**Original Research Article**

**Nutritional Comparison of Fresh and Pressure-Cooked Yellowfin Tuna (*Thunnus albacares*) Stomach Waste**

**ABSTRACT**

Yellowfin tuna is a leading commodity in the capture fisheries sector and has high economic value in the global market. High tuna production results in large amounts of waste, including stomach waste that is not yet optimally utilized. This study aims to analyze changes in the chemical composition of stomach waste from yellowfin tuna. The sample consisted of 9 individuals and the proximate results were analyzed using the t-test and described descriptively in narrative form. Analysis of five parameters: water, ash, fat, protein, and carbohydrate content. The study found a water content of 78.350 ± 0.200% for fresh and 75.267 ± 0.208% for pressure-cooked. Ash 1.700 ± 0.040% for fresh and 2.530 ± 0.044% for pressure-cooked. Fat 8.020 ± 0.017% for fresh and 7.083 ± 0.065% after pressure-cooked. Protein 11.507 ± 0.309% for fresh and 10.733 ± 0.064% for pressure-cooked. Carbohydrate 0.423 ± 0.168% and 4.387 ± 0.216 for pressure-cooked. The results of the proximate test on the gastric waste of yellowfin tuna in fresh condition and after the pressure-cooked process for all parameters showed significant differences (p<0.05). The decrease in water content is caused by evaporation during heating, while the decrease in fat and protein occurs due to oxidation, decay, denaturation and dissolution of organic compounds in the cooking medium. Conversely, ash content increased as a result of the relative concentration of minerals after the loss of volatile components. Carbohydrate content also increased relatively, as a result of the reduction in other nutrients. These changes indicate that the pressure-cooked process functions as a method of softening the tissue and modifying the nutritional value of the waste fish organs. These findings are important to support the use of fish stomach waste as an alternative raw material in the animal protein-based feed or functional food industry.

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Keywords: Gastric waste, yellowfin tuna, nutritional composition, high pressure heating

1. **INTRODUCTION**

The fisheries sector produces large volumes of by-products during processing. These by-products include fish parts not directly used as staple foods, such as bones, heads, scales, skin, internal organs, and blood. Furthermore, processing by-products accumulate in the form of crustacean shells and shellfish from marine bioprocessing plants (Shahidi & Varatharajan, 2019). Rustad et al. (2021) emphasized that in some countries, fish by-products are still considered waste or used only as low-quality animal feed. Yet, these by-products contain beneficial natural bioactives, such as protein, collagen, bioactive peptides, omega-3 fatty acids, gelatin, minerals, and enzymes.

Tuna is a leading commodity in the fisheries industry, contributing significantly to the national economy and fisheries exports in Indonesia. One of the most exploited and economically valuable species is the yellowfin tuna (*Thunnus albacares*). This species is a large pelagic fish found abundantly in tropical waters, including the Makassar Strait (Kantun and Malawa 2016; Kantun 2018), which is ecologically important as part of the global Coral Triangle and a major migration route for various tuna species (KPRI Ministerial Decree 121, 2021). Yellowfin tuna is widely recognized in the international market for its high protein content, firm flesh texture, and diverse processing potential, including sashimi, steak, canned goods, and frozen fish.

The high economic value of tuna as a primary product is not accompanied by the utilization of non-edible parts (non-direct consumption) such as the head, gills, skin, bones, and internal organs such as the stomach waste and intestines. Based on quantitative studies, the waste portion of tuna fillets can reach 50–60% of the total body weight, depending on the cutting method and market demand specifications (Wahab et al., 2023). In other words, in one medium-sized tuna (±40–60 kg), the potential waste can reach 20–30 kg per fish. Meanwhile, Kantun et al. (2015) obtained yellowfin tuna waste weighing 22.27 kg without the stomach waste , intestines, fins, and gills when loined only produced ± 62.11% clean loin meat and the remaining ± 37.89% was waste in the form of heads, bones, and meat that had no economic value. One of the underutilized waste parts is the stomach waste , which is usually simply discarded without further processing.

