Physical, chemical, and functional characteristics of small pelagic fish meat in Indonesia

Junianto, Iis Rostini

Department of Fisheries, Faculty of Fisheries and Marine Science, Universitas Padjadjaran, Sumedang 45363, Indonesia. Corresponding author: Junianto, junianto@unpad.ac.id

Abstract. The physical, chemical and functional properties of fish meat meal are greatly influenced by the type and habitat of the fish used. The aim of this research was to examine the physical, chemical and functional properties of some small pelagic fish meat meal. The types of pelagic fish used as ingredients for making fish meat meal were mackerel scad (*Decapterus* sp.), lemuru (*Sardinella lemuru*), mackerel (*Rastrelliger* sp.), anchovies (*Stolephorus commersonii*), and yellowstripe scad (*Selaroides leptolepis*). The research results showed that anchovy meal had better physical properties (yield, bulky density and color intensity) as indicated by higher values compared to other fish meal. Mackerel scad meat meal had better chemical properties than other fish meal as indicated by the lowest water content and the highest protein content. Fish meat meal had the highest glutamate amino acid content compared to other types of amino acids. Anchovy meal had the highest glutamate amino acid content compared to other fish meal. Mackerel scad meat meal had better functional properties (water absorption and solubility in water) than other fish meal as indicated by a higher value compared to other fish meal.
Key Words: bulk density, chemical, protein, water absorption.

Introduction. The Indonesian equatorial marine water is a convergence zone for hot and cold currents, fostering a rich diversity of marine biological resources (Wagey et al 2020). One of the marine biological resources that supplies prime-quality protein for human body is fish (Yadav & Yadav 2021). Subsequently, the protein content contained in various types of seawater fish ranges from 18.83 to 26.30% (Motondang 2022). Using fish as a sustainable food source is crucial for supporting human well-being (de Boer et al 2020).

Despite the nutritional benefits, global fish consumption, including in Indonesia, remains relatively low (Guillen et al 2019). Various countries including Indonesia, have established recommended fish consumption figures, with the target set at 56.48 kilograms per capita in 2022. However, the national average for fish consumption in Indonesia has not been achieved.

Increasing fish consumption among the Indonesian population is crucial due to its positive effects. According to Djunaidah (2017), this initiative not only increases intelligence and public health, but also contributes to job creation, higher incomes, and improved welfare for fish processors, farmers, and fishermen

To increase fish consumption, an approach that can be taken is diversification and fortification of fish processing for use as food (Hasselberg et al 2020). Fish processed in flour form is more effective as a supplementation ingredient in food products than fresh fish meat. The flour integrates more evenly with the main ingredients, improving its utility (Gómez & Martínez 2016). Additionally, the flour form is more durable, has wider applications, and is easier to package and store compared to the powdered form of fish meat (Jung et al 2018).

According to Aini et al (2016), the characteristics of flour determine its use in food products in relation to the quality of the product, and these include physical, chemical, and functional properties. The characteristics of fish meal are greatly influenced by the type of fish, habitat, and food source. Subsequently, small pelagic fish primarily inhabits the surface water above the continental shelf and around coastlines in a range of 1 to 5 miles (Doray et al 2018). The habitat preference of this fish is greatly influenced by oceanographic conditions or parameters of water such as sea surface temperature, salinity, chlorophyll-*a*, and current speed (Bonanno et al 2015).

Small pelagic fish has abundant availability with excess catches not only in Indonesia but also in several countries (Siaila & Rumerung 2022). The types in Indonesia are very diverse (Hidayat et al 2019) and the most commonly caught and commercial ones include mackerel scad (*Decapterus* sp.), lemuru (*Sardinella lemuru*), mackerel (*Rastrelliger* sp.), anchovies (*Stolephorus commersonii*), and yellowstripe scad (*Selaroides leptolepis*) (Andriyono 2018). Based on the research, the physical, chemical, and functional characteristics of fish meat meal have not been investigated. Therefore, this research aims to examine the physical, chemical, and functional characteristics of small pelagic fish meat meal.

Material and Method. The experiment was conducted from June to December 2023 at the fishery product processing technology laboratory of Fisheries and Marine Science Faculty, Padjadjaran University, Indonesia.

