

Comprehensive analysis of the chemical content of tuna fish skin, including fatty acids, heavy metals, proximate content, and amino acids from Kendari, Indonesia

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Abstract. The fishing and tuna processing industry in the waters of Kendari has been generating fish skin waste, which has been discarded so far. However, it has been found that tuna skin waste contains nutritional content similar to that of tuna meat. The research aimed to analyze the chemical content of tuna skin waste in Kendari, Indonesia, including fatty acids, heavy metals, proximate content and amino acids. The results revealed that *Thunnus obesus* (bigeye tuna) loin skin waste had the highest percentage of water content at 55.62%. The fish skin waste has a protein content of 26.175%, a fat content of 10.10%, and an ash content of 5.375%. Further analysis of the fatty acid profile of *T. obesus* loin skin waste revealed that it contains 6.32% unsaturated fat and 3.78% saturated fat. The dominant omega-9 fatty acid is oleic acid at 2.35%. Although it contains omega 6, arachidonic acid, linoleic acid, docosahexaenoic acid, linolenic acid, and eicosapentaenoic acid, each fatty acid does not exceed 1%. Additionally, the analysis showed that *T. obesus* loin skin waste has relatively low levels of heavy metals, with arsenic at 1.79%, lead at 0.36%, mercury at 0.6%, and cadmium at 0.03%. Nickel was not detected in this fish skin waste. Meanwhile, analysis of the protein content reveals that glycine has the highest level at 55,927.53 mg kg⁻¹, followed by L-arginine, L-proline, and L-glutamic acid. However, based on the phytochemical analysis results, flavonoid, phenolic, and saponin compounds were not detected in the skin waste. Thus, the skin waste of *T. obesus* loin in Kendari, Indonesia, has nutritional value and is relatively low in heavy metal content. Therefore, the skin of this fish can be further utilized as a nutritious food source, similar to tuna fish meat.

Key Words: tuna, fish skin, waste, fatty acid, amino acid.

Introduction. Bigeye tuna, *Thunnus obesus*, is a popular type of fish worldwide due to its high nutritional value and significance as a protein source. In Indonesia, various types of tuna are commonly found in Kendari waters (Oetama 2023). However, the fish processing industry typically only utilizes tuna meat, while the skin waste is often discarded as it is considered useless (Kantun 2015). Tuna is a type of saltwater fish that belongs to the Scombridae family. This fish is highly valued commercially due to its delicious meat and is believed to contain beneficial nutrients. Tuna meat is a good source of protein and omega-3 fatty acids, which are beneficial for health (Singer et al 2021). Tuna is known to live at great depths and often gathers in large groups. It has a wide distribution and can be found in various parts of the world, including the Atlantic, Pacific, and Indian Oceans. Kendari is located near the Pacific Ocean through the Banda Sea, which is the deepest sea in Indonesia. In that area, schools of tuna fish are commonly found, making the area potentially suitable for the tuna industry. The tuna industries found in that area only utilizes the meat products for marketing, while the skin is discarded as waste. The waste from processing tuna loin, specifically the fish skin, contains nutrients that are similar to those

found in tuna meat. Additionally, the fish skin waste from tuna loin processing is rich in amino acids, collagen (Tanaka et al 2018; Kolanus et al 2019; Nurjanah et al 2021), vitamins, minerals, and fish oil (Apituley et al 2020). During the processing of tuna loin, it is observed that the skin waste contains oil. Fish oil, a valuable component, can be extracted from the fish skin waste generated from tuna loin processing and utilized as a raw material in the production of various products like food, cosmetics, and industrial supplements. However, tuna skin may also contain heavy metals as a result of contamination from the environment. Heavy metals are a type of pollutant that can be harmful to human health if present in high concentrations. Therefore, it is important to determine the levels of heavy metals in tuna skin waste, which can then be treated in industries that specialize in removing heavy metals to prevent environmental pollution.

The chemical composition of tuna skin in Kendari waters is not well-known, therefore it is crucial to determine it in order to enhance the economic value of marine products. Additionally, this research can offer valuable insights into the nutritional benefits and health impacts of consuming tuna skin, benefiting the public. By effectively utilizing tuna skin waste, the fish processing industry can positively impact local communities. Therefore, a comprehensive analysis of the chemical content of tuna skin in Kendari waters can bring significant economic, health, and social advantages. It is anticipated that the findings of this research will serve as a foundation for developing a more sustainable fish processing industry and improving the well-being of communities in the Kendari waters area. This research aimed to determine the proximate, fatty acid, and amino acid content in fish skin waste from *T. obesus* loin processing, as well as to determine the heavy metal content in tuna skin waste.