Tuna stomach waste is thought to still contain nutrients such as crude protein, fat, and minerals, as well as certain bioactive compounds with the potential to be utilized in secondary product development. With increasing awareness of the concepts of zero waste and a circular bioeconomy in the fisheries sector, the study of internal organ waste utilization has become a relevant and interesting issue. Several studies have shown that marine fish internal organs, including stomachs waste , possess nutritional content that allows them to be used as raw materials for animal feed, liquid fertilizer, or even raw materials for the pharmacology and cosmetics industries (Najoan, 2019; Grasela et al., 2022).

One processing method that can be used to increase the utility value of fish stomach waste is the pressure-cooked technique. This method utilizes a combination of high temperature and pressure to soften hard tissue and partially decompose protein and fat structures, thereby increasing digestibility and nutrient availability (Hardianti et al., 2017). However, the pressure-cooked process can also alter the nutritional profile, depending on the duration, pressure, and temperature of processing. Therefore, a systematic study is needed to examine the changes in nutritional content or proximate composition of yellowfin tuna stomach waste due to the pressure-cooked process, especially for those originating from tropical ecosystems such as the Makassar Strait.

The paradigm of fish waste management must shift from waste as a problem to waste as an economic and ecological asset. This aligns with the Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production) and SDG 14 (Life Below Water) (Coppola et al. 2021). The FAO (2022) report concluded that fish waste represents both a challenge and an opportunity for the global fisheries sector. Utilizing fish waste through technological innovation and circular economy principles is a crucial part of a more sustainable fisheries development strategy, in line with the Blue Transformation agenda

The results of this research are expected to provide a scientific contribution to sustainable fisheries waste management efforts and serve as a basis for developing value-added products from underutilized fish parts. Furthermore, utilizing fish waste not only reduces food loss but also strengthens the sustainability of the fisheries sector, opens up new economic opportunities, and supports global food security. This approach is a crucial part of developing an environmentally friendly blue economy.

1. **MATERIALS AND METHODS**

**2.1 Sample origin**

Test samples totaling 9 individuals were taken at the Fish Landing Place and samples were caught by fishermen in the waters of the Makassar Strait. Proximate testing was conducted at the Biochemistry Laboratory of the Pangkajene and Kepulauan State Agricultural Polytechnic.

**2.2 Tools and Materials**

The tools used during the research were, pressure cooker, destruction; distillation; burette; stand and clamp; scales; erlenmeyer, destruction; distillation; burette; stand and clamp; scales; analytical balance; erlenmeyer 500 mL, 250 mL; upright cooler; measuring flask; funnel, burette; hot plate; 10 mL, 25 mL pipette; measuring cup; dropper; filter paper. Goldfish; lead; beaker; digital scale, filter paper, cotton, analytical balance with a sensitivity of 0.0001 g; ashing furnace (Furnace), blender or food grinder; clamps/pliers. desiccator. Sample spoon; sieve no. 20 mesh size 0.0331 inch, wire diameter 0.355 mm, al, filter paper, cotton

The materials used during the research were yellowfin tuna stomach waste, ice, selen mixture, bromocresolgreen 0.1%, HCL 0.01 N, 95% alcohol; NaOH 3%; Methyl-orange; H3BO3 2%, HCl 3%; NaOH 30%, CH3COOH 3%; KIO3, litmus paper; 20% KI solution; 25% H2SO4 solution; 4N H2SO4 solution; 0.1 N thiosulfate solution; 0.5% starch indicator; table luff schroorl.

**2.3 Sample handling**

The stomach waste, which is solid waste from yellowfin tuna, is taken from the stomach waste. The waste is then placed in a sample bottle and placed in a Styrofoam container filled with ice as a cooling medium to maintain the temperature so that the tuna stomach waste remains fresh. The test samples taken are divided into two parts: fresh and for pressure cooking purposes. The samples are then taken to the laboratory for testing. Each test is repeated three times for all parameters.

**2.4** **Sample Testing Procedure**

Testing for water, ash, fat, protein and carbohydrate content refers to the Association of Official Analytical Chemists (Al-Mentafji 2005).