Materials. Five types of small pelagic fish, namely mackerel scad, lemuru, mackerel, anchovies, and yellowstripe scad were purchased from the Caringin market in Bandung City, the largest fresh fish market. These fish were used as raw materials for producing fish meat meal. The procedure for making fish meat meal was as follows (Domili et al 2020). Fish undergoes a series of steps: it was gutted (removing entrails and gills), washed with running water to eliminate blood and adhering dirt, steamed for 30 minutes, and then cooled. Subsequently, the flesh was extracted, squeezed using a cloth, and dried in a blower oven at 60°C for 5 hours. The dried fish meat was then ground with a grinder and filtered using a 80 mesh (0.177 mm). Fish meat meal was then packaged in plastic bags and stored at 4^{o}C before analysis.

Physical characteristics. The physical characteristics of fish meat meal observed were yield, bulk density, color intensity, and pH. The yield was calculated by comparing fish meal obtained with the fresh fish used as raw material multiplied by 100.

The bulk density was determined by weighing a 5 grams sample of fish meal and then placing it in a 20 mL measuring cylinder and determining the volume. The calculation of bulk density was as follows (Wani et al 2013):

$$\text{Bulk density} = \frac{\text{Sample weight (g)}}{\text{Volume (mL)}}$$

Color intensity analysis was carried out using a Hunterlab ColorFlex EZ spectrophotometer. The color test was carried out using the Hunter color system L* (white), a* (red), and b* (yellow). The L* value indicates a change in brightness with a value range of 0 (black) to 100 (white). Value of a* signifies the red-green mixed chromatic color with a positive a (a+) from a range of 0 to +100 for red, and a negative a value (a-) ranging from 0 to -80 for green. Meanwhile, the b* value represent the chromatic color of the blue-yellow mixture with a value of yellow. The chromameter was first calibrated with the standard white color found on the instrument.

The pH measurements were carried out using a pH meter and fish meat meal sample was prepared in suspension form at a concentration of 10%. Subsequently, the sample was left to settle at room temperature for 30 minutes, and the suspension was centrifuged at a speed of 3000 rpm for 10 minutes at a temperature of 27^{o}C. The supernatant obtained was separated and the pH value was measured (Junianto et al 2023).

Chemical characteristics. The chemical characteristics of fish meat meal observed were water content, ash content, protein content, lipid content, carbohydrate content, and amino acid profile. Subsequently, water, ash, protein, and fat contents were measured according to the procedures established by the AOAC (2012). Water content was analyzed using the thermogravimetric method by drying the sample in an oven at 105°C for 6 hours or until a constant sample weight was obtained. Ash content was determined by drying the sample in a furnace at a temperature of 600°C for 4 hours. Protein content was determined using the Kjeldahl method through the stages of digestion, distillation, and titration. The total conversion factor of nitrogen to protein was 6.25. Lipid content was determined by the Soxhlet method using hexane solvent. Carbohydrate content was determined using a different method, namely 100% minus the total percentage of water, ash, protein, and fat content. Amino acids were determined using the ultra-performance liquid chromatography (UPLC) method (Szkudzinska et al 2017).

Functional characteristics. Functional characteristics of fish meat meal observed were water absorption, oil absorption, and water solubility. Subsequently, water absorption test was carried out using the procedure by Gao et al (2019). A sample of fish meal was weighed at 1 gram, and placed in a centrifuge tube, then 10 mL of distilled water were added. The mixture was stirred (vortexed) for 2 minutes and then left for 60 minutes at room temperature. In the next stage, the mixture was centrifuged for 25 minutes at a rotation speed of 3000 rpm at room temperature. The volume of water phase obtained was quantified using a measuring cup to determine the amount of water that was not absorbed. The calculation of water absorption capacity was carried out as follows:

$$\text{Water absorption capacity (mL g}^{-1}\text{)} = \frac{\text{Initial water volume - Volume of water not absorbed}}{\text{Sample weight}}$$

The oil absorption test procedure was carried out as follows (Gao et al 2019): a sample of fish meal was weighed at 1 gram, and put into a centrifuge tube, and then 3 mL of corn oil was added. The mixture was stirred (vortexed) for 2 minutes and left for 60 minutes at room temperature. In the next stage, the mixture was centrifuged for 25 minutes with a rotation speed of 3000 rpm at room temperature. The volume of the oil phase obtained was measured with a measuring cup to determine the amount of the oil that was not absorbed. The calculation of the oil absorption capacity is carried out as follows:

$$\text{Oil absorption capacity (mL g}^{-1}\text{)} = \frac{\text{Initial oil volume - Volume of oil not absorbed}}{\text{Sample weight}}$$

The procedure for testing the level of solubility in water was carried out as follows (Rieuwpassa et al 2013): a sample of 5 grams of fish meal was weighed, and dissolved in 150 mL of water (neutral pH) in 250 mL Erlenmeyer tube. The solution was filtered with Whatman filter paper. The filter paper was previously dried in an oven at 100°C for 30 minutes and then weighed. The filter paper and remaining precipitate were dried in a 100°C oven for 3 hours, then cooled in a desiccator and weighed. The calculation formula of water solubility is as follows:

$$\text{Solubility (\%)} = \frac{M_3 - M_2}{M_1} \times 100$$

where: M_1 is the mass of the sample used for testing, M_3 is the total mass of supernatant and filter paper after drying, M_2 is the mass of filter paper.

