

PHYSICOCHEMICAL AND SENSORY PROPERTIES OF COOKIES FORTIFIED WITH ENCAPSULATED SNAKEHEAD FISH (*Channa sp.*) PROTEIN HYDROLYSATE AND FISH OIL

Aisya Dwi Nur Cahyani¹, Jeny Ernawati Tambunan^{1*}, Eddy Suprayitno¹,
Arif Rahman Hakim², Diah Ikasari²

¹Fishery Product Technology, Faculty of Fisheries and Marine Sciences, Brawijaya University
Veteran st., Ketawanggede, Malang, East Java Indonesia 65145

²Research Center for Food Technology and Processing,
National Research and Innovation Agency of Republic Indonesia
Raya Jakarta - Bogor KM 46, Cibinong, West Java Indonesia 16911

Submitted: 26 October 2025/Accepted: 19 February 2026

*Correspondence: jenyetambunan@ub.ac.id

How to cite (APA Style 7th): Cahyani, A. D. N., Tambunan, J. E., Suprayitno, E., Hakim, A. R., & Ikasari, D. (2026). Physicochemical and sensory properties of cookies fortified with encapsulated snakehead fish (*Channa sp.*) protein hydrolysate and fish oil. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 29(3), 257-269. <http://dx.doi.org/10.17844/qne51w12>

Abstract

Snakehead fish (*Channa sp.*) are freshwater fish with high protein and albumin content, making them potential functional foods. Cookies are a popular food product; however, they generally have low protein and fatty acid content, requiring fortification to increase their nutritional value. This study aimed to determine the effect of varying amounts of encapsulated protein hydrolysate and snakehead fish oil on the characteristics of cookies. The study used a completely randomized design (CRD) with four treatments (0%, 3%, 6%, and 9% encapsulation addition) and five replicates each. The analysis included physical tests (colorimetry, texture analysis, and scanning electron microscopy), proximate analysis, and hedonic analysis. The data were statistically analyzed, and the best treatment was determined using the De Garmo method. The results showed that the addition of encapsulated powder significantly affected the physical, chemical, and hedonic properties of the cookies. Encapsulation addition increased the protein, fat, and ash content but decreased the carbohydrate and moisture content. Higher encapsulation resulted in a harder cookie texture and reduced expansion. The best treatment was obtained in cookies with 6% encapsulation, with protein, fat, moisture, ash, and carbohydrate contents of 7.15%, 3.78%, 3.10%, 1.62%, and 84.35%, respectively. Based on the results, the sensory characteristics were acceptable to the panelists. In conclusion, the addition of 6% fish oil and protein hydrolysate encapsulation produced cookies with better nutritional value and acceptable sensory properties.

Keywords: albumin, encapsulation, fortification, FPH, physicochemical

Karakteristik Fisikokimia dan Sensori Kukis dengan Penambahan Enkapsulasi Hidrolisat Protein dan Minyak Ikan Gabus

Abstrak

Ikan gabus (*Channa sp.*) merupakan ikan air tawar dengan kandungan protein dan albumin yang tinggi sehingga berpotensi dikembangkan sebagai pangan fungsional. Kukis adalah salah satu produk pangan yang digemari masyarakat namun umumnya memiliki kandungan protein dan asam lemak yang rendah sehingga diperlukan upaya fortifikasi untuk meningkatkan nilai gizinya. Penelitian ini bertujuan untuk menentukan pengaruh variasi penambahan enkapsulasi hidrolisat protein dan minyak ikan gabus terhadap karakteristik kukis. Penelitian menggunakan rancangan acak lengkap (RAL) dengan empat perlakuan (penambahan enkapsulasi 0%, 3%, 6%, dan 9%) serta lima kali ulangan. Analisis meliputi uji



fisik (colorimetri, texture analyzer, scanning electron microscopy), proksimat, dan hedonik. Data dianalisis secara statistik dan ditentukan perlakuan terbaik menggunakan metode De Garmo. Hasil menunjukkan bahwa penambahan enkapsulasi berpengaruh nyata terhadap sifat fisik, kimia, dan hedonik dari kukis. Penambahan enkapsulasi meningkatkan kadar protein, lemak, dan abu, namun menurunkan kadar karbohidrat serta kadar air kukis. Peningkatan penambahan enkapsulasi menyebabkan tekstur cookies lebih keras dan daya kembang menurun. Perlakuan terbaik diperoleh pada kue kering dengan enkapsulasi 6%, dengan kandungan protein, lemak, air, abu, dan karbohidrat masing-masing sebesar 7,15%, 3,78%, 3,10%, 1,62%, dan 84,35%. Berdasarkan hasil tersebut, karakteristik sensorik dapat diterima oleh panelis. Kesimpulannya, penambahan 6% minyak ikan dan enkapsulasi protein hidrolisat menghasilkan cookies dengan nilai gizi yang lebih baik dan sifat sensorik yang dapat diterima.

Kata kunci: albumin, enkapsulasi, fisikokimia, fortifikasi, HPI

INTRODUCTION

Snakehead fish (*Channa* sp.) is widely used because of its nutritional content. The species contains relatively high levels of fatty and amino acids, which contribute to its pharmacological properties. These include glycine, lysine, arginine, arachidonic acid, palmitic acid, and docosahexaenoic acid. Snakehead fish can produce polyunsaturated fatty acids that regulate prostaglandin synthesis, thereby reducing the healing process (Rahman *et al.*, 2018). Several other advantages are beneficial for wound healing and various diseases caused by a lack of protein in the blood, including thick white flesh and good albumin content (Silaban & Marsaulina, 2024).