Material and Method. The raw material used was fresh *T. obesus* skin obtained from the tuna loin processing industry in Kendari City. Other materials used include hexane, hydrochloric acid (HCl), 10% sodium chloride (NaCl), 5% iron (III) chloride (FeCl₃), sulfuric acid (H₂SO₄), and Dragendorf solution. The equipment used includes test tubes, desiccators, autoclaves, analytical scales, Kjeldahl apparatus, ultra-performance high chromatography (UPLC), and gas chromatography-mass spectrometry (GC-FID). Tuna shell waste was collected from *T. obesus* loin industry in the city of Kendari, Indonesia. Before collecting the skin waste, a sterile and safe storage facility was prepared for the waste collection. The waste was stored in containers made of stainless steel or industrial food-grade materials that could be tightly closed. The tuna skin was separated from the meat at the processing plant. Subsequently, the skin was removed from other parts like bones, remaining meat, and scales. After separation, the samples were washed with clean water to get rid of dirt, blood, and other residues. Then, the sample was placed in a container under cold conditions (below 4°C) to preserve its quality and was labelled with the date and time of collection, name of the processing industry, and storage conditions.

Research implementation. The samples used in this study were the skin of large-eye tuna processed into loin obtained from a tuna loin processing industry in Southeast Sulawesi. The tuna loin skin samples were transported in styrofoam boxes with ice to maintain the material in good condition. The obtained tuna skin samples were then analyzed in the laboratory including Proximate analysis, fatty acid profile, heavy metal content, amino acid and phytochemical analysis.

Proximate analysis. Determination of water content, ash content, fat content, protein, carbohydrates using the AOAC (2005) standard method.

Fatty acid profile. The fatty acid profile analysis was based on the AOAC (2000) standard method using Gas Chromatography Flame Ionization Detection (GC-FID) Shimadzu. The peaks of the chromatogram from the sample measurement results corresponded to the C4-C24 chain fatty acids which were determined by comparing the retention time of each fatty acid component from the sample with the retention time of each fatty acid component from the standard.

Heavy metal content. The analysis of heavy metals mercury (Hg), lead (Pb), cadmium (Cd) and Arsenic (As) was done based on the AOAC (2013) standard Method, using an Inductively Coupled Plasma-mass spectrometry (ICP-MS) 7900 single quadrupole Agilent device, while the analysis of nickel (Ni) was done based on the AOAC (2011) standard method using Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES) device Agilent 5800 VDV.

Amino acid. Amino acid testing uses the chromatography method (Waters Corporation 2012) using an Ultra Performance Liquid Chromatography (UPLC) device Nexera X2 LCMS-8045 Shimadzu with separation column (C18), mobile phase (AccQ-Tag Ultra Eluent B Reagent; Aqua Bidest distilled water; column temperature 49°C), gradient pump system, and PDA detector. The amino acid concentrations in samples used the chromatographic peak area ratios (analyte vs. internal standard) method.

Phytochemical analysis. The phytochemical screening method was carried out based on the colorimetric method Folin-Ciocalteu, using a color reagent (Hariyanto et al 2018). Screening phytochemical includes flavonoids, alkaloids, phenolic, tannin, saponin and steroid.

Statistical analysis. The chemical content was determined by descriptive analysis aimed to obtain objective exposure about tested parameters including fatty acids, heavy metals, proximate content, and amino acids.

Results and Discussion

Proximate analysis. The research results on the proximate analysis of obese tuna loin skin waste indicate that water content at 55.62%, protein content is 26.175%, the fat content is 10.10%, and the ash content is 5.375% as shown in Figure 1. A marine biota is a group of diverse organisms found in the sea, including fish, crustaceans, molluscs, algae, and others. Each type of marine organism has varying proximate contents based on the species. Generally, the proximate content of marine biota includes water, protein, fat, and ash. Fish is the most commonly consumed marine organism by humans, so this discussion will compare the proximate content of tuna skin with that of other marine fish. The research on fish skin from tuna loin processing found that the water content percentage was 55.62%. This is lower than the typical water content range of 60-85% in marine fish. This difference can be explained by the fact that tuna skin primarily comprises connective tissue and dry skin tissue. Additionally, the protein content in tuna skin is 26.175%. The content is quite high and indicates that tuna fish skin may be utilized as a good source of protein. The protein content of processed tuna loin is still higher compared to other types of tuna fish (Sasidharan et al 2023), such as *Thunnus albacares* which only reaches 23.5% (Peng et al 2013) and *Katsuwonus pelamis* from the waters of Sri Lanka which only reaches 24.13% (Mahaliyana et al 2015). Meanwhile, the fat content of the processed tuna loin skin is 10.10%. The fat content in the skin of processed tuna loin tends to be lower compared to tuna fish meat, which usually ranges from 15-30%. However, the fat content in other marine organisms can be lower than in tuna skin, such as the fat content in the sea urchin eggs of the species *Heterocentrotus trigonarius*, which is 0.29% (Pringgienies et al 2020). The research results revealed that the ash content in fish skin from tuna loin processing was 5.375%, which is relatively high compared to other marine organisms. Typically, the ash content in marine organisms is around 1-2%. Fish have a higher ash content compared to other marine organisms (Shabir et al 2018).