Data analysis. The method used was experimental, using a completely randomized design for this research. The treatment was pelagic fish as raw material for fish meat meal. Treatment A was mackerel scad, treatment B was mackerel, treatment C was lemuru, treatment D was anchovies and treatment E was yellowstripe scad. The five treatments were repeated 4 times. All observational data obtained except the amino acid profiles were analyzed statistically using ANOVA test (variance) and followed by Duncan's multiple range test at a confidence level of 95%, respectively.

Results

Physical characteristics of small pelagic fish meat meal. Understanding the physical characteristics of fish meal for food is crucial as it significantly influences both the manufacturing process and the quality of the product when meal is formulated (Khalil et al 2020). The results of observations of the physical properties of small pelagic fish meat meal are shown in Table 1.

Table 1

Physical properties of small pelagic fish meat meal

Type of pelagic fish	*Yield (%)*	*Bulk density ($g\ mL^{-1}$)*	*Color intensity*	*pH*
Mackerel scad	8.20±0.27^a	0.65±0.02^a	L* = 67.69±0.50 a* = 2.01±0.03 b* = 15.45±0.14	5.6±0.1^a
Mackerel	8.96±0.17^b	0.52±0.02^b	L* = 69.70±0.27 a* = 3.05±0.09 b* = 21.56±0.19	5.9±0.1^b
Lemuru	8.29±0.13^c	0.79±0.06^c	L* = 68.36±0.29 a* = 1.92±0.06 b* = 15.94±0.06	5.7±0.1^a
Anchovies	13.13±0.26^a	0.96±0.05^d	L* = 72.87±0.20 a* = 0.40±0.05 b* = 3.70±0.32	6.1±0.1^c
Yellowstripe scad	11.01±0.49^d	0.69±0.02^a	L* = 71.62±0.09 a* = 0.64±0.03 b* = 13.37±0.21	5.9±0.1^b

Values are presented as mean±SD; values with different superscript within the same row are significantly different ($p < 0.05$) by Duncan test.

Chemical characteristics of pelagic fish meat meal. Chemical characteristics of fish meal can describe the nutritional value contained in meal (Ween et al 2017). The results of observations of chemical properties of small pelagic fish meat meal are shown in Table 2.

Table 2

Chemical characteristics of small pelagic fish meat meal

Type of pelagic fish	*Water content (%)*	*Protein content (%)*	*Lipid content (%)*	*Ash content (%)*	*Carbohydrate content (%)*
Mackerel scad	7.25±0.07^a	79.68±0.80^a	5.30±0.23^a	7.13±0.18^a	0.64±0.07^a
Mackerel	8.36±0.08^b	78.22±0.28^b	7.95±0.19^b	4.70±0.19^b	0.77±0.03^b
Lemuru	8.72±0.12^c	75.43±0.72^c	8.02±0.15^b	7.35±0.18^a	0.48±0.08^c
Anchovies	8.12±0.11^d	78.37±0.29^b	4.80±0.33^c	8.47±0.15^c	0.34±0.04^d
Yellowstripe scad	8.30±0.10^b	79.48±0.73^a	5.21±0.23^a	6.65±0.12^d	0.36±0.08^d

Values are presented as mean±SD; values with different superscript within the same row are significantly different ($p < 0.05$) by Duncan test.

Amino acid profile of small pelagic fish meat meal. The nutritional quality of a food ingredient can be evaluated through its amino acid profile (Machado et al 2020). The results of observing the acid profile of pelagic fish meal are shown in Table 3.