The protein content in fish is relatively high, ranging from 15-25% (Suprayitno, 2020), with amino acids including arginine, alanine, histidine, tyrosine, methionine, valine, phenylalanine, isoleucine, leucine, and lysine (Nadimin, 2015). The high protein and amino acid content of snakehead fish can be used to produce fish protein hydrolysate products. Fish protein hydrolysate is used as a flavor enhancer and source of protein and amino acids in food (Susanty, 2021). Snakehead fish also have a high fatty acid content, specifically omega-3 fatty acids, which play an important role in health and brain development (Patted *et al.*, 2024). Omega-3 is an essential unsaturated fatty acid. Fatty acids can be used to produce fish oil products that are beneficial to health. Fish oil contains saturated and unsaturated fatty acids in proportions of 25% and 75%, respectively. According to a previous study, the main fatty acid found in snakehead fish oil is palmitic acid (Hadi *et al.*, 2024). Some of the benefits of fatty acids include preventing

and treating cardiovascular diseases, brain development in infants, and lowering blood triglyceride levels (Pandiangan, 2022).

One food product that can be used as a fortification medium is cookies, because they have a taste that is popular with the public, an easy manufacturing process, and a long shelf life. However, baking at high temperatures can cause protein denaturation and fat degradation (Amrah *et al.*, 2020; Pulungan *et al.*, 2020). To overcome this, encapsulation technology can be applied to protect active compounds from thermal damage and oxidation. Encapsulation is a technique for coating active ingredients with materials such as maltodextrin or gum arabic to maintain the stability of nutrients and sensory characteristics of the product (Hasibuan *et al.*, 2017). Previous research has shown that fortifying biscuits with 6% shrimp oil encapsulation can increase their nutritional value without affecting sensory quality (Takeungwongtrakul & Benjakul, 2017).

Recent advances in encapsulation research have demonstrated the effectiveness of various wall materials in protecting bioactive compounds. Maltodextrin is widely used because of its high solubility, low viscosity, and ability to provide a physical barrier that reduces the oxidation of core materials, such as oils and peptides. Gum arabic offers excellent emulsifying and film-forming properties that enhance encapsulation stability, while sodium caseinate exhibits strong surface activity that improves emulsification and encapsulation efficiency, especially for lipid-rich cores such as fish. Blending different wall materials has been shown to optimize encapsulation outcomes. For example, proteins combined with maltodextrin provide improved oxidative

stability compared to singular matrices (Damerau *et al.*, 2022), and polysaccharide blends can enhance the structural integrity of microcapsules. Therefore, this study aimed to determine the effects of varying amounts of encapsulated protein hydrolysate and snakehead fish oil on cookie characteristics.

MATERIALS AND METHODS

Encapsulation Procedure Using the Spray Drying Method

The encapsulation process was modified according to Unnikrishnan *et al.* (2019). The ratio of fish oil, FPH, and coating material is (0.5: 0.5: 5). The core material consisted of fish oil and FPH. The coating material consists of maltodextrin, gum arabic, and sodium caseinate (2:2:1). The emulsion was prepared by dissolving sodium caseinate in distilled water at 40 °C using a magnetic stirrer for 30 min. After the solution cooled, gum Arabic was added while stirring continuously. Once mixed evenly, maltodextrin was added, and the mixture was stirred with a magnetic stirrer until evenly mixed and a homogeneous solution was obtained. After the coating material was dissolved, fish oil and FPH were gradually added while stirring. The mixture was homogenized using a high-speed homogenizer at 21,000 rpm for 5 min. The emulsion was allowed to stand overnight at 4°C to eliminate air bubbles that had formed. Next, the mixture was dried using a spray dryer with an inlet temperature of 160°C, outlet temperature of 80°C, and nozzle diameter of 0.7 mm for 1 h.

Cookies Production

Cookie production with fortification of protein hydrolysate and snakehead fish oil encapsulation was based on the research of Maulani *et al.* (2024), and the addition of encapsulation was based on Takeungwongtrakul & Benjakul (2017), which was modified. The cookie samples consisted of four formulations with different levels of encapsulation powder (0%, 3%, 6%, and 9% w/w). The cookie production process began with the first mixing stage, in which all the ingredients (wheat flour, margarine, caster sugar, eggs, milk powder, baking powder, and vanilla) were combined. Next, the encapsulation powder was added at different concentrations (0%, 3%, 6%, and 9%). All the ingredients were mixed for 10 min. The cookies were weighed at 5 g and manually shaped into balls. The cookies were baked for 15 min at 175°C in an electric oven. The formulation for making the cookies is presented in Table 1.

Texture Profile

The texture analyzer test consisted of hardness and fracturability tests. Hardness is the force required to break a cake, whereas fracturability is an indicator of texture brittleness and its tendency to crumble (Nićetin *et al.*, 2024). Hardness and fracturability were measured using a TA.XT Plus texture analyzer (Stable Micro Systems, Great Britain) with a 3-point bend probe, a test speed of 3.00 mm/s, and a target force of 50 g (Kristanti *et al.*, 2020).

Table 1 Cookies formulation with variation of encapsulated fortification protein hydrolysate

Ingredients (g)	Formulation			
	A0	A3	A6	A9
Wheat flour	38.0	38.0	38.0	38.0
Margarine	30.5	30.5	30.5	30.5
Refined sugar	18.0	18.0	18.0	18.0
Eggs	8.5	8.5	8.5	8.5
Milk powder	4.0	4.0	4.0	4.0
Baking powder	0.6	0.6	0.6	0.6
Vanilla	0.4	0.4	0.4	0.4
Concentration of encapsulation powder (w/w)	0.0	3.0	6.0	9.0

Modified from Maulani *et al.* (2024)



Spread Ratio

The spread ratio test was conducted using the AACC (2000) method, as described by Baraiya *et al.* (2024). The thickness and diameter of the baked cookies were measured in mm using a caliper. The spread ratio was calculated using the following formula:

$$\text{Spread ratio} = \frac{\text{Cookie diameter (mm)}}{\text{Cookie thickness (mm)}}$$

Colorimetri

Color analysis using a colorimeter involves the use of the notations L^* , a^* , and b^* . The L^* notation indicates the lightness parameter (lightness) between 0 and 100, representing black and white. The notation a^* (positive) indicates the chromatic color mixture between red and green with a value of 0 to +100 for red and a^* (negative) with a value of 0 to -80 for green. The b^* notation (positive) indicates the chromatic color mixture between blue and yellow, with values ranging from 0 to +70 for yellow and b^* (negative) with values ranging from 0 to -70 for blue (Trisyani & Syahlan, 2022).