Furthermore, this research also presents the findings of proximate content analysis, which includes water, protein, fat, ash, carbohydrate, and fiber content in tuna skin. It is important to understand the nutritional value of fish skin obtained from processing tuna loin. This information can serve as a reference for processing food ingredients that utilize this component. Oktariani et al (2023) showed that tuna caught in clean waters, particularly in the Indian and Pacific Oceans, and processed according to quality processing standards (Rana et al 2023), contains heavy metals that are still within acceptable limits.

Devita et al (2021) found that tuna skin has a high protein content of 65.42%, and Nurilmala et al (2021) reported a content of 75.29%, making it a potential source of dietary protein. In addition, Nurilmala et al (2021) also found that the fat content in tuna skin is 15.06%, indicating its potential use as a source of polyunsaturated fatty acids in the form of fish oil that are beneficial for human health.

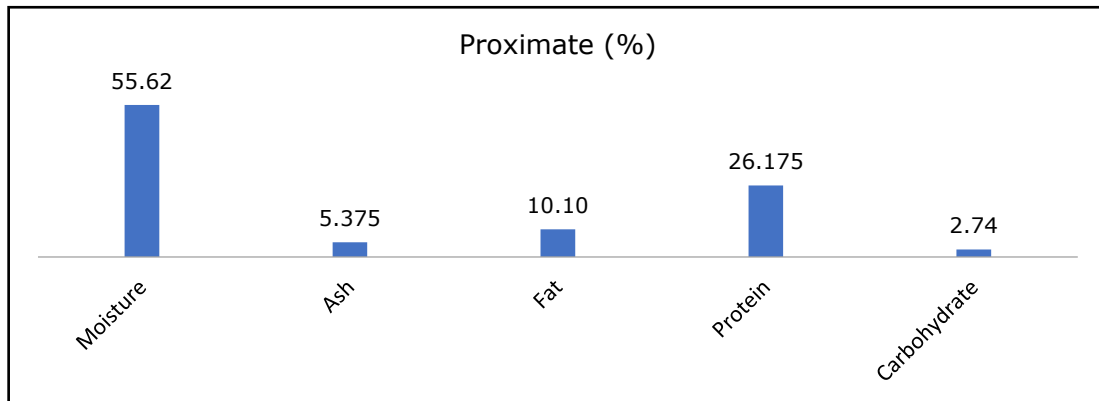
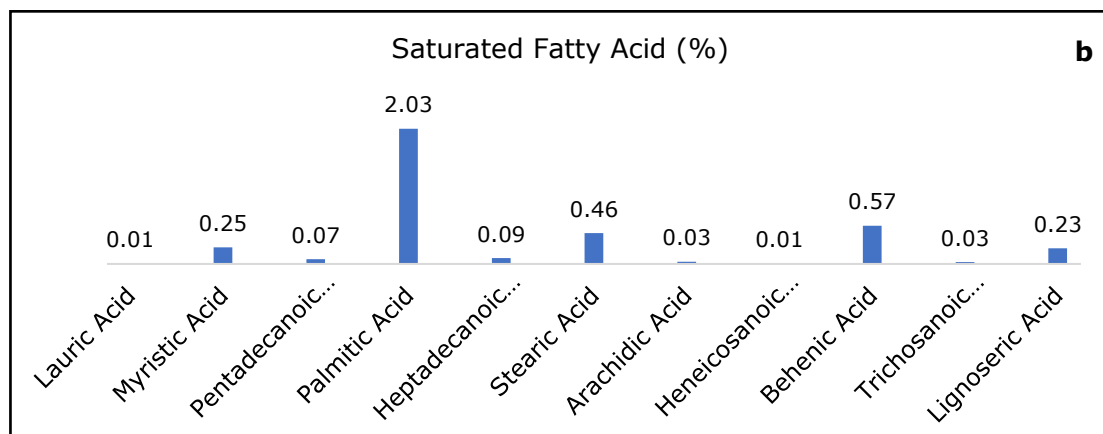
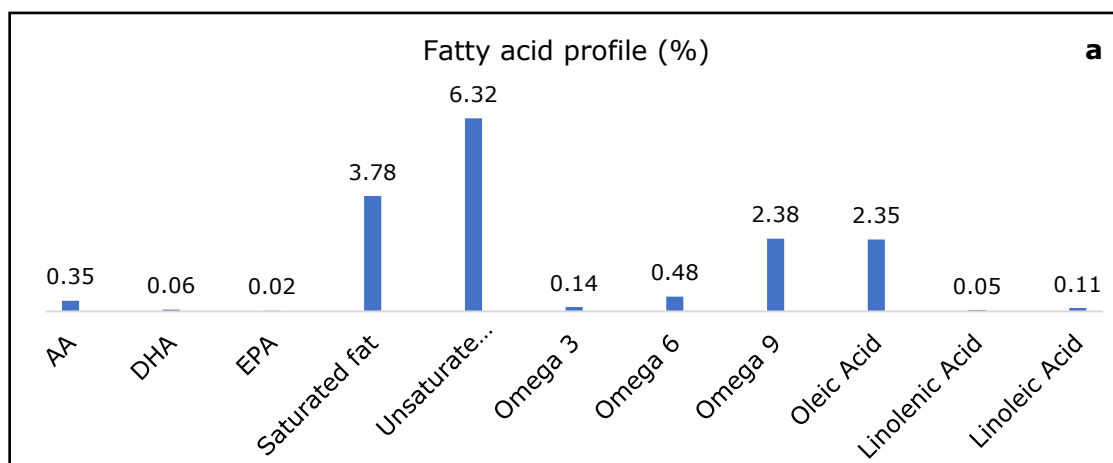