Table 3

Amino acid profile of small pelagic fish meat meal

Amino acid (g kg^{-1})	*Type of pelagic fish*				
	Mackerel scad	*Mackerel*	*Lemuru*	*Anchovies*	*Yellowstripe scad*
Alanine	41.61±0.01	41.35±0.16	39.22±0.06	38.39±0.01	40.43±0.04
Arginine	56.40±0.03	49.46±0.17	55.81±0.07	60.01±0.02	54.24±0.01
Aspartic acid	59.89±0.04	61.02±0.18	58.20±0.04	57.48±0.01	58.90±0.04
Glycine	38.05±0.00	35.44±0.10	37.80±0.03	36.31±0.05	37.78±0.02
Glutamic acid	93.20±0.01	97.83±0.35	91.81±0.05	99.02±0.08	93.01±0.05
Histidine	40.46±0.01	33.40±0.11	37.70±0.01	24.02±0.01	30.41±0.05
Isoleucine	39.87±0.05	38.22±0.16	35.72±0.04	35.77±0.01	38.32±0.00
Cysteine	49.05±0.04	37.28±0.01	36.61±0.02	44.33±0.01	31.29±0.01
Leucine	66.02±0.08	63.32±0.26	59.64±0.08	61.17±0.03	64.66±0.01
Lysine	55.88±0.03	61.81±0.21	50.29±0.04	49.50±0.01	55.6±0.06
Methionine	12.75±0.01	12.36±0.01	12.35±0.05	12.87±0.01	12.24±0.01
Tryptophan	8.82±0.01	7.60±0.01	7.24±0.01	7.70±0.01	7.90±0.01
Valine	44.16±0.01	41.27±0.13	40.29±0.01	39.30±0.02	42.60±0.02
Phenylalanine	46.75±0.02	38.30±0.09	50.79±0.00	51.73±0.04	43.83±0.04
Proline	26.74±0.01	26.50±0.10	25.29±0.01	26.87±0.05	26.36±0.01
Serine	36.39±0.01	33.13±0.11	34.54±0.03	34.97±0.04	35.62±0.04
Threonine	45.07±0.04	40.01±0.14	41.84±0.01	43.72±0.01	43.33±0.02
Tyrosine	36.12±0.01	29.18±0.06	37.90±0.02	41.99±0.04	33.67±0.04

Functional characteristics of small pelagic fish meat meal. The functional characteristics of flour consist of the physical and chemical attributes, which influence the outcome of food products created with the particular flour (Dereje et al 2020). The application of fish meat meal as a fortification and supplementation ingredient in a food product depends on the functional characteristics. The results of observations of the functional properties of small pelagic fish meat meal are shown in Table 4.

Table 4

Functional properties of pelagic fish meat meal

Type of pelagic fish	*Water absorbtion capacity (mL g^{-1})*	*Oil absorbtion capacity (mL g^{-1})*	*Water solubility (%)*
Mackerel scad	2.04±0.09^{a}	0.95±0.06^{a}	19.38±0.144^{a}
Mackerel	1.87±0.09^{b}	1.15±0.06^{b}	16.20±0.23^{b}
Lemuru	1.63±0.09^{c}	0.83±0.05^{c}	15.25±0.25^{c}
Anchovies	1.70±0.03^{c}	0.98±0.05^{a}	14.38±0.29^{d}
Yellowstripe scad	1.96±0.09^{b}	1.25±0.06^{d}	17.63±0.38^{e}

Values are presented as mean±SD; values with different superscript within the same row are significantly different ($p < 0.05$) by Duncan test.

Discussion. Knowing the yield value of the production process is essential for assessing efficiency and conducting economic analyses (van Dijk et al 2017). Based on Table 1, the highest yield value of fish meat meal was obtained from anchovies (13.13%), and the lowest yield value was obtained from lemuru (8.29%). The yield value of small pelagic fish meat meal was calculated based on the type of fish used, significantly influencing the overall yield. The high yield of anchovies meat meal is because no part of fish is discarded or removed during the flouring process. In other fish, the head, entrails, bones, and tail are removed in making fish meat meal.

The fiber density value of product plays a significant role in determining storage planning and packaging use for product (Stranzinger et al 2019). Based on Table 1, the highest bulk density value was obtained from anchovies meal (0.96 g mL^{-1}). The lowest bulk density value was obtained from mackerel meat meal (0.52 g mL^{-1}). According to the statistical analysis of the ANOVA test, the bulk density of pelagic fish meat meal is influenced by the type of fish. The bulk density value of flour products is influenced, among other factors, by the chemical composition (Kolanus 2020). The bulk density value of anchovies flour is greater than the density value of wheat flour (0.85 g mL^{-1}) (Hyacinthe et al 2021). Flour products with greater bulk density values require smaller packaging volumes (Sumanti et al 2022). Subsequently, at an equivalent weight, anchovies meal necessitates a smaller packaging volume compared to wheat flour.