Proximate Analysis

Proximate analysis was performed to determine the effect of adding varying concentrations of encapsulated powder on the nutritional content of cookies. Proximate analysis included protein (AOAC, 2006), fat (AOAC, 2005), moisture (AOAC, 2005), ash (AOAC, 2005), and carbohydrates by difference (AOAC, 2005).

Hedonic Test

Organoleptic analysis using the hedonic method SNI 01-2346 2015 (BSN, 2015). The hedonic test was used to assess the panelists' level of liking for a product using a 9-point hedonic scale with parameters of appearance, aroma, taste, and texture. Scale 1=dislike extremely, scale 2=dislike very much, scale 3=dislike moderately, scale 4=dislike slightly, scale 5=neither like nor dislike, scale 6=like slightly, scale 7=like moderately, scale 8=like very much, and scale 9= like extremely. Thirty untrained panelists were used.

Scanning Electron Microscopy (SEM)

Scanning electron microscopy (SEM) was used to study the surface morphology of the cookie samples (Gagnetan *et al.*, 2023). The cookie samples were placed on an aluminum support and inserted into the device. SEM analysis was performed using a Hitachi TM3000 Tabletop Microscope at magnifications of 25x, 50x, 100x, and 500x.

Data Analysis

This was an experimental study using a simple completely randomized design (CRD). The treatments were the addition of microencapsulation at 0%, 3%, 6%, and 9%, with five replicates. Data analysis in this study used a non-factored completely randomized design. Data analysis was performed using SPSS 27 software with various statistical methods as required for testing. Normality tests were used to determine the data distribution, while homogeneity tests were used to ensure variance similarity between groups. If the data were normally distributed and homogeneous, a one-way ANOVA test was performed to determine the differences between treatments, followed by a Tukey test if there were significant differences. If the normality assumption was not met, a non-parametric Kruskal-Wallis test was used, and if the results were significant, a Dunn test was performed to determine the pairs of treatments that were significantly different. In addition, the DeGarmo method was applied to determine the best treatment. The main step in the De Garmo test is to determine the weight of the panelists (Rifkowitz & Fitriarni, 2020). Once the weight was determined, the weighted value (WV) was calculated by multiplying the score and weight of each parameter. Next, the effectiveness value (EV) was calculated for each parameter in each treatment by summing all the WV. The effectiveness values of the various parameters were summed to produce the productivity value (PV), which is the final score that reflects the overall quality of a treatment. The highest productivity value (PV) was considered the best treatment for the plants.

RESULTS AND DISCUSSION

Physical Characteristics of Cookies

Physical tests were conducted to evaluate the quality of the cookies. The parameters analyzed included hardness, fracturability, spread ratio, and colorimetry, which are important indicators of the physical properties and overall acceptability of the products. The results of these physical analyses are listed in Table 2.

Table 2 presents the data on the physical characteristics of cookies with varying levels of encapsulation. The data were analyzed statistically using one-way analysis of variance (ANOVA), followed by Tukey's post hoc test to determine significant differences between treatments. The results showed that an increase in the encapsulation concentration significantly affected all physical parameters, except for color.

Hardness

Texture analysis revealed that increasing the concentrations of encapsulated snakehead fish protein hydrolysate and fish oil significantly affected cookie hardness ($p < 0.05$). Cookies without encapsulation (A0) had the lowest hardness value of 10.22 ± 0.09 N, whereas cookies with 9% encapsulation (A9) had the highest value of 40.98 ± 0.98 N. This increase in hardness was due to the formation of a denser dough structure as a result of the interaction between the encapsulation components and the protein-starch matrix, which required greater force

to break the cookies (Nićetin *et al.*, 2024). Factors influencing the texture of biscuit products include gluten-forming proteins, fat content, and starch granules (Arsil & Asih, 2023). These results are consistent with those of Hashem *et al.* (2023), who reported that the addition of hydrolyzed protein increased cookie hardness by forming a more compact and stronger dough matrix.

Fracturability

In addition to the hardness parameter, the fracturability value also showed a significant effect ($p < 0.05$) on the addition of encapsulation. The highest fracturability value was obtained in treatment A9 at 0.77 ± 0.14 mm, while the lowest value was obtained in A6 at 0.53 ± 0.06 mm. Increased encapsulation concentration strengthened the matrix structure, making the cookie texture more resistant to breakage. According to Gani *et al.* (2015), an increase in the protein content of the dough can reduce hydration owing to the binding of water with the hydrophilic groups of proteins, resulting in a harder and more brittle texture. The decrease in A6 was attributed to uneven encapsulation distribution and the formation of large pores that made the structure brittle. The SEM micrograph of treatment A6 reveals an uneven distribution of encapsulated materials, characterized by dense matrix regions adjacent to porous areas and the formation of relatively large and non-homogeneous pores. These large pores act as structural weak points (stress concentration points), facilitating crack initiation and

Table 2 Physical characteristics of cookies with added encapsulation protein hydrolysate and snakehead fish oil

Parameter	Addition of encapsulation protein hydrolysate (%)			
	No addition (A0)	3 (A3)	6 (A6)	9 (A9)
Hardness (N)	10.22 ± 0.09^a	29.15 ± 0.63^b	33.76 ± 1.54^c	40.98 ± 0.98^d
Fracturability (mm)	0.62 ± 0.02^{ab}	0.69 ± 0.07^{ab}	0.53 ± 0.06^a	0.77 ± 0.14^b
Spread ratio (mm)	3.46 ± 0.09^a	3.36 ± 0.06^a	3.35 ± 0.16^a	3.00 ± 0.08^b
L*	62.84 ± 0.50^a	62.30 ± 0.97^a	62.26 ± 0.94^a	62.15 ± 0.75^a
a*	3.71 ± 0.44^a	4.12 ± 0.51^a	4.39 ± 0.34^a	4.23 ± 0.43^a
b*	27.42 ± 0.62^{ab}	27.00 ± 0.33^a	28.21 ± 0.35^b	26.96 ± 0.54^a

Different letters in the same row indicate significant differences



propagation when a mechanical force is applied. Previous studies have reported that phase distribution inconsistency and the formation of large pores within encapsulated food matrices are associated with a reduction in textural parameters, such as hardness and fracturability, owing to the presence of preferential crack propagation pathways (Nath *et al.*, 2023).

