of shrimp skin and head flour added resulted in a more concentrated brownish color in the wet noodles, which is thought to reduce their appeal according to the panelists' preferences.

Table 2. Analysis of the Acceptability of Wet Noodles with the Addition of Shrimp Skin and Head Flour

Parameters	Treatment				P-*Value*
	F1	F2	F3	F4	
Color	$4{,}07 \pm 1{,}02^{b}$	$3{,}27 \pm 0{,}91^{a}$	$3{,}27 \pm 0{,}95^{a}$	$2{,}75 \pm 1{,}18^{a}$	0,00
Aroma	$4{,}18 \pm 0{,}93^{b}$	$3{,}70 \pm 0{,}92^{a}$	$3{,}57 \pm 0{,}89^{a}$	$3{,}20 \pm 1{,}24^{a}$	
Taste	$4{,}03 \pm 0{,}84^{b}$	$3{,}30 \pm 0{,}88^{a}$	$3{,}18 \pm 0{,}94^{a}$	$2{,}83 \pm 0{,}99^{a}$	
Texture	$4{,}14 \pm 0{,}77^{b}$	$3{,}57 \pm 0{,}72^{a}$	$3{,}43 \pm 0{,}85^{a}$	$3{,}05 \pm 1{,}18^{a}$	

* The data presented consists of Mean ± Std. Deviation. Different notations in the same row and column indicate significant differences (P<0.05)

The color change in wet noodles is due to shrimp skin and head flour having an antixanthin color pigment (Halimah & Maghfiroh, 2022). In addition, according to Ramadhani et al., (2022), the brownish color in products that are given additional shrimp flour is also caused by the Maillard reaction that occurs during the heating process. The Maillard reaction is the relationship between reducing sugars and free amine groups of amino acids or proteins during heating. Reducing sugars will react with primary or secondary amine groups, forming dark-colored melanoidin compounds that cause color changes in food ingredients (Ishak et al., 2024). This difference in visual expectations has a direct effect on sensory acceptance by panelists, which confirms that increasing nutritional content must be balanced with an assessment of visual aspects and consumer preferences. Thus, it can be concluded that the use of shrimp skin and head flour at high levels is less preferred in terms of color, so that in the development of wet noodle formulations, it is necessary to pay attention to the optimal limit to maintain a balance between nutritional benefits and the visual appeal of the product.

Furthermore, the aroma parameter results presented in Table 2 also show a significant difference in panelists' level of preference (P <0.05). The significant differences were found in treatments F1 and F2, F1 and F3, and F1 and F4. At the same time, the level of panelist preference that did not differ significantly was in treatments F2 and F3, F3 and F4, and F4 and F2. The results of the aroma aspect assessment by the panelists showed that the highest level of aroma preference was in treatment F1 (0%) which was 4.18, followed by treatment F2 (5%) which was 3.70, in treatment F3 (8%) which was 3.57, and the lowest average was F4 (10%) which was 3.20. These results indicate that the higher the composition of shrimp skin and head, the lower the level of panelist preference. This is thought to be due to the increasing shrimp aroma in wet noodles, along with the increase in the addition of shrimp skin and head flour. This is reinforced by the statement of Halimah & Maghfirah (2022) that the higher the percentage of shrimp skin and head flour added to wet noodles, the stronger the shrimp aroma produced by the wet noodles.

This decrease in the level of preference is closely related to the increase in the intensity of the distinctive shrimp aroma, which is getting stronger as the Concentration of shrimp skin and head flour increases. According to Pratiwi (2021), the distinctive aroma of shrimp can appear due to enzymatic and microbiological activity in raw materials and during processing, which produces aldehyde, ketone, free amino acid, and volatile fatty acid compounds. The higher the Concentration of shrimp skin and head flour, the higher the content of these compounds, so that the aroma becomes more pungent or unusual for consumers who are not used to it. Although the aroma of shrimp at a certain concentration (such as 5%) is still acceptable, at higher concentrations the aroma becomes more dominant. It has the potential to reduce consumer preference, especially for those who prefer a neutral or typical noodle aroma. Thus, although the addition of shrimp skin and head flour provides added nutritional value, changes in aroma need to be a major concern in the formulation.