Figure 1. Proximate analysis of *Thunnus obesus* loin skin waste (%).

Fatty acid profile of fish skin waste from *T. obesus* loin. Fatty acid profile analysis using GC-FID. The results indicated that the fatty acid profile of fish skin waste from tuna loin contained 6.32% unsaturated fat and 3.78% saturated fat. The Fatty acid profile analysis shown in Figure 2.



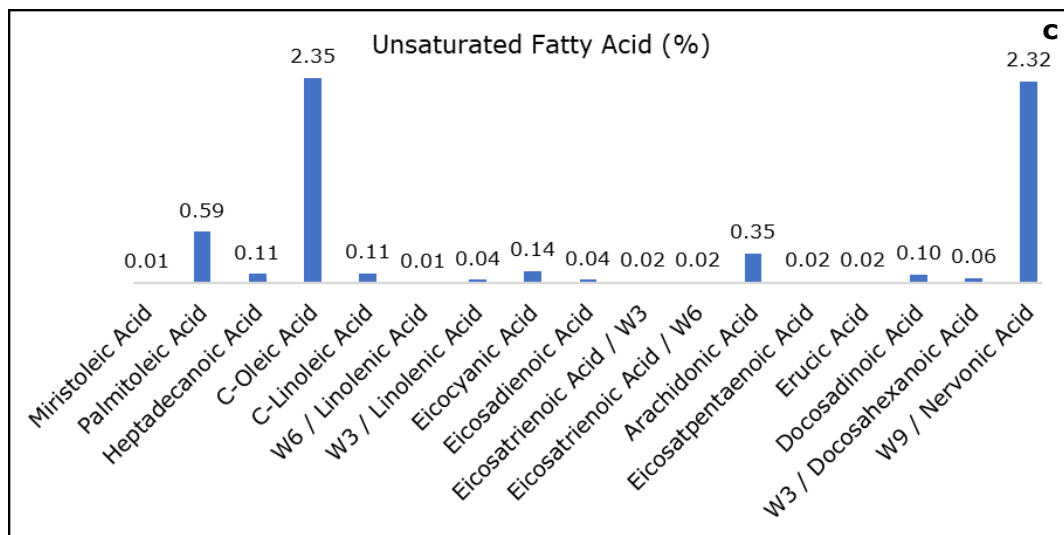


Figure 2. Composition of fatty acid profile (a), saturated fatty acid (b) and unsaturated fatty acid (c) from *Thunnus obesus* loin skin waste (%).

Additionally, it was found that omega-9 fatty acids made up 2.38% of the total, with oleic acid being the dominant component at 2.35%. On the other hand, the levels of omega 6, AA, linoleic acid, DH, linolenic acid, and EPA were all below 1%. The results showed that the percentage of saturated fatty acids in *T. obesus* loin skin waste was as follows: palmitate at 2.03%, behenat at 0.57%, stearate at 0.46%, myristat at 0.25%, and lignoserat at 0.23%. Other saturated fatty acids such as heptadecanoate, pentadecanoate, tricosanoate, arachidate, pentadecanoate, and laurate had very low percentages, all below 0.01%. Additionally, the research results indicated that the percentage of unsaturated fatty acids in *T. obesus* loin tuna skin waste included C-oleic acid at 2.35%, W9 (nervonic) at 2.32%, palmitoleic at 0.59%, W6 (arachidonic) at 0.35%, elcosenoate at 0.14%, C-linoleic acid and heptadecanoate at 0.11%, and docosadienoate at 10%. Furthermore, there were various types of fatty acids such as myristoleic, and W6 (Linolenic). Figure 3 shows the percentage of omega 3, 6, and omega 9.