Spread Ratio

The spread ratio test results showed that the addition of the encapsulation concentration had a significant effect ($p < 0.05$) on the spread ratio of the cookies. The control treatment (A0) had the highest spread ratio value (3.46 ± 0.09), whereas A9 had the lowest value (3.00 ± 0.08). The decrease in the spread ratio at high concentrations was due to the ability of fish protein hydrolysate to absorb water, thereby reducing the availability of water in the dough. Consequently, the dough became denser and less spreadable during baking (Baraiya *et al.*, 2024). This high water absorption results in reduced water availability in the dough, thereby making the resulting cookie structure denser. Gluten dilution and lack of water available for rehydration can decrease the spread ratio after adding fish protein hydrolysate (Hashem *et al.*, 2023). This finding is supported by Tang & Liu (2017), who reported that an increase in whey protein concentration, can reduce the spread ratio of cookies.

Color

Color testing using a colorimeter showed that the addition of encapsulation did not cause a significant difference ($p > 0.05$) in the L^* , a^* , and b^* parameters. The highest L^* value was found in A0 (62.84 ± 0.50), while the lowest value was in A9 (62.15 ± 0.75), although the difference was not significant. This indicates that the addition of encapsulation only slightly affected the brightness of the product. The a^* value, which represents the green–red spectrum, ranged from 3.71 ± 0.44 to 4.39 ± 0.34 and did not differ significantly between the treatments ($p > 0.05$). Conversely, the b^* value, which describes the blue–yellow spectrum, showed a significant difference ($p < 0.05$),

with the highest value at A6 (28.21 ± 0.35) and the lowest at A9 (26.96 ± 0.54). The color of cookies is greatly influenced by sugar content, especially by caramelization due to the low heat stability of sugar in the Maillard reaction, which is non-enzymatic browning caused by reducing sugars. This reaction requires high temperatures and involves significant color changes on the cookie surface during baking. Baking strongly influences the brightness level (Park *et al.*, 2021). Factors that influence the dark color on the surface of bread include the moisture content, pH, reducing sugar, and amino acid content of the raw dough, as well as processing conditions, including temperature, time, air velocity, and relative humidity (Sivaraman *et al.*, 2023).

Proximate Analysis of Cookies

The chemical characteristics of the cookies were evaluated through proximate analysis to determine their nutritional compositions. The analyzed parameters included protein, fat, moisture, ash, and carbohydrate contents. The results of the proximate analysis are shown in Table 3.

Based on Table 3, a one-way ANOVA was performed to determine the effect of variations in the concentration of protein hydrolysate encapsulation and snakehead fish oil on the chemical composition of the cookies. The proximate parameters analyzed included the protein, fat, moisture, ash, and carbohydrate content.

The results of the analysis showed that the protein content of cookies increased significantly ($p < 0.05$) with increasing encapsulation concentration, with the highest value in treatment A9 at $7.39 \pm 0.02\%$ and the lowest in treatment A0 at $6.96 \pm 0.04\%$. This increase in protein content was influenced by the contribution of the snakehead fish protein hydrolysate, which was an additional protein source in the cookie formulation. This finding is consistent with that of Baraiya *et al.* (2024), who reported that the addition of fish protein isolate significantly increased the protein content of cookies. In addition, the use of sodium caseinate as a coating material in the encapsulation process also contributed to the total protein content of the microcapsules

Table 3 Proximate analysis of cookies with added encapsulation protein hydrolysate and snakehead fish oil

Parameter (%)	Addition of encapsulation protein hydrolysate (%)			
	No addition (A0)	3 (A3)	6 (A6)	9 (A9)
Protein	6.96±0.04 ^a	7.08±0.02 ^b	7.15±0.03 ^c	7.39±0.02 ^d
Fat	3.28±0.03 ^a	3.57±0.04 ^b	3.78±0.05 ^c	4.01±0.05 ^d
Moisture	3.41±0.03 ^a	3.31±0.04 ^b	3.10±0.03 ^c	3.07±0.02 ^c
Ash	1.49±0.03 ^a	1.55±0.03 ^b	1.62±0.04 ^c	1.67±0.02 ^c
Carbohydrate	84.86±0.03 ^a	84.49±0.04 ^b	84.35±0.12 ^c	83.86±0.06 ^d

Different letters in the same row indicate significant differences ($p < 0.05$)

(Yerramilli & Ghosh, 2017). Based on the SNI 2973:2022 standard, the minimum protein content in biscuits is 4.5% (BSN, 2022); therefore, the protein content of the cookies in this study, both in the control and fortified treatments, met the quality criteria.

The fat content of cookies also increased significantly with the increase in encapsulation concentration, from 3.28±0.03% (A0) to 4.01±0.05% (A9). This was due to the presence of snakehead fish oil in the encapsulation, which increased the total fat content of the final product. Encapsulation plays an important role not only as a protector of fish oil but also in maintaining lipid stability against heat during the baking process (Jeyakumari *et al.*, 2016). In addition, gum arabic as a coating agent helps maintain oil stability through the formation of a protective film and protein-polysaccharide interactions that reduce damage during drying (Putri *et al.*, 2021). Thus, the use of encapsulation in cookie fortification not only increases the nutritional value but also maintains the physical quality of the product. The fat content in cookies is also due to the use of butter (Syuliana *et al.* 2024).