Then, the taste parameter results presented in Table 2 also show significant differences in the panelists' level of preference (P <0.05). The significant differences were in treatments F1 and F2, F1 and F3, and F1 and F4. At the same time, the level of panelist preference that did not differ significantly was in treatments F2 and F3, F3 and F4, and F4 and F2. The results of the assessment of the taste parameters showed that the highest average level of panelist preference was in treatment F1 (0%) which was 4.03, followed by treatment F2 (5%) which was 3.30, in treatment F3 (8%) which was 3.18, and the lowest average was F4 (10%) which was 2.83. These results indicate that the higher the composition of shrimp skin and head flour used, the lower the level of panelist preference for the taste of wet noodles. The decrease in the level of preference for the taste of wet noodles with the addition of shrimp skin and head flour can be associated with the chemical composition of shrimp skin and head flour, especially the content of flavor compounds, such as free amino acids. According to

Halimah & Maghfirah (2022), the dominant amino acid in shrimp skin and head is glutamic acid, which is the main component of umami taste. According to the United States Department of Agriculture (USDA), shrimp skin and head contain amino acids such as methionine (sulfuric and meaty taste), cysteine (sulfuric), and tryptophan (which gives a bitter and slightly sweet taste). The combination of these compounds can cause a distinctive taste that is different from ordinary noodles. At low concentrations (eg, 5%), the distinctive taste of shrimp may still be acceptable and even provide added value as a savory or seafood taste. However, at higher concentrations (8–10%), the intensity of the taste may be too strong, deviating from consumer expectations of the taste of noodles in general, and ultimately reducing the level of preference. Overall, the results of the study showed that the Concentration of shrimp skin and head flour greatly influences the taste of wet noodles. Therefore, to produce wet noodle products with a formulation that has high nutritional value while still being preferred, it is necessary to determine the optimal formulation level, where the nutritional value increases without sacrificing the taste characteristics expected by consumers.

Lastly, the wet noodle texture parameters shown in Table 2 also indicate significant differences in panelists' preferences across the different treatments ($P < 0.05$). The significant differences were in treatments F1 and F2, F1 and F3, and F1 and F4. Meanwhile, the panelist preference levels that did not differ significantly were in treatments F2 and F3, F3 and F4, and F4 and F2. The results of the assessment of the texture parameters showed that the highest average level of panelist preference was in treatment F1 (0%) which was 4.14, followed by treatment F2 (5%) which was 3.57, in treatment F3 (8%) which was 3.43, and the lowest average was F4 (10%) which was 3.05. These results indicate that the higher the composition of shrimp skin and head flour used, the lower the level of panelist preference for the texture of wet noodles. This is because if the amount of wheat flour in the dough decreases, the wet noodles will experience a decrease in elasticity. After all, the gluten content that makes the noodle texture more chewy also decreases (Halimah & Maghfiroh, 2022).

The decrease in the panelists' preference for this texture is closely related to the results of the physical test of noodle elasticity. In treatment F1 (0%), the highest elasticity (33.54 mm) provides a good chewy sensation, so that panelists prefer it. Conversely, in treatment F4 (10%), which has the lowest elasticity (15.05 mm), the noodles tend to break and are not elastic when bitten, so the texture feels less pleasant. Thus, the addition of excessive shrimp skin and head flour has the potential to reduce the preference for the texture of wet noodles, so it is important to determine a balanced formulation between increasing nutritional value and consumer sensory preferences.

Analysis of Protein and Calcium Content

Analysis of Protein and Calcium Content was conducted on selected wet noodle formulations, namely F1 and F2, where F1 is a control formulation with 0% shrimp skin and head flour content and F2 is a formulation with 5% shrimp skin and head flour content. The results of the Protein and Calcium content test on wet noodles in the selected formulation can be seen in the following graph:

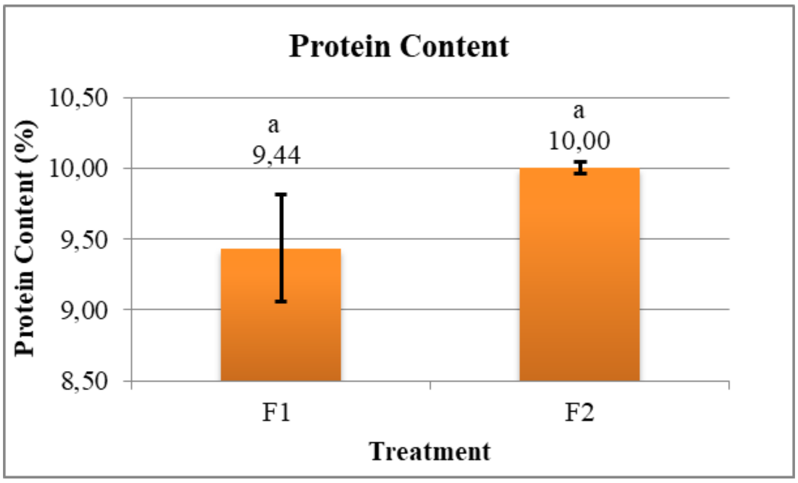


Figure 3. Average comparison graph of wet noodle protein content in selected formulations