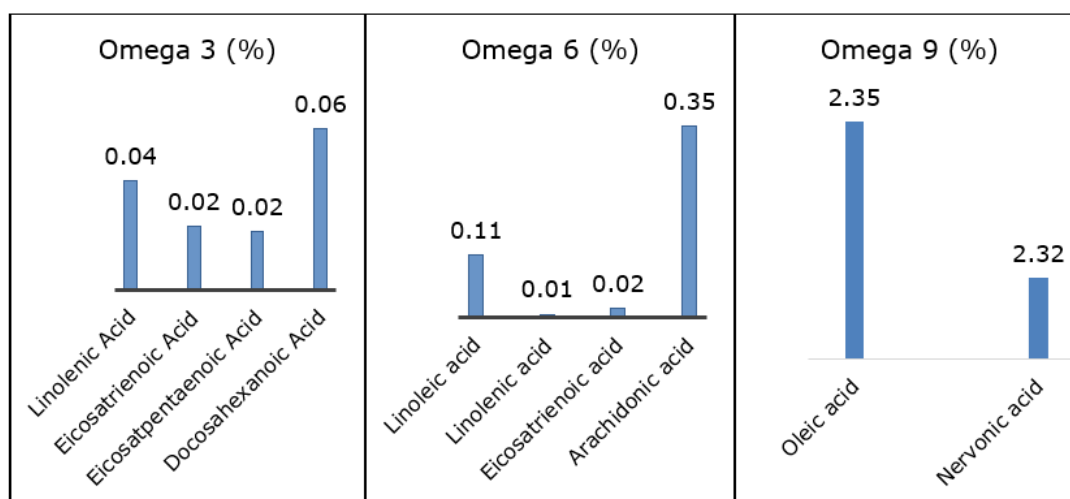


Figure 3. Grouping of unsaturated fatty acids omega 3, omega 6 and omega 9 (%).

Research on unsaturated fatty acids reveals that they consist of omega-3, omega-6, and omega-9 fatty acids. The highest percentages are found in oleic acid at 2.35% and nervonate at 2.32%. Arachidinic fatty acid comprises 0.35%, while linoleic acid makes up only 0.11%. Additionally, there are other unidentified fatty acids present.

In addition to its main components, tuna skin also contains unsaturated fatty acids that are beneficial for human health. These fatty acids, such as eicosapentaenoic acid (EPA)

and docosahexaenoic acid (DHA), have multiple double bonds. It is important to note that the fatty acid content in processed tuna skin may be lower compared to tuna meat, which is more commonly used as the primary ingredient in processed products. In general, while the protein content in fish skin from processed tuna loin is not very high, it can still serve as a good source of protein. Additionally, fish skin from processed tuna loin also contains fish oil that can be utilized in other processed products. However, compared to other marine organisms, the protein content in tuna skin tends to be lower.

One interesting research finding is the fatty acid profile found in the fish skin waste originated from processing *T. obesus* loin. The results indicated that the fish skin from processed tuna loin contained 6.32% unsaturated fat and 3.78% saturated fat. These results demonstrate that fatty acids, particularly unsaturated fatty acids, are important compounds that are beneficial for human health. Unsaturated fats, particularly monounsaturated fats, have been linked to a decreased risk of cardiovascular disease (Wu 2019). Additionally, fish oil contains omega-9 fatty acids at a concentration of 2.38%, with oleic acid being the dominant component at 2.35%. Oleic acid also referred to as omega 9, is a monounsaturated fatty acid that offers several benefits, including improving heart health and reducing inflammation (Schwingshackl & Hoffmann 2012). Furthermore, this research indicates that the skin of processed tuna loin also contains omega-6 fatty acids, AA, linoleic acid, DHA, linolenic acid, and EPA in amounts not exceeding 1%. These fatty acids also have significant health benefits, such as improving brain function and reducing the risk of heart disease (Calder 2010). The research findings indicate that fish skin from processing *T. obesus* loin, typically seen as waste, can be utilized to produce unsaturated fatty acids rich in omega-3 and beneficial amino acids for human health. It is crucial to conduct proper processing and monitor heavy metal levels to guarantee the safety and quality of the end product. This study has the potential to support the sustainable utilization of fish resources and the conversion of fish waste into a valuable nutritional source.

Tuna, including *T. obesus*, is a valuable fishery commodity in Indonesia due to its high economic value. In addition to the meat that can be processed into various products, the fish skin is also a valuable resource that can be utilized effectively. Research has shown that fish skin contains various components, such as fatty acids in the form of fish oil, heavy metals, proximate content, and amino acids, which can enhance the value of the final product. Fatty acids are one of the important components found in *T. obesus* loin skin. In this study, the percentage of saturated fatty acids in fish skin waste from processing is: palmitate at 2.03%, behenat at 0.57%, stearate at 0.46%, myristate at 0.25%, and lignoceric acid at 0.23%. Other saturated fatty acids such as heptadecanoate, pentadecanoate, tricosanoate, arachidate, pentadecanoate, and laurate have very low percentages, below 0.01%. These findings suggest that fish skin waste from processing tuna loin could serve as a potential source of raw materials for fish oil, which can be utilized in products like health supplements and cosmetics.