Color serves as an important parameter for flour products, influencing consumers purchasing decisions (Luo et al 2019). Color functions to determine consumer perceptions regarding the taste, texture, and functional value of the product (Figueiredo Muniz et al 2023). According to Table 1, the highest color intensity value, namely brightness (L), of fish meal was obtained from anchovies meal. The L value shows the level of whiteness (Boral et al 2015). The higher the L value of a flour product, the closer the color of the flour to white. Based on the variance test, the L value of fish meat meal is influenced by the type of fish. Anchovies has a whiter color than mackerel scad, mackerel, lemuru, and Yyellowstripe scad.

The pH level of fish meat meal is crucial to assess as it is directly related to the quality. The pH plays a significant role in influencing the taste, aroma, and texture of the product (Dzandu et al 2023). Based on Table 1, the pH of pelagic fish meat meal ranges from 5.6 to 6.1. The observed pH range suggests that fish used as raw material for producing this flour falls in the fresh category. Initially, the pH of fish meat after catch or slaughter typically ranges from 6.6 to 7.0. However, this pH tends to decrease after one hour of storage at room temperature, reaching a range of 4 to 6 (Komolka et al 2020). Based on statistical analysis of the variance test (F test), the pH of fish meal is influenced by the type of fish. The lowest or most acidic pH of fish meal was mackerel scad meat meal.

Water content of flour, including fish meat meal, in the production process can affect dough cohesiveness, processing time, and product stability. The highest water content of pelagic fish meal was obtained from lemuru (8.72%) and the smallest was obtained from mackerel scad (7.25%). The amount of water in flour including flour made from fish meat affects the stability of the finished product, processing time, and dough cohesion during manufacturing. Lemuru had the highest water content (8.72%) of any pelagic fish flour, whereas mackerel scad had the lowest (7.25%). The quality standards for fish meal are then based on the water content, which is approximately 6-10%, as per the Indonesian National Standard (National Standardization Agency, SNI 2715:2013) quality standard A (Domili et al 2020).

The primary reason for selecting fish meal as a crucial source of animal protein was the high protein content (Luthada-Raswiswi et al 2021). In this research, protein content of small pelagic fish meat meal obtained ranged from 75.43 to 79.68%. The highest protein content was obtained from mackerel scad and the lowest was obtained from lemuru. Subsequently, the quality standard for fish meal according to the National Standardization Agency (SNI 2715:2013) quality standard A has a minimum protein content of 60% (Domili et al 2020).

Minimizing the lipid content in fish meal is preferred, as the high-fat content is not suitable for use in food formulations (Hilmarsdottir et al 2020). The lipid content of small pelagic fish meat meal obtained ranged from 4.80 to 8.02%. The highest lipid content was obtained from lemuru and the lowest was obtained from anchovies. According to the National Standardization Agency (SNI 2715:2013) quality standard A, the maximum fat content allowed for fish meal is 10%.

The ash content in fish meal serves as an indicator of minerals and other organic compounds (Janbakhsh et al 2018). The ash content of small pelagic fish meat meal obtained ranged from 4.70 to 8.47%. The highest ash content was obtained from anchovies and the lowest was obtained from mackerel. According to the National Standardization Agency (SNI 2715:2013) quality standard A, fish meal should not exceed a maximum ash content of 20%.

The carbohydrate content in fish meal is typically minimal and not considered a significant quality parameter (Rifath & Thariq 2023). The carbohydrate content of small pelagic fish meal obtained ranged from 0.34 to 0.77%. The highest carbohydrate content was obtained from mackerel and the smallest is obtained from anchovies. Subsequently, the size of fish body inversely correlates with the carbohydrate content, where smaller fish generally has lower carbohydrate content. Consequently, when smaller fish is processed into flour, the resulting flour tends to have a low carbohydrate content.

According to Table 3, the largest amino acid found in small pelagic fish meat meal is glutamic acid. Among small pelagic fish observed, anchovies had the highest amount of glutamic acid, and lemuru had the lowest. Subsequently, glutamic acid was an amino acid with neurotransmitter functions, playing a key role in providing a savory taste (Diepeveen et al 2022). The savory taste of a product tends to enhance general satisfaction and enjoyment of the product (Hartley et al 2019).

Water absorption capacity of a product denotes the capability to absorb water from the external environment and retain or store it (Schopf & Scherf 2021). The absorbed water, known as imbibition water, plays a crucial role in the application of a product, particularly in influencing the viscoelastic properties of dough during formation (Gasparre & Rosell 2023). Therefore, water absorption capacity is used as a determining factor in the quality of flour products.