**2.5 Data Analysis**

The results obtained from two types of samples, namely fresh and after the pressure-cooked process, were tested using Student's t-statistics and analyzed descriptively using narrative analysis.

**RESULT AND DISCUSSION**

The chemical composition of tuna, including protein, fat, water, and ash, is known to vary widely. This variation is influenced by various biological and environmental factors such as species, age (Rasul et al. 2021), sex, season (Ali et al. 2013), metabolic activity (Graham & Dickson 2004), gonadal maturity, and fish movement patterns (Kitagawa et al. 2006). Differences between tuna species affect the chemical composition of body tissues. This is due to different physiological adaptations between species to their habitat and diet.

The proximate analysis results obtained for the moisture, ash, fat, protein, and carbohydrate content of fresh and pressure-cooked yellowfin tuna stomachs waste are shown in Table 1.

Table 1. Proximate test results by sample type

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No | Test Parameters | Sample Type | Analysis results (%) | Information (%) |
| 1 | Water content | Fresh shape | 78.350 ± 0.200 | Decrease of 3.93 |
| Pressure cooked  | 75.267 ± 0.208 |
| 2 | Ash Content | Fresh shape | 1.700 ± 0.040 | Increase of 48.82 |
| Pressure cooked | 2.530 ± 0.044 |
| 3 | Fat Content | Fresh shape | 8.020 ± 0.017 | Penurunan 11,68 |
| Pressure cooked | 7.083 ± 0.065 |
| 4 | Protein Content | Fresh shape | 11.507 ± 0.309 | Decrease of 6.73 |
| Pressure cooked | 10.733 ± 0.064 |
| 5 | Carbohydrate Content | Fresh shape | 0.423 ± 0.168 | Increase of 937.11 |
| Pressure cooked | 4.387 ± 0.216 |

Based on the results of the Student's t-test on the data in Table 1, the results obtained were that the results of the proximate test for water, ash, fat, protein and carbohydrate content in yellowfin tuna stomach waste in fresh conditions and after the pressure-cooked process showed a significant difference (p<0.05).

**3.1 Water content**

The proximate test results showed a decrease in water content of 3.93% (Table 1) and showed a significant difference (p<0.05). This significant decrease in water content was caused by the effect of temperature and pressure on water release and protein denaturation, which reduced the tissue's ability to bind water. The pressure-cooked process is a processing method that softens the texture of hard tissue and reduces water content, which supports the stability of material storage. This denaturation process directly reduces water content in the tissue. As a result, pressure-cooked fish stomachs waste show a decrease in water content depending on the duration and pressure of the heating process. This change in water content indicates that the tissue has lost most of its free water and become denser.

The stomach waste of fresh tuna tends to have a high water content because the tissue has not undergone thermal processing and the protein structure is still intact, allowing the water-holding capacity in the tissue to remain optimal. In general, the water content in the internal organs of fresh fish can reach 70–80% depending on the species and physiological condition of the fish. Kantun et al. (2015) stated that the high water content in fish is influenced by the distance traveled and the handling method of tuna catches.

Water content generally decreases after the pressure-cooked process. This is due to the evaporation of water during heating and the release of free water due to protein denaturation. Tissues subjected to intense heating lose their water-binding capacity, resulting in decreased water content (Iyenagbe et al. 2017). Furthermore, it has been stated that the high temperatures applied in the pressure-cooked method can cause intensive protein denaturation, which can reduce the water-binding capacity of the tissue. As a result of this denaturation, the protein is no longer able to retain water within the tissue matrix as it does in its fresh state. According to Utami et al. (2016), in their research on cooked methods affecting water and protein content in fish, they found that pressure-cooked process causes greater water loss than conventional steaming or boiling. This is due to the combination of high temperature and pressure, which triggers the efficient release of water from the tissue.

**3.2 Ash content**

The results of the proximate test showed an increase in ash content of 48.82% (Table) and showed a significant difference (p<0.05). Ash content reflects the content of essential minerals such as calcium, phosphorus, magnesium, sodium, and other microelements. When a proximate analysis was carried out on the tuna stomach waste in two different conditions, namely in fresh condition and after the pressure-cooked, it was found that the ash content experienced a very significant increase after the pressure-cooked. This is because the loss of water and fat components results in a higher ratio of mineral content to total dry weight (Sahar et al. 2024). The pressure-cooked involves heating under high pressure for a specific period of time, which causes water evaporation and a decrease in fat content.