In addition to saturated fatty acids, fish skin waste from processing obese tuna loin also contains unsaturated fatty acids. According to the research conducted by Lopies et al (2021), there are various types of unsaturated fatty acids found in fish skin waste resulting from processing obesus tuna, such as oleic acid, omega-3 (DHA and EPA), palmitoleic, and omega-6 (arachidonic acid). The results show that fish skin waste from processing obese tuna loin can be utilized as a source of unsaturated fatty acids that are beneficial for human health. This research also shows that fish skin from processed tuna loin contains a variety of unsaturated fatty acids, including omega-3, omega-6, and omega-9 fatty acids. Omega-3 fatty acids are particularly important for the body as they offer various health benefits, such as protecting the heart and blood vessels, maintaining brain function, and reducing the risk of degenerative diseases (Fonda et al 2016). In addition, tuna skin contains polyunsaturated fatty acids such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which are important for brain and nervous system development and maintaining hormonal balance in the body.

Heavy metal content. The research results show that tuna loin skin has relatively low levels of heavy metals, specifically 1.79% arsenic, 0.36% lead, 0.6% mercury, and 0.03% cadmium. Nickel was not detected in the tuna loin skin (Table 1).

Table 1

Heavy metal content from *Thunnus obesus* loin skin

Sample	Heavy metals	Unit	Results
Tuna loin skin	As	ppm	1.79
	Pb	ppm	0.36
	Hg	ppm	0.06
	Cd	ppm	0.03
	Ni	ppm	0.00

Arsenic (As); Lead (Pb); Mercury (Hg); Cadmium (Cd); Nickel (Ni).

The results show that fish skin waste from processing obese tuna loin can be utilized as a source of unsaturated fatty acids that are beneficial for human health. In addition to information about fatty acid content, Ahmed et al (2017) revealed the presence of heavy metals in fish skin tuna waste as 4.6 ppm arsenic (As), 0.1 ppm cadmium (Cd), 1.0 ppm copper (Cu), and 25 ppm iron (Fe). Dia et al (2022) also revealed the presence of heavy metals in by-product is 4.48 ppm mercury (Hg) and 0.03 ppm arsenic (As). In this study, low amounts of heavy metals such as lead (Pb), cadmium (Cd), and copper (Cu) were detected. However, these findings warrant attention as tuna skin waste contaminated with higher levels of heavy metals could have adverse effects on the environment and human health.

In addition to the fatty acid content, this research also reveals the presence of heavy metals in the skin of fish that come from processing tuna loin. According to the Food and Drug Monitoring Agency (BPOM), an excess of heavy metals in food can lead to various diseases and endanger human health such as kidney damage, neurological disorders, and cancer (BPOM 2022). Therefore, it is important to closely monitor food ingredients that have heavy metal content, including tuna skin. Tuna skin also has low levels of heavy metals, making products made from it safe to consume.

Amino acid. The results of tuna skin amino acid content analysis are displayed in Figures 4, 5 and 6. Figure 4 shows the amount of amino acid found in tuna skin. The results indicated that the amino acid profile of fish skin waste from tuna loin contained essential amino acid and non-essential amino acid. The tuna skin amino acid content analysis results obtained 18 types. Amino acid content highest obtained is glycine ($55,927.53 \text{ mg kg}^{-1}$) and lowest is L-tryptophan ($491.73 \text{ mg kg}^{-1}$).

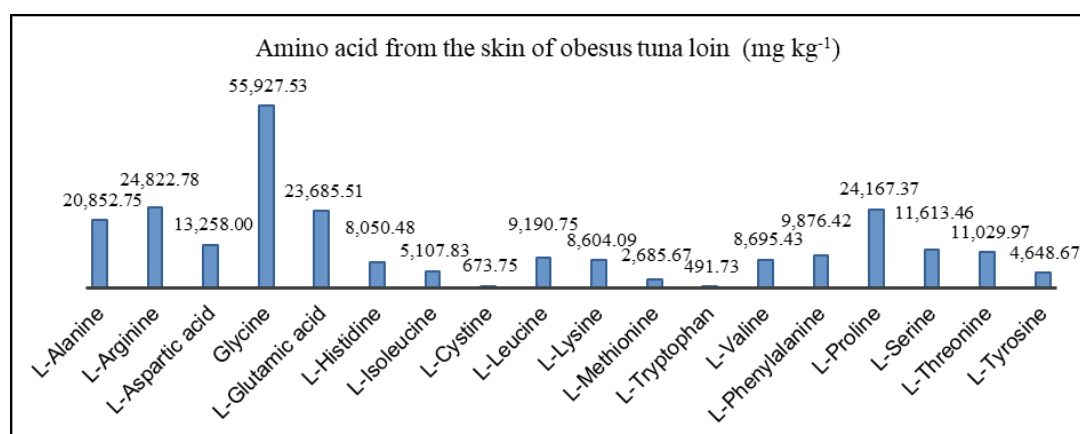


Figure 4. Analysis of *Thunnus obesus* skin amino acid content from highest to lowest (mg kg^{-1}).