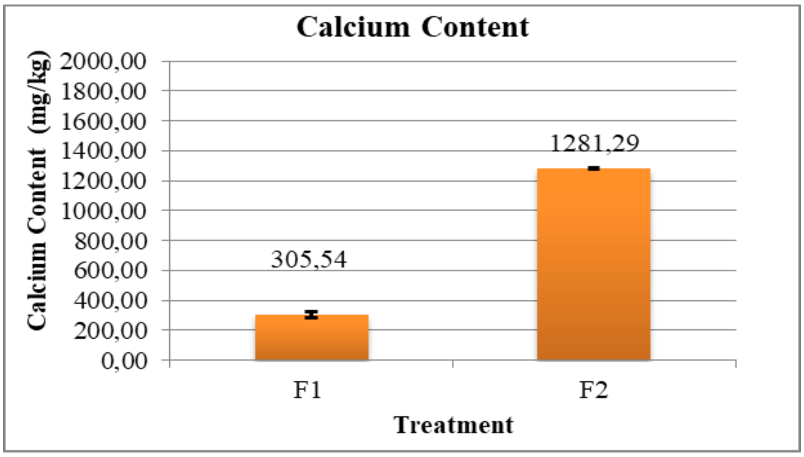


Figure 4. Average comparison graph of calcium content of wet noodles in selected formulations

The results of the protein content analysis in Figure 3 showed that there was no significant difference between treatments (P>0.05), so it can be concluded that Ha was rejected on protein content because the addition of shrimp skin and head flour did not significantly affect the protein content in wet noodles. The results of the calculation of protein content in treatment F1 were 9.44% while in treatment F2, it was 10%. However, the results of the statistical test showed no significant difference; in this case, there was an increase in protein content in wet noodles with the addition of shrimp skin and head flour by 0.56%. The results of this study are reinforced by the research of Halimah & Maghfirah (2022), which states that the higher the percentage of shell flour addition, the higher the protein content contained in wet noodles. This is because the protein content in shrimp skin and head flour is higher than that of wheat flour. In addition, the results of the protein content test on wet noodles have met the requirements for wet noodle protein content according to Badan Standarisasi Nasional (2015), which is a minimum of 9%.

The results of the calcium content test in Figure 4 showed that the calcium content in the F1 (0%) treatment was 305.54 mg/kg, while in the F2 (5%) treatment it was 1281.29 mg/kg. These results indicate a very high increase in calcium levels in wet noodles with the addition of shrimp skin and head flour, with a difference of 975.75 mg/kg or an increase of 4 times higher. In this case, the higher the percentage of shrimp skin and head flour addition, the higher the calcium content of wet noodles. The results of this study are supported by the research of Sary (2024), which states that the addition of shrimp skin and head flour is in line with the increase in calcium levels in wet noodles, so that the higher the composition of shrimp skin and head flour in wet noodles, the higher the calcium content. According to Permenkes (2019) on Number 28, it is stated that the Adequate Nutritional Intake (AKG) for daily calcium requirements for men and women aged 10-18 years is 1200 mg/day and for those aged 19-49 years 1000 mg/day, meaning that the addition of shrimp skin and head flour to wet noodles is sufficient to meet daily calcium nutrition.

CONCLUSION

Based on the results of the study, it can be concluded that the addition of shrimp skin and head flour to wet noodles affects the physical quality of the product. The higher the concentration added, the longer the cooking time, and the elasticity of the noodles decreased, although the cooking loss value did not change significantly. From the organoleptic side, increasing the concentration resulted in a darker brownish noodle color, a stronger shrimp aroma and taste, and a texture that tended to be less chewy. Based on the overall results, the best formulations were F2 (5%). The 5% formulation (F2) was optimal, as it enhanced protein and calcium contents while maintaining consumer acceptance. Specifically, F2 increased protein content from 9.44% to 10% and calcium from 305.54 mg/kg to 1281.29 mg/kg, demonstrating that greater addition of shrimp shell and head flour leads to higher protein and calcium levels in wet noodles. This study provides a low-cost functional food fortification strategy using shrimp by-products, with potential applications in school feeding programs and SME noodle industries, while also supporting waste reduction.

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How To Cite This Article, with *APA style* :

Nurfita., Safrida., Iskandar, W., & Febriansyah, M. I. (2025). Shrimp Shell and Head Flour Formulation in Wet Noodle Products as Source of Protein and Calcium. *Jurnal Pembelajaran dan Biologi Nukleus*, *11*(3), 1015-1032. https://doi.org/10.36987/jpbn.v11i3.7764

Conflict of interest : The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author contributions : All authors contributed to the study's conception and design. Material preparation, data collection and analysis were performed by all authors. The first draft of the manuscript was submited by [**Safrida Safrida**]. All authors contributed on previous version and revisions process of the manuscript. All authors read and approved the final manuscript.