As moisture and fat content decrease, the ratio of minerals to total dry weight increases. This causes the ash content, which is a relative measure of the total weight of the sample, to appear higher. This is known as the relative concentration effect (Utami et al., 2016). Heating at high temperatures can break down bonds between proteins or other organic compounds and minerals, allowing minerals to become freer and more readily detectable during combustion in ash analysis. Some minerals bound in complex compounds may not be fully detectable fresh but become more readily available after heating (Iyenagbe et al., 2017).

Organic compounds such as proteins and carbohydrates undergo denaturation and degradation during heating, increasing the proportion of ash in the total mass. This results in higher levels of ash being detected even though the absolute amount of minerals does not increase significantly. Fish products have varying ash content. Fishery products have varying ash content, for fresh fish ash content based on SNI 01-2354.1-2006, it is less than 2%.

**3.3 Fat Content**

The proximate test results showed a significant decrease in fat content of 11.68% (Table 1) (p<0.05). This significant decrease in fat content was due to oxidation and decay during the heating process. Fat found in internal organ tissue is thermolabile and easily damaged at high temperatures, especially if not protected from oxygen contact (Utami et al., 2016). The decrease in fat content after the pressure-cooked process is caused by several factors: fat, especially unsaturated fatty acids, is very susceptible to oxidation when exposed to high temperatures and air. The pressure-cooked process, which uses high temperatures and pressure, triggers an oxidation reaction that breaks down fat into volatile compounds such as aldehydes, ketones, and volatile alcohols (Iyenagbe et al., 2017). These compounds are not detected in gravimetric measurements of fat, so the fat content appears lower.

The heating process causes melting and release of fat from the stomach waste tissue to the surface of the material or into the cooking liquid. Some of this fat is lost in the steam condensate or remains in the pressure cooker, which is not included in laboratory analysis (Utami et al., 2016). Heating causes protein denaturation and damage to the cell membrane, which initially functions to maintain the internal structure of the fat (as bound fat). When the membrane is damaged, the fat becomes more easily released and oxidized or lost with the liquid (Manzano et al., 2018). When water and fat are reduced, other components, such as ash and protein, appear to increase proportionally. This results in a decrease in the percentage of fat in total weight, although some fat is also lost in absolute terms. The fat content of fish varies depending on the species, age, amount of red meat, and feeding conditions.

**3.4 Protein Content**

The proximate test results showed a 6.73% decrease in protein content (Table 1), indicating a significant difference (p<0.05). This significant decrease in protein is due to denaturation during heating, but chemically, the total amount does not always decrease. However, depending on the analytical method, measurement results can fluctuate because changes in protein structure affect reactivity to analytical reagents (Manzano et al., 2018). This decrease in protein content is thought to be caused by high pressure over a period of time, which causes massive protein denaturation, a change in protein structure without breaking peptide bonds. Under these conditions, proteins lose their solubility. Some proteins also undergo thermal hydrolysis, the breaking of peptide bonds into smaller or even more soluble compounds that are lost in the cooking liquid (Iyenagbe et al., 2017). During proximate analysis, some proteins are undetectable or remain in lower amounts.

Denatured proteins become more soluble in water, especially water-soluble protein fractions such as albumin and globulin. During pressure-cooked, steam and cooking liquids can carry some of these soluble nitrogen compounds out of the stomach waste tissue, resulting in less protein remaining in the food (Manzano et al., 2018). This results in decreased protein content analysis results because most of the nutrients have dissolved and been lost during cooking.

The proportion of protein in the total weight of the material may also appear to decrease due to the relative increase in ash or mineral components, which become more dominant after heating. Although the water content decreases, the loss of nitrogen compounds causes the dry weight of the material to become less nutrient-dense. Research conducted by Utami et al. (2016) shows that high-pressure cooking methods such as pressure cooking can cause a 10–20% decrease in protein content, depending on the type of material and cooking time. This decrease not only affects nutritional value but also impacts the functional properties of the protein, such as solubility and water-holding capacity.