The tuna skin amino acid essential content analysis results obtained 9 types contained $63,732.73 \text{ mg kg}^{-1}$. The analysis of essential amino acids concentration reveals the presence of L-threonine ($11,029.97 \text{ mg kg}^{-1}$) as amino acid highest and L-tryptophan ($491.73 \text{ mg kg}^{-1}$) as lowest as shown in Figure 5.

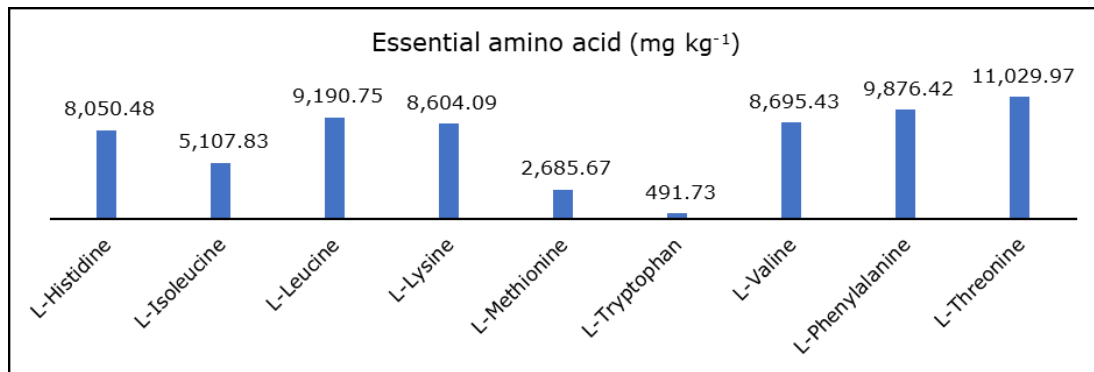


Figure 5. Essential amino acid concentrations in *Thunnus obesus* fish skin (mg kg⁻¹).

The results indicated that the non-essential amino acid of fish skin waste from tuna loin contained 179,649.82 mg kg⁻¹. The analysis of non-essential amino acids concentration shows the presence of glycine (55,927.53 mg kg⁻¹) as amino acid highest and L-cystine (673.75 mg kg⁻¹) as lowest as depicted in the Figure 6.

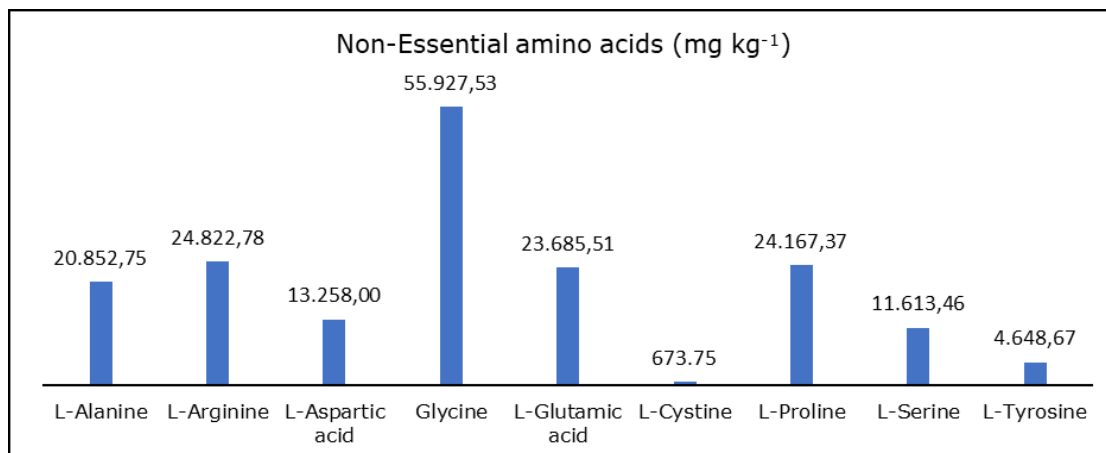


Figure 6. Non-essential amino acid concentrations in *Thunnus obesus* fish skin (mg kg⁻¹).

The results show that amino acids were also detected in tuna loin skin waste. The findings of this study align with previous research that has also identified the presence of heavy metals in tuna skin (Devita et al 2021). The amino acid content in fish skin waste is important for the growth and development of the human body. This waste can be utilized as food that is beneficial for human health. A thorough analysis of the chemical content in fish skin waste from processing *T. obesus* loin reveals that it contains various nutrients that can enhance the value of the products. However, it is crucial to consider environmental and health factors during the waste processing process to ensure the production of safe and high-quality products. The findings of this study align with previous research that has also identified the analysis of proximate and amino acids in fish skin tuna (Tanaka et al 2018; Nurilmala et al 2021).