The ash content of the cookies increased significantly with the addition of encapsulated ginger ($p < 0.05$), from 1.49±0.03% (A0) to 1.67±0.02% (A9), indicating an increase in the mineral content, such as calcium, phosphorus, magnesium, and zinc in the product (Syukri *et al.*, 2022). These results are consistent with those of Sharma *et al.* (2025), who reported an increase in the ash content of cookies with the addition of fish protein hydrolysate. Conversely, the moisture

and carbohydrate contents decreased from 3.41±0.03% to 3.07±0.02% and from 84.86% to 83.86%, respectively. The decrease in moisture content was due to the hygroscopic properties of maltodextrin and gum arabic, which formed a solid matrix and reduced water retention (Fishi *et al.*, 2023). A high protein content in a product has the potential to reduce the amount of carbohydrates. The carbohydrate content of biscuits is lower when the protein concentration of biscuits fortified with fish protein increases (Patimah *et al.*, 2019). Rejeki *et al.* (2019) reported that the carbohydrate content calculated by difference was influenced by other components, such as protein, fat, moisture, and ash. Therefore, an increase in other nutrients corresponded to a decrease in carbohydrate content, whereas lower levels of these nutrients corresponded to higher carbohydrate content.

Hedonic Characteristics of Cookies

Hedonic tests were conducted on 30 panelists to assess the appearance, aroma, taste, and texture. The samples presented to the panelists during the hedonic test are shown in Figure 1. The data were statistically analyzed using the Kruskal–Wallis test, followed by Dunn's post hoc test. The results of the hedonic test for the cookies are presented in Table 4.

The hedonic test results for the appearance parameter showed that the addition of encapsulation had a significant effect ($p < 0.05$) on the panelists' acceptance level. The appearance parameter in treatment A3 (3%) obtained the highest liking score of

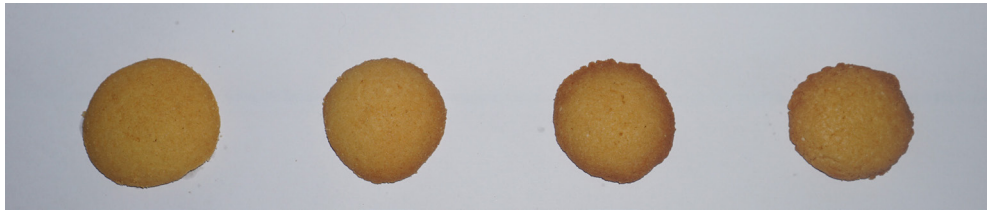


Figure 1 Appearance of cookies with added encapsulation protein hydrolysate and snakehead fish oil

Table 4 Hedonic test of cookies with added encapsulation protein hydrolysate and snakehead fish oil

Parameter (%)	Addition of encapsulation protein hydrolysate (%)			
	No addition (A0)	3 (A3)	6 (A6)	9 (A9)
Protein	7.00±0.63 ^a	7.17±0.46 ^a	7.1±0.43 ^a	6.49±0.49 ^b
Fat	5.60±0.46 ^a	6.60±0.34 ^a	6.60±0.38 ^a	4.00±0.40 ^b
Ash	7.25±0.35 ^a	7.30±0.30 ^a	7.35±0.30 ^a	7.24±0.30 ^a
Carbohydrate	6.55±0.35 ^a	6.65±0.45 ^a	6.63±0.53 ^a	6.53±0.43 ^a

Different letters in the same row indicate significant differences ($p < 0.05$)

7.17±0.46, while treatment A9 (9%) obtained the lowest score of 6.49±0.49. This difference indicates that the higher the encapsulation concentration, the darker the appearance of the cookies, owing to the Maillard reaction between protein and reducing sugars, which causes the formation of brown pigments (Honrado *et al.*, 2024). The darker color at high concentrations was considered less attractive by the panelists, even though the nutritional quality of the product improved. In addition, coating ingredients such as maltodextrin contribute to the browning reaction because they contain reducing sugars (Putri *et al.*, 2021).

For the texture parameter, statistical test results showed a significant difference between treatments ($p < 0.05$). The highest preference scores were observed for cookies with the addition of A3 (3%) and A6 (6%) encapsulation (6.60±0.34 and 6.60±0.38, respectively), while cookies with the addition of 9% (A9) received the lowest scores (4.00±0.40). High encapsulation concentrations resulted in harder textures. This increase in hardness is consistent with a previous study that reported that the addition of fish protein can increase protein-starch interactions and form a denser dough structure, thereby affecting the final

texture of the cookies (Hashem *et al.*, 2023). Another study showed that the addition of fish oil and garlic oil encapsulation significantly increased bread hardness (Sridhar *et al.*, 2021).

Hedonic testing of the aroma parameter showed no significant differences between the treatments ($p > 0.05$). All cookies, both control and with encapsulation additions, had a distinctive aroma without a fishy smell. This was due to the success of the encapsulation process in masking the unpleasant aroma of the protein hydrolysate and snakehead fish oil encapsulation. This study supports this finding, as microencapsulation can improve sensory acceptance by stabilizing volatile compounds that have the potential to produce unpleasant odors (Kumari *et al.*, 2023). Thus, the addition of encapsulation did not reduce the aroma quality of the cookies.

The hedonic test results for taste parameters also showed no significant differences between the treatments ($p > 0.05$). All treatments produced the characteristic sweet taste of cookies without the bitter taste that usually arises from protein hydrolysate. This is because encapsulation using maltodextrin can mask the bitter taste by reducing the exposure of hydrophobic amino acids (Sarabandi *et al.*, 2018). The bitter

taste produced in fish protein hydrolysate is related to the exposed hydrophobic amino acid groups; therefore, the application of encapsulation in hydrolysate can reduce the bitter taste in the final product (Breternitz *et al.*, 2017).

Scanning Electron Microscopy (SEM)

Morphological observations of the cookie surface using scanning electron microscopy (SEM) were conducted to evaluate changes in microstructure due to the addition of fish protein hydrolysate and snakehead fish oil encapsulation at concentrations of 0%, 3%, 6%, and 9%. The results of the SEM observations are shown in Figure 2.

The results showed that the addition of encapsulation material can affect the microscopic structure of cookies. In the control cookies (A0), the surface structure had fairly large voids between the particles, indicating that the cookie structure was still quite open. The A3 (3%) treatment cookies showed structural changes compared to the control cookies, namely small to medium-sized cavities, indicating that the encapsulated filling had filled the gaps between particles. The A6 (6%) cookies exhibited a denser and more cohesive structure. The surface structure

appeared smoother, with a decrease in the number and size of cavities. In cookies with treatment A9 (9%), encapsulation resulted in a denser and more homogeneous surface structure than that of other treatments. The cavities were smaller and limited in number. This indicates that the addition of encapsulation concentration can form a compact matrix that is strongly bound between particles, resulting in a dense microstructure with smaller cavities.