According to Table 4, water absorption capacity of fish meat meal was influenced by the type of fish. Water absorption capacity of small pelagic fish meal ranges from 1.63 to 2.04 mL g^{-1}. Pelagic fish meat meal with the highest water absorption capacity was mackerel scad and the lowest was lemuru. Subsequently, fish meat meal with high-fat content typically has a lower water absorption capacity.

Another functional characteristic was oil absorption capacity (Kakar et al 2022). This capacity reflects the ability of the product to absorb oil from the external environment and at the same time retain it (Iwe et al 2016). The oil absorption capacity of small pelagic fish meal ranged between 0.83 and 1.25 mL g^{-1} (Table 4). This value was influenced by the type of fish, with yellowstripe scad showing the highest oil absorption capacity.

Water solubility level of small pelagic fish meal ranged from 14.38 to 19.38% (Table 4). The highest level of solubility in water is found in mackerel scad while the lowest was anchovies. This solubility level shows the part of the flour fraction that can dissolve in water (Nuryanto et al 2022). The solubility level of this small pelagic fish meat meal was smaller when compared to the solubility level of the pugnose ponyfish (*Deveximentum insidiator*) protein hydrolyzate meal (75.7%) (Dinakarkumar et al 2022).

Conclusions. Based on this research, it can be concluded that the physical, chemical, and functional characteristics of small pelagic fish meal were influenced by the type of fish. Anchovy meal has higher bulk density, color intensity, ash content and amino acid glutamate content compared to other types of fish meal. Lemuru fish meal has a higher fat and water content than other types of fish meal. Mackerel scad fish meal has a higher protein content, water absorption capacity and water solubility level than other types of fish meal. Yellowstripe scad fish meal has a higher fat absorption capacity than other types of fish meal.

Acknowledgements. We take this opportunity to thank the Directorate General of Higher Education, Research and Technology for funding this research. We would also like to express our thanks to Padjadjaran University for facilitating this research activity.

Conflict of interest. The authors declare that there is no conflict of interest.

References

Association of Official Analytical Chemists (AOAC), 2012 Official methods of analysis. 19th edition. Washington, DC (USA): Association of Official Analytical Chemists, 771 pp.

Andriyono S., 2018 Overview of Indonesia fisheries sector: Java and Bali island. International Journal of Life Sciences & Earth Sciences 1(1):39-48.

