Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 28(5): 1315 – 1329 (2024)
www.ejabf.journals.ekb.eg

Quality of the Yellowfin Tuna (*Thunnus albacares*) Fishing on Small-Scale Fishers in Bone Bay, Indonesia

Nurdin Kasim[1], Muhammad Maskur[1], Mohammad Roin Najih[1], Kurnia Sada Harahap[2], Rahmatang[1], Budiyati[1]

[1]Polytechnic of Marine and Fisheries Bone, South Sulawesi, 92718, Indonesia
[2]Polytechnic of Marine and Fisheries Dumai, Riau Province, 28826, Indonesia

[*]**Corresponding author:** lenterabone71@gmail.com

ARTICLE INFO

Article History:
Received: Aug. 19, 2024
Accepted: Sep. 10, 2024
Online: Oct. 5, 2024

Keywords:
Smal-scale fisher,
Yellowfin tuna,
Microbiological,
Chemical

ABSTRACT

The quality of the yellowfin tuna caught by small-scale fishers is heavily influenced by how the catches are handled and stored on board. One effective method that small-scale fishers can use to maintain the quality of their catch is by cooling it with ice. This helps prevent the growth of bacteria in the fish, which can cause sensory, physical, microbiological, and chemical damage. Such damage can result in poor catch quality and lower market value. Therefore, this study aimed to assess the quality of the yellowfin tuna catches by small-scale fishermen in Bone Bay, specifically at the Lonrae fish landing site. This assessment involved conducting sensory, physical, microbiological, and chemical tests on the catch. The results indicated that the catch had high quality, as evidenced by a sensory score of 8. The fish had a pH ranging from 5.7 to 5.8 and a temperature close to 0°C. The average total bacteria count was 1.1 x 104 colonies/g, and there were no traces of *Salmonella* or *Escherichia coli* (<3 MPN/g). The histamine values ranged from 6.99 to 7.31. Heavy metals, specifically mercury, lead, and cadmium, were measured at 0.05, 0.0166, and 0.0049mg/ k, respectively.

INTRODUCTION

Fish is a highly perishable food product due to the bacterial germs and biochemical reactions occurring during preparation and storage. The high water activity, pH value above 6, and abundance of low molecular weight components in fish create an optimal environment for bacterial growth. This bacterial growth is primarily responsible for causing sensory impairment in fish **(Dainty, 1996; Gram & Huss, 1996)**. Fish can get spoiled at any stage from catching to consumption. Factors such as fishing methods, fish species, sanitation, processing, and storage conditions can all contribute to the bacterial spoilage of fish. Inadequate fish handling practices, such as improper gutting and delayed scraping, can result in higher levels of microbial contamination and spoilage **(Ikape, 2017)**. Additionally, elevated ambient temperatures can expedite fish spoilage by enhancing the activity of bacteria, enzymes, and fat oxidation in the fish flesh **(Ghaly *et al.*, 2010)**. This is supported by the report of **Muhammad and Al-Taie (2024)**, which

describes how fluctuation in the environment can affect microorganism mobility. Consequently, these factors can contribute to reducing market prices **(Akande & Diei-Ouadi, 2010)** and substantial losses for fishermen.

Tuna, a type of fish in the Scombridae family, has a significant economic value in the world and is the third largest fishery commodity in Indonesia after shrimp and demersal fish **(Waileruny *et al.*, 2024)**. This species naturally contains more histidine than fish from other families **(Visciano *et al.*, 2012; Visciano *et al.*, 2014)**. If not handled promptly, appropriately, and accurately, bacterial activity can lead to decay and the production of biogenic amines including histamine, which can cause food poisoning. Histamine serves as a signal of fish spoilage because it is produced as a result of bacterial activity involving the histidine decarboxylase (HDC) gene, which catalyzes the conversion of histidine into histamine **(Nurilmala *et al.*, 2019)**. Bacterial proliferation is accelerated at temperatures exceeding 21.1°C (70°F), whereas the production of histamine experiences a rapid surge at temperatures around 32.2°C (90°F). Therefore, it is advisable to store fish on board at a temperature of 4.4°C (40°F) using ice or refrigerated seawater immediately after the fish dies, and the storage duration should not exceed 12 hours **(Food & Drug Admnistration, 2022)**. The yellowfin tuna (*Thunnus albacares*) is the predominant species in tropical and subtropical regions worldwide including bone bay waters **(Silbande *et al.*, 2016)**. *Thunnus albacares*, also known as the yellowfin tuna, is a prominent species captured by small-scale fishermen using hand-line fishing gear. The procedure of impressing is employed to store the catch. This study aimed to assess the quality of *T. Albacares* caught by small-scale fishers in Bone Bay waters. The assessment involved analyzing sensory test parameters, physical test parameters (temperature and pH), microbiological test parameters (total bacteria, *Salmonella*, and *Escherichia coli*), and chemical parameters (histamine and heavy metal tests).