Cookies enriched with encapsulated protein hydrolysate and snakehead fish oil exhibited a significantly denser structure than the control samples. The control cookies exhibited a more porous matrix with larger cavities. This could be due to the release of CO₂ during the baking process, which caused the dough to expand and resulted in a porous cookie structure. Cookies with encapsulation fortification had fewer cavities because the encapsulation of protein hydrolysate and fish oil snakehead filled the gaps, creating a denser matrix. The structural changes in cookies were in line with a decrease in the spread ratio and an increase in thickness (Sharma *et al.*, 2025). The denser structure associated with encapsulation can be attributed to the high water absorption of the fish protein hydrolysate. This high water absorption

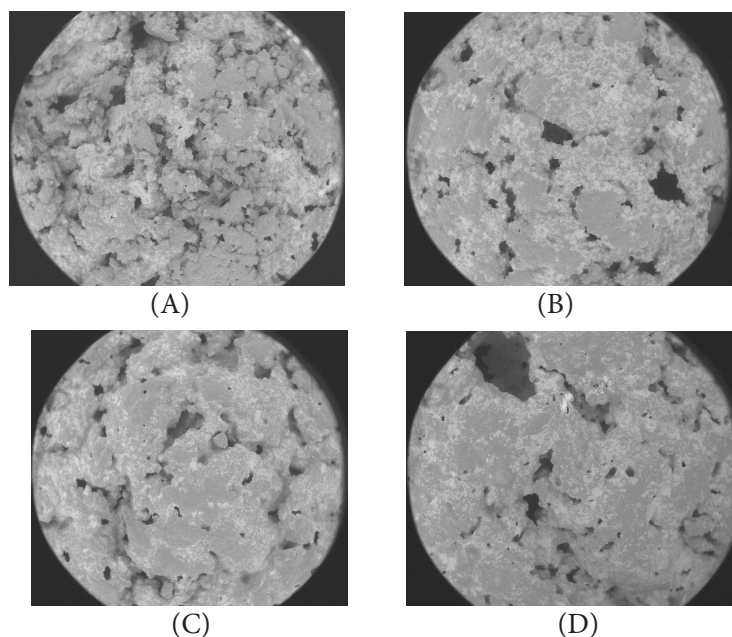


Figure 2 Morphological observations of the cookie with added encapsulation protein hydrolysate and snakehead fish using scanning electron microscopy (SEM)



reduces the water availability in the dough, resulting in a denser cookie structure. This also contributed to the harder cookie texture.

CONCLUSION

The addition of various microencapsulated protein hydrolysates and snakehead fish oil (*Channa sp.*) significantly affected the hardness, fracturability, spread ratio, proximate composition, appearance, and texture characteristics. However, it did not significantly affect the color, aroma, or taste of the cookies. The De Garmo method assessment indicated that the best treatment was cookies with 6% encapsulation (A6).

ACKNOWLEDGMENTS

The author would like to express their deepest gratitude to the UB STARS (Student Academic Research Scheme) Program at Brawijaya University with the contract number 00637/UN10.A0101/B/TU/2025, awarded to Aisya Dwi Nur Cahyani, for providing financial support that facilitated the successful completion of this study.

REFERENCES

- Amrah, W., Sirajuddin, S., Jafar, N., Syam, A., & Battung, S. (2020). Produksi & analisis zat gizi makro, mikro dan asam lemak omega 3 abon ikan layang sebagai pangan fungsional. *Jurnal Gizi Masyarakat Indonesia: The Journal of Indonesian Community Nutrition*, 9(1), 63–71. <https://doi.org/10.30597/jgmi.v9i1.10159>
- [AOAC] Association of Official Analytical Chemist. (2005). *Official Methods of Analysis*. Association of Official Analytical Chemist Inc. Mayland. USA
- Arsil, Y., & Asih, E. R. (2023). Sifat fungsional choux pastry kering dengan substitusi konsentrat protein ikan gabus. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 26(2), 260-270. <http://dx.doi.org/10.17844/jphpi.v26i2.430>
- Baraiya, K. G., Bojayanaik, M., Surasani, V. K. R., Chavan, S. D., Chavan, M. R., Lende, S. R., & Alandur, V. S. (2024). Utilization of fish protein isolates to supplement oat-based cookies and assessment of end product quality. *Environmental Science and Pollution Research*, 31(53), 62201–62212. <https://doi.org/10.1007/s11356-023-27804-6>
- Breternitz, N. R., Bolini, H. M. A., & Hubinger, M. D. (2017). Sensory acceptance evaluation of a new food flavoring produced by microencapsulation of a mussel (*Perna perna*) protein hydrolysate. *LWT-Food Science and Technology*, 83, 141-149. <https://doi.org/10.1016/j.lwt.2017.05.016>
- [BSN] Badan Standardisasi Nasional. (2015). SNI 2346:2015. Pedoman pengujian sensori pada produk perikanan. Jakarta: Badan Standardisasi Nasional.
- [BSN] Badan Standardisasi Nasional. (2022). SNI 2973:2020. Biskuit. Jakarta: Badan Standardisasi Nasional.
- Damerau, A., Mustonen, S. A., Ogrodowska, D., Varjotie, L., Brandt, W., Laaksonen, O., Tanska, M., & Linderborg, K. M. (2022). Food fortification using spray-dried emulsions of fish oil on sensory perception, volatiles and storage stability. *Molecules* 27(11), 1-21. <https://doi.org/10.3390/molecules27113553>
- Fishi, A. N. A., Nurhadi, B., Mahani, & Saputra, R. A. (2023). The effect of Arabic gum and maltodextrin on the physicochemical properties of vacuum-dried stevia (*Stevia rebaudiana bertonii*) extract powder. *Food Research*, 7(1), 244–255. [https://doi.org/10.26656/fr.2017.7\(1\).738](https://doi.org/10.26656/fr.2017.7(1).738)
- Gagneten, M., Pieniazek, F., Archaina, D., Messina, V., Salvatori, D., & Schebor, C. (2023). Texture study of gluten-free cookies added with fibre by instrumental, image and sensory analysis. *Journal of Food Measurement and Characterization*, 17(4), 4034–4044. <https://doi.org/10.1007/s11694-023-01943-3>
- Gani, A., Broadway, A. A., Ahmad, M., Ashwar, B. A., Wani, A. A., Wani, S. M., Masoodi, F. A., & Khatkar, B. S. (2015). Effect of whey and casein protein hydrolysates on rheological, textural and sensory properties of cookies. *Journal of Food Science and Technology*, 52(9),