**3.5 Carbohydrate Content**

The proximate test results showed a 937.11% increase in carbohydrate content (Table 1), indicating a significant difference (p<0.05). This significant increase in carbohydrate content was due to water reduction or could have decreased due to the loss of some soluble components during the cooking process. Pressure-cooked reduces water, fat, and protein content because these components shrink due to evaporation, oxidation, and denaturation. Heating can cause cell wall damage and the release of organic compounds, including structural carbohydrates and other non-protein compounds, thereby increasing the total amount of soluble solids categorized as carbohydrates (Manzano et al., 2018). The higher carbohydrate content after pressure cooking can contribute to increased metabolic energy in the food.

Yellowfin tuna is a leading commodity in the capture fisheries sector, possessing high economic value in the global market. High levels of tuna production not only produce the primary product, meat, but also produce large amounts of waste, including stomach waste contents, which are generally underutilized. The potential for utilizing tuna stomach waste, particularly as a raw material for feed or other processed products, is strongly influenced by its nutritional content, which is fundamentally formed by a complex interaction between biological factors and the environment in which the fish live (Wang et al. 2023).

Tuna live in deep-sea waters, which have different environmental conditions than fish from coastal waters. Factors such as water temperature, natural food availability, salinity, and water quality influence fish metabolism and the nutrient content of their body tissues, including the stomach waste (Wang et al. 2023). Tuna living in tropical waters with optimal temperatures of around 18–28°C and high natural food availability tend to store optimal amounts of protein and fat in their body tissues and internal organs (Weng et al. 2009). Exposure to polluted environments or waters with low productivity can negatively impact fish physiology, including decreased protein and lipid accumulation.

In addition to protein and fat components, the mineral content in fish, as indicated by ash content, is also influenced by the ecosystem conditions in which the fish live. Tuna from mineral-rich waters tend to have higher ash content due to the accumulation of minerals such as calcium and magnesium in organ tissue (Manzano et al., 2018). Meanwhile, the carbohydrate content in fish stomachs waste, which is largely derived from food waste and glycogen, is also influenced by the variety of natural food types in their habitat.

The habitat and environmental conditions in which tuna live directly influence the initial nutritional profile of the fish's stomach waste, which then influences changes in nutritional content after processing. Therefore, managing marine environmental quality, such as pollution control and natural habitat conservation, is crucial to maintaining the quality of the catch, both for the main product and the usable internal organ waste.

These findings demonstrate that efforts to utilize fishery waste, such as tuna stomachs waste, cannot be separated from ecosystem aspects. Healthy ocean waters will produce raw materials with optimal nutritional quality, including their waste components. This opens up opportunities for the food and feed industry to utilize fishery waste as a source of value added raw materials.

On the other hand, Rustad et al. (2021) revealed that fish by-products, previously considered waste, can be processed into high-value materials in the food, health, and cosmetics sectors. The development and utilization of fish by-products not only increases the added value of the fisheries sector but also supports the industry's sustainability by reducing waste and optimizing resources.

**CONCLUSIONS**

The pressure-cooked process, which involves heating at high temperatures and pressures, changes the chemical composition of yellowfin tuna stomach waste. Water, fat, and protein contents decreased due to evaporation, oxidation, denaturation, and the dissolution of organic compounds into the cooking medium. Conversely, ash content increased due to the higher relative concentration of minerals after the loss of volatile components, while carbohydrate content increased due to the differential calculation of the reduction of other key nutrients. These findings indicate that the pressure cooking process not only affects the physical properties of fish stomachs waste but also significantly modifies the nutritional value that can be utilized for the development of processed fish waste-based products. Utilizing fish waste not only reduces food loss but also strengthens the sustainability of the fisheries sector, opens up new economic opportunities, and supports global food security. This approach is a crucial part of developing an environmentally friendly blue economy.

**Conflict of Interest**

There is no conflict of interest in writing this article.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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