Aini N., Wijonarko G., Sustriawan B., 2016 [Physical, chemical and functional properties of corn flour processed by fermentation]. Agritech 36(2):160-169. [in Indonesian]
Bonanno A., Zgozi S., Basilone G., Hamza M., Barra M., Genovese S., Rumolo P., Nfate A., Elsger M., Goncharov S., Popov S., Mifsud R., Bahri T., Giacalone G., Fontana I., Buongiorno Nardelli B., Aronica S., Ceriola L., Patti B., Ferreri R., Colella S., Volpe G., Mazzola S., 2015 Acoustically detected pelagic fish community in relation to environmental conditions observed in the central Mediterranean sea: a comparison of Libyan and Sicilian-Maltese coastal areas. Hydrobiologia 755:209-224.
Boral D. J., Gupta A. K., Khan F. A., 2015 Comparing the performance of L*A*B* and HSV color spaces with respect to color image segmentation. International Journal of Emerging Technology and Advanced Engineering 5(2):192-203.
de Boer J., Schösler H., Aiking H., 2020 Fish as an alternative protein-a consumer-oriented perspective on its role in a transition towards more healthy and sustainable diets. Appetite 152:104721.
Dereje B., Girma A., Mamo D., Chalchisa T., 2020 Functional properties of sweet potato flour and its role in product development: a review. International Journal of Food Properties 23(1):1639-1662.
Diepeveen J., Moerdijk-Poortvliet T. C. W., van der Leij F. R., 2022 Molecular insights into human taste perception and umami tastants: a review. Journal of Food Science 87(4):1449-1465.
Dinakarkumar Y., Krishnamoorthya S., Margavelua G., Ramakrishnana G., Chandran M., 2022 Production and characterization of fish protein hydrolysate: effective utilization of trawl by-catch. Food Chemistry Advances 1:100138.
Djunaidah I. S., 2017 [Level of fish consumption in Indonesia: irony in the nautical country]. Jurnal Penyuluhan Perikanan dan Kelautan 11(1):12-24. [in Indonesian]
Domili I., Labatjo R., Ntau L. A., Anasiru M. A., Arbie F. Y., 2020 Quality test of long-jawed mackerel (*Rastrelliger* sp.) fish flour. Food Research 4(3):926-931.
Doray M., Hervy C., Huret M., Petitgas P., 2018 Spring habitats of small pelagic fish communities in the Bay of Biscay. Progress in Oceanography 166:88-108.
Dzandu B., Kumi S., Asirifi-Addo T., 2023 Quality assessment of gluten-free cookies from rice and bambara groundnut flour. CyTA - Journal of Food 21(1):258-268.
Figueiredo Muniz V. R. G., Ribeiro I. S., Beckmam K. R. L., Godoy R. C. B., 2023 The impact of color on food choice. Brazilian Journal of Food Technology 26:e2022088.
Gao C., Wang F., Yuan L., Liu J., Sun D., Li X., 2019 Physicochemical property, antioxidant activity, and cytoprotective effect of the germinated soybean proteins. Food Science and Nutrition 7(1):120-131.
Gasparre N., Rosell C. M., 2023 Wheat gluten: a functional protein still challenging to replace in gluten-free cereal-based foods. Cereal Chemistry 100(2):243-255.
Gómez M., Martínez M., 2016 Changing flour functionality through physical treatments for the production of gluten-free baking goods. Journal of Cereal Science 67(1):68-74.
Guillen J., Natale F., Carvalho N., Casey J., Hofherr J., Druon J. N., Fiore G., Gibin M., Zanzi A., Martinsohn J., 2019 Global seafood consumption footprint. Ambio 48(2): 111-122.
Hartley I. E., Liem D. G., Keast R., 2019 Umami as an 'alimentary' taste. A new perspective on taste classification. Nutrients 11(1):182.
Hasselberg A. E., Aakre I., Scholtens J., Overå R., Kolding J., Bank M. S., Atter A., Kjellevold M., 2020 Fish for food and nutrition security in Ghana: challenges and opportunities. Global Food Security 26:100380.
Hidayat D., Oclandhi B., Maulidinia N., Sa'adah N. N., Nurhayati A. P. D., 2019 Short communication: the species and body size composition of pelagic fishes that caught by troll line in the fish landing of Sendang Biru, East Java, Indonesia. Biodiversitas 20(6):1764-1769.
Hilmarsdottir G. S., Ogmundarson O., Arason S., Gudjónsdóttir M., 2020 The effects of varying heat treatments on lipid composition during pelagic fishmeal production. Processes 8(9):1142.

Hyacinthe A. A., Bedel F. J., Gisèle K. A., Atta A. H. F., Patrice K. L., 2021 Functional properties of composite flours produced with ivorian taro (*Colocasia esculenta* L. Cv Fouê) corms flour and wheat (*Triticum aestivum* L.) flour. GSC Biological and Pharmaceutical Sciences 15(3):164-176.

Iwe M. O., Onyeukwu U., Agiriga A. N., 2016 Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea seeds composite flour. Cogent Food and Agriculture 2(1):1142409.

Janbakhsh S., Shekarabi H., Mergan S., 2018 Nutritional value and heavy metal content of fishmeal from the southwest Caspian Sea. Caspian Journal of Environmental Sciences 16(4):307-317.

Jung H., Lee Y. J., Yoon W. B., 2018 Effect of moisture content on the grinding process and powder properties in food: a review. Processes 6(6):69.

Junianto, Kurniawan F. A., Muqoddimah B. D., Ardytiandi R., Hidayati S. I., Nurafni S., 2023 Physico-chemical and sensory characteristics of bream fish meat flour. Asian Journal of Food Research and Nutrition 2(3):188-198.

Kakar A., Miano T. F., Soomro A. H., Yar A., Memon S. A., Khan B., 2022 Oil and water absorption capacity of wheat, rice and gram flour powders. International Journal of Ecosystems and Ecology Science 12(2):585-594.

Khalil, Nur Y. S., Andri, 2020 Physical properties, crude nutrient content, and nutritive values of fish meals produced from overflowed fishes for laying quails. Advances in Animal and Veterinary Sciences 8(9):967-975.

Kolanus J. P. M., 2020 Functional properties and chemical composition of dried surimi mackerel (*Scomberomorus* sp.) with different cryoprotectants and drying methods. Journal of Physics: Conference Series 1463:012022.

Komolka K., Bochert R., Franz G. P., Kaya Y., Pfuhl R., Grunow B., 2020 Determination and comparison of physical meat quality parameters of Percidae and Salmonidae in aquaculture. Foods 9(4):388.