- 5718–5726. <https://doi.org/10.1007/s13197-014-1649-3>
- Hadi, A. O., Ofsah, O. N., & Primaningsih, R. A. (2024). Efectivity of spink fish (*Channa striata*) oil on healing section caesarea wounds in rats wistar (*Rattus norvegicus*). *Journal of TSCNers*, 9(1), 2503–2453. <http://ejournal.annurpurwodadi.ac.id/index.php/TSCNers>
- Hashem, A. M. A., Sakhare, S. D., & Kudre, T. G. (2023). Effect of *Piaractus brachypomus* fish protein hydrolysate on physicochemical, sensory, and storage properties of cookies. *Biocatalysis and Agricultural Biotechnology*, 51(2), 102761. <https://doi.org/10.1016/j.bcab.2023.102761>
- Hasibuan, N. E., Muis, Y., Kimia, D., & Utara, U. S. (2017). Mikroenkapsulasi minyak ikan pora-pora (*Mystacoleucus padangensis*) menggunakan metode spray drying untuk aplikasi nutrisi makanan. *Jurnal Kimia Mulawarwan*, 14(2), 108–114.
- Honrado, A., Ardila, P., Leciñena, P., Beltrán, J. A., & Calanche, J. (2024). Nutritional enrichment of cereal foods: feasibility study and characterisation of biscuits fortified with seabass by-products. *International Journal of Food Science and Technology*, 59(8), 5376–5388. <https://doi.org/10.1111/ijfs.17230>
- Jeyakumari, A., Janarthanan, G., Chouksey, M. K., & Venkateshwarlu, G. (2016). Effect of fish oil encapsulates incorporation on the physico-chemical and sensory properties of cookies. *Journal of Food Science and Technology*, 53(1), 856–863. <https://doi.org/10.1007/s13197-015-1981-2>
- Kristanti, D., Setiaboma, W., & Herminiati, A. (2020). Karakteristik fisikokimia dan organoleptik cookies mocaf dengan penambahan tepung tempe. *Biopropal Industri*, 11(1), 1. <https://doi.org/10.36974/jbi.v11i1.5354>
- Kumari, A., Kaushik, N., Slizyte, R., & Khushboo. (2023). Production and microencapsulation of protein hydrolysate of pink perch (*Nemipterus japonicus*) by-products obtained from surimi industry for its sustainable utilization. *Waste and Biomass Valorization*, 14(1), 209–226. <https://doi.org/10.1007/s12649-022-01853-3>
- Maulani, A., Poernomo, A., Lisyana, H., & Sumandiarsa, I. K. (2024). Karakteristik gluten free cookies fortifikasi hidrolisat protein ikan lele. *Jurnal Pascapanen dan Bioteknologi Kelautan dan Perikanan*, 19(1), 73–82. <https://doi.org/10.15578/jpbkp.v19i1.991>
- Nadimin, R. S. L. (2015). Peningkatan nilai gizi mikro kudapan lokal melalui substitusi tepung ikan gabus untuk pencegahan stunting di Sulawesi Selatan. *Media Kesehatan Politeknik Kesehatan Makassar*, 14(2), 152–157. <https://doi.org/https://doi.org/10.32382/medkes.v14i2.1021152>
- Nath, P. C., Debnath, S., Sridhar, K., Inbaraj, B. S., Nayak, P. K., & Sharma, M. (2023). A comprehensive review of food hydrogels: principles, formation mechanisms, microstructure, and its applications. *Gels*, 9(1), 1–25. <https://doi.org/10.3390/gels9010001>
- Nićetin, M., Filipović, J., Djalović, I., Stanković, D., Trivan, G., Košutić, M., Živančev, D., & Filipović, V. (2024). Quality optimization and evaluation of new cookie product with celery root powder addition. *Foods*, 13(17), 1–24. <https://doi.org/10.3390/foods13172712>
- Pandiangan, M. (2022). Potensi minyak ikan gabus (*Clarias* sp.) sebagai sumber asam lemak omega 3 dan 6. *Jurnal Riset Teknologi Pangan Dan Hasil Pertanian (RETIPA)*, 33(1), 1–12. <https://doi.org/10.54367/retipa.v2i2.1895>
- Park, H. R., Kim, G. H., Na, Y., Oh, J. E., & Cho, M. S. (2021). Physicochemical and sensory properties of protein-fortified cookies according to the ratio of isolated soy protein to whey protein. *Food Science and Biotechnology*, 30(5), 653–661. <https://doi.org/10.1007/s10068-021-00909-9>
- Patimah, S., Arundhana, A. I., Mursaha, A., & Syam, A. (2019). Development of foxtail millet and flying fish flour-based cookies as functional food. *Current*