Tuna fish skin also contains various amino acids essential for human body metabolism. The research results show that tuna skin contains essential amino acids that the human body cannot produce, including lysine, leucine, valine, threonine, tryptophan, isoleucine, phenylalanine, and methionine. Additionally, non-essential amino acids like arginine, histidine, and glycine are also present in tuna skin. Therefore, when processing tuna skin into products, it is crucial to prevent amino acid degradation to maintain the nutritional quality of tuna skin. Conclusively, a detailed examination of the chemical makeup of tuna skin reveals its diverse and beneficial properties for human health. Essential amino acids make tuna skin a nutritious source with the potential for further development. However, proper processing is essential to preserve the quality and nutritional value of tuna skin.

The analysis of the amino acid content in the skin of fish processed from tuna loin in Kendari, Indonesia revealed that the levels of non-essential amino acids, particularly glycine, L-arginine, and L-proline, were quite high. This indicates that tuna skin is a valuable source of amino acids essential for human body growth and development. Glycine, a non-essential amino acid, is crucial for the body's metabolism, particularly in collagen formation, which is important for bone and connective tissue development. Additionally, L-arginine offers benefits such as boosting immunity and enhancing male reproductive function. In addition to non-essential amino acids, fish skin of tuna loin from Kendari also contains essential amino acids that are important for the human body, such as L-glutamic acid, L-alanine, and L-aspartic acid. The presence of these essential amino acids is crucial for protein synthesis and maintaining overall body health. This suggests that fish skin from processed tuna loin could be utilized as a valuable source of amino acids. Furthermore, further research conducted by Nurjanah et al (2021) has also discovered that tuna skin contains a variety of amino acids and is considered to be a valuable and complete protein source for the human body. Based on the analysis results backed by recent references, it can be inferred that the skin of processed tuna loin from Kendari, Indonesia is a source full of beneficial amino acids that are essential for human health. This highlights the significance of utilizing tuna fish by products like skin as a beneficial protein source, with a good potential of development within the food and health sectors.

In recent years, there has been increasing research focusing on the chemical properties of tuna skin. This is because of the potential health benefits associated with tuna skin, particularly the fish oil and amino acids it contains. It is also important to consider the presence of heavy metals, which can have adverse effects on human health. A comprehensive analysis was conducted on the chemical composition of fish skin from processed tuna loin in Kendari, Indonesia.

Phytochemical analysis. Phytochemical analysis using qualitative methods. The phytochemical results indicated that it contained alkaloids, tannins, and steroids, but phenolic, flavonoids and saponins were not present. Test results are shown in Table 2.

Table 2

Phytochemical results from *Thunnus obesus* loin skin

<i>Compound</i>	<i>Results</i>	<i>Note</i>
Flavonoids	Red, yellow, and orange colours are formed on the layers of amyl alcohol	-
Alkaloids	A brick-red solid forms	+
Phenolic	A dark blue colour form	-
Tannin	A white solid formed by a chemical reaction	+
Saponin	Foam arises	-
Steroids /Triterpenoids	A positive triterpene red colour is formed, and a green steroid-positive	+

Positive (+); Negative (-).

The research findings revealed that fish skin from processed tuna loin contains alkaloids, tannins, and steroids, but does not contain flavonoids, phenolics, and saponins. This aligns with earlier research carried out by Dewi et al (2023), who also discovered alkaloid, tannin, and steroid compounds in catfish skin (*Pangasius* sp). Alkaloids are compounds known for their analgesic, antioxidant, and anti-inflammatory properties (Ouriagli et al 2023). On the other hand, tannin may help prevent cardiovascular disease, cancer, and osteoporosis (Squillaro et al 2018). The presence of these compounds in processed tuna loin fish skin suggests that it could be utilized as a natural source of beneficial ingredients with pharmacological activity for human health. However, this study's results indicate that fish skin from processed tuna loin lacks flavonoid, phenolic, and saponin compounds. Phytochemical compounds found in tuna fish skin can be used in the food, pharmaceutical,

and nutraceutical industries (Ningrum et al 2020). Therefore, their presence in tuna skin can offer additional health benefits.

Conclusions. The study showed that the skin of *T. obesus* loin has a high fat and protein content, but is low in heavy metals such as arsenic, lead, mercury, and cadmium. Further analysis revealed that this fish skin waste contains omega-9 fatty acids, primarily oleic acid, while the other fatty acids are not present in significant amounts. The amino-acids content is mainly composed of glycine, L-arginine, L-proline, and L-glutamic acid. No flavonoid, phenolic, or saponin compounds were detected in the phytochemical analysis results. Therefore, *T. obesus* loin skin waste can be utilized as a food ingredient to provide energy and protein that is relatively free from heavy metal contamination.

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

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