Luo D., Yu L., Westland S., Mahon N., 2019 The influence of colour and image on consumer purchase intentions of convenience food. Journal of the International Colour Association 24:11-23.

Luthada-Raswiswi R., Mukaratirwa S., O'Brien G., 2021 Animal protein sources as a substitute for fishmeal in aquaculture diets: a systematic review and meta-analysis. Applied Sciences 11:3854.

Machado M., Machado S., Pimentel F. B., Freitas V., Alves R. C., Oliveira M. B., 2020 Amino acid profile and protein quality assessment of macroalgae produced in an integrated multi-trophic aquaculture system. Foods 9(10):1382.

Motondang S. E., 2022 Comparison of protein levels in freshwater fish and saltwater fish. Lavosier: Chemistry Education Journal 1(1):1-10.

National Standardization Agency, 2013 SNI 2715:2013: Fish Flour - Feed Raw Materials. Indonesia: SNI.

Nuryanto, Chasanah E., Afifah D. N., Fawzya Y. N., Suryaningrum T. D., Martosuyono P., Putri Y. I., Rossalia A., Asmak N., Ihsani K., 2022 Characteristics of product complementary feeding with fortified fish protein hydrolysate. Food Research 6(1): 78-89.

Rieuwpassa F. J., Santoso J., Trilaksani W., 2013 [Characterization of functional properties fish protein concentrate of skipjack roe (*Katsuwonus pelamis*)]. Jurnal Ilmu dan Teknologi Kelautan Tropis 5(2):299-309. [in Indonesian]

Rifath M. R. A., Thariq M. G. M., 2023 Fish waste to fish meal: potential, sustainability and emerging issues related to microplastics and regulations. Journal of Fisheries and Environment 47(2):1-18.

Schopf M., Scherf K. A., 2021 Water absorption capacity determines the functionality of vital gluten related to specific bread volume. Foods 10(2):228.

Siaila S., Rumerung D., 2022 Analysis of the profitability of small pelagic capture fisheries in Ambon City, Indonesia. AACL Bioflux 15(2):608-620.

Stranzinger S., Faulhammer E., Li J., Dong R., Khinast J. G., Zeitler A., Markl D., 2019 Measuring bulk density variations in a moving powder bed via terahertz in-line sensing. Powder Technology 344:152-160.

Sumanti D. M., Hanidah I. I., Abdullatif M. A., 2022 Physical, chemical, and functional characteristics of composite flours from banana corm and tempeh. Jurnal Teknologi dan Manajemen Agroindustri 11(2):139-150.
Szkudzinska K., Smutniak I., Rubaj J., Korol W., Bielecka G., 2017 Method validation for determination of amino acids in feed by UPLC. Accred Qual Assur 22:247-252.
van Dijk M., Morley T., Jongeneel R., van Ittersum M., Reidsma P., Ruben R., 2017 Disentangling agronomic and economic yield gaps: an integrated framework and application. Agricultural Systems 154:90-99.
Wagey B. T., Boneka F. B., Mantiri R., 2020 Status of marine biodiversity and community perception on marine conservation in Mantehage Island, Bunaken National Park, North Sulawesi, Indonesia. AACL Bioflux 13(6):3830-3839.
Wani I. A., Sogi D. S., Gill B. S., 2013 Physicochemical and functional properties of flours from three black gram (*Phaseolus mungo* L.) cultivars. International Journal of Food Science and Technology 48(4):771-777.
Ween O., Stangeland J. K., Fylling T. S., Aas G. H., 2017 Nutritional and functional properties of fishmeal produced from fresh by-products of cod (*Gadus morhua* L.) and saithe (*Pollachius virens*). Heliyon 3(7):e00343.
Yadav R. C., Yadav J., 2021 Designer quality fish production technology. Journal of Aquaculture and Marine Biology 10(5):207-216.

Received: 06 March 2024. Accepted: 14 June 2024. Published online: 26 July 2024.
Authors:
Junianto, Department of Fisheries, Faculty of Fisheries and Marine Science, Padjadjaran University,
Ir. Soekarno Street, KM 21, Sumedang Regency-Indonesia, 45363, e-mail: junianto@unpad.ac.id
Iis Rostinini, Department of Fisheries, Faculty of Fisheries and Marine Science, Padjadjaran University,
Ir. Soekarno Street, KM 21, Sumedang Regency-Indonesia, 45363, e-mail: iis.rostini@unpad.ac.id

How to cite this article:
Junianto, Rostini I., 2024 Physical, chemical, and functional characteristics of small pelagic fish meat in Indonesia. AACL Bioflux 17(4):1424-1433.