- Research in Nutrition and Food Science*, 7(2), 504–516. <https://doi.org/10.12944/CRNFSJ.7.2.20>
- Patted, P. G., Masareddy, R. S., Patil, A. S., Kanabargi, R. R., & Bhat, C. T. (2024). Omega - 3 fatty acids: a comprehensive scientific review of their sources, functions and health benefits. *Future Journal of Pharmaceutical Sciences*, 10(1), 1-11. <https://doi.org/10.1186/s43094-024-00667-5>
- Pulungan, M. H., Putri, S. R. G., & Perdani, C. G. (2020). Formulasi pembuatan cookies dengan metode linear programming. *Jurnal Pangan dan Agroindustri*, 8(4), 208–218. <https://doi.org/10.21776/ub.jpa.2020.008.04.4>
- Putri, D. N., Pakpahan, O. P., Damat, Ningrum, A. R. Y., & Santoso, D. E. N. (2021). The effect of maltodextrin concentration in high protein frozen dough on bread characteristics. *Jurnal Teknologi dan Industri Pangan*, 32(2), 126–135. <https://doi.org/10.6066/jtip.2021.32.2.126>
- Rahman, M., Molla, M., Sarker, M., Chowdhury, S., & Shaikh, M. (2018). Snakehead fish (*Channa striata*) and its biochemical properties for therapeutics and health benefits. *SF Journal of Biotechnology and Biomedical Engineering*, 1(1), 1-5.
- Rejeki, F. S., Rahayuningsih, T., Wedowati, E. R., Studi, P., Industri, T., Teknik, F., Wijaya, U., & Surabaya, K. (2019). Proporsi mocaf dan tepung larut dengan penambahan maltodekstrin pada pengolahan cookies. *Jurnal Agroteknologi*, 13(2), 137-147. <https://doi.org/10.19184/j-agt.v13i02.14105>.
- Rifkowitz, E. E., Fitriarni, D. (2020). Pengaruh konsentrasi sukrosa dan gliserin terhadap sabun transparan daun ketepeng (*Cassia alata*). *Jurnal PATANI: Pengembangan Teknologi Pertanian Dan Informatika*, 4(2), 26-33. <https://doi.org/10.47767/patani.v4i2.83>
- Sarabandi, K., Mahoonak, A. S., Hamishekar, H., Ghorbani, M., & Jafari, S. M. (2018). Microencapsulation of casein hydrolysates: physicochemical, antioxidant and microstructure properties. *Journal of Food Engineering*, 237(3), 86–95. <https://doi.org/10.1016/j.jfoodeng.2018.05.036>
- Sharma, K., Chanchi Prashanthkumar, M., Patil, U., Ma, L., & Benjakul, S. (2025). Characteristics and nutritional value of cookies fortified with debittered salmon (*Salmo salar*) frame protein hydrolysate. *Journal of Agriculture and Food Research*, 19(2), 101732. <https://doi.org/10.1016/j.jafr.2025.101732>
- Silaban, G., & Marsaulina, I. (2024). Peningkatan produksi ikan gabus (*Channa striata*) untuk bahan baku nutrisi kesehatan pada masyarakat di Desa Sei Dua Hulu Kecamatan Simpang Empat Kabupaten Asahan. *Talenta Conference Series: Agricultural and Natural Resources (ANR)*, 5(1), 156–162. <https://doi.org/10.32734/anr.v5i1.2156>
- Sivaraman, L., Deshmukhe, G., Xavier, K. A. M., Hirekudel, S. K., Desai, A. S., & Balange, A. K. (2023). Effect of incorporation of seaweed (*Portieria hornemanii*) and tilapia fish protein concentrate on the nutritional, physical and sensory attributes of cookies. *International Journal of Food Science and Technology*, 58(8), 4415–4424. <https://doi.org/10.1111/ijfs.16549>
- Sridhar, K., Sharma, M., Choudhary, A., Dikkala, P. K., & Narsaiah, K. (2021). Fish and garlic oils hybridized microcapsules: fortification in functional bread. *Journal of Food Processing and Preservation*, 45(4), 1–8. <https://doi.org/10.1111/jfpp.15346>
- Suprayitno, E. (2020). Kajian kesegaran ikan di pasar tradisional dan modern Kota Malang. *JFMR-Journal of Fisheries and Marine Research*, 4(2), 289–295. <https://doi.org/10.21776/ub.jfmr.2020.004.02.13>
- Susanty, A. (2021). Pengaruh waktu hidrolisis terhadap karakteristik hidrolisat protein ikan toman (*Channa micropeltes*) asal DAS Kalimantan Timur. *Jurnal Riset Teknologi Industri*, 15(2), 463-475. <https://doi.org/10.26578/jrti.v15i2.7462>
- Syukri, S., Hutomo, G. S., & Ndobe, S. (2022). Perlakuan jenis minyak berbeda sebagai bahan enkapsulasi hidrolisat ikan gabus

- (*Channa striata*). *Jurnal Pascapanen dan Bioteknologi Kelautan dan Perikanan*, 17(2), 145-156. <https://doi.org/10.15578/jpbkp.v17i2.845>
- Syuliana, S. R. B., Susanto, A., & Irianto, H. E. (2024). Pengembangan produk kukis ikan gabus (*Channa striata*) menggunakan mixture design. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 27(1), 37-48. <http://dx.doi.org/10.17844/jphpi.v27i1.45733>
- Takeungwongtrakul, S., & Benjakul, S. (2017). Biscuits fortified with micro-encapsulated shrimp oil: characteristics and storage stability. *Journal of Food Science and Technology*, 54(5), 1126–1136. <https://doi.org/10.1007/s13197-017-2545-4>
- Tang, X., & Liu, J. (2017). A comparative study of partial replacement of wheat flour with whey and soy protein on rheological properties of dough and cookie quality. *Journal of Food Quality*, 2017(1), 1-10. <https://doi.org/10.1155/2017/2618020>
- Trisyani, N., & Syahlan, Q. (2022). Karakteristik organoleptik, sifat kimia dan fisik cookies yang di substitusi dengan tepung daging kerang bambu (*Solen sp.*). *Jurnal Agribisnis Perikanan*, 15(1), 188–196. <https://doi.org/10.52046/agrikan>
- Unnikrishnan, P., Kizhakkethil, B. P., Annamalai, J., Ninan, G., Abubacker, Z. A., & Nagarajarao, R. C. (2019). Tuna red meat hydrolysate as core and wall polymer for fish oil encapsulation: a comparative analysis. *Journal of Food Science and Technology*, 56(4), 2134–2146. <https://doi.org/10.1007/s13197-019-03694-w>
- Yerramilli, M., & Ghosh, S. (2017). Long-term stability of sodium caseinate-stabilized nanoemulsions. *Journal of Food Science and Technology*, 54(1), 82–92. <https://doi.org/10.1007/s13197-016-2438-y>