MATERIALS AND METHODS

1. Sampling of *T. albacares*

T. albacares was collected from the catch of artisanal fishermen in Bone Bay (the fishing ground shown in Fig. (1)) over the course of one month. The fishing coordinates were: 06°47’13.86”S - 120°52’59.15’’E, 06°39’18.85”S - 120°50’25.90’’E, 06°27’56.63”S - 120°48’43.26’’E, 06°09’56.79”S - 120°59’05.34’’E, and 05°54’53.41”S - 121°13’01.17’’E. The fish were landed at the Lonrae Fish Landing Site in Bone District, South Sulawesi, Indonesia (04°32’23.91”S - 120°23’39.11”E) in February 2024. In addition, 30 individuals of *T. albacares* were purposively sampled and subjected to temperature and storage conditions as per the treatment on the ship. In addition, 30 samples of *T. albacares* were purposively selected and subjected to temperature and storage conditions as per the treatment on the ship. To ensure accurate bacterial analysis,

the fish samples were collected aseptically to avoid contamination from other pathogens before being examined in the Fishery Product Quality Testing Laboratory.

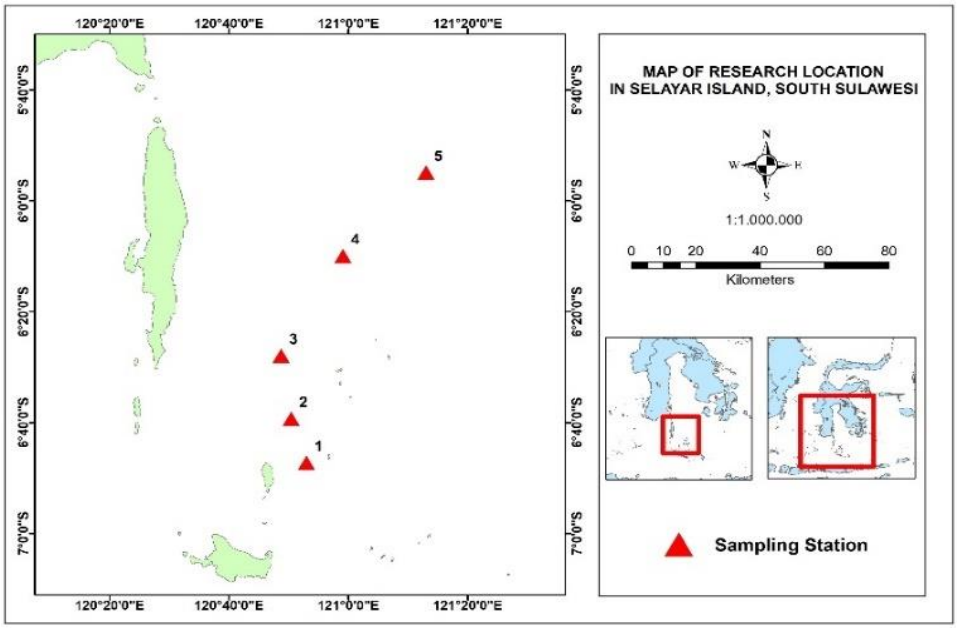

Fig. 1. Map of fishing grounds

2. Sensory test

The sensory evaluation of *T. albacares*, as described in the **National Standardization Agency (2015a)**, involves the use of a score sheet to assess various quality specifications of fresh fish. These specifications include the condition of the eyes, gills, body surface mucus, meat, odor, and texture. The assessment is conducted by a minimum of six standard panelists or individuals responsible for evaluating the quality specifications. Each quality specification is assigned a number ranging from 1 to 9, with a minimum value of 7 necessary for the desired quality. The quality value is determined through the calculation of a sensory test using the following formula:

$$P(x - (1.96.s\ n)) \leq \mu \leq (x + (1{,}96.s\ n)) \cong 95\%$$

Explanation:

P = Quality value;
x = Mean of quality value;
1.96 = Standard deviation coefficient at 95% level;
s = Standard deviation of quality value (SD)
n = Number of panelists;
≅ = Approximately equal to.

3. Physical test

The Fluke 52 II Dual Probe Digital Thermometer is used to measure temperature, with a range of -40 to 260°C (-40 to 500°F) and an accuracy of ± 1.1°C (± 2.0°F). To record the temperature, the thermocouple probe tip is inserted into the thickest part of the

fish body or the center point that allows for the longest penetration. The pH of the fish was measured using the HI981036 digital pH brand, which has a pH range of 0.00 to 12.00, a resolution of 0.01 pH, and an accuracy of +0.05 pH. Moreover, the pH was measured by simply putting the probe tip into the flesh of the fish.

4. Microbiological analysis

The testing technique for total bacteria, or total plate count, as specified by the **National Standardization Agency (2015b)**, sets a maximum quality standard of 5.0 x 10^5 colonies per gram. Negative results for *Salmonella* are recommended, and the acceptable limit for *E. coli* is less than 3 MPN.

To analyze the samples, 25 grams were mixed with 225mL of Butterfield's Phosphate Buffer solution, which was then diluted from 10^{-1} to 10^{-5}. From each dilution, 1mL was transferred to a plate count agar for inoculation. The agar was incubated at 35°C for 48 hours. The quantification of total bacteria was determined using the following formula:

$$N = \frac{\Sigma C}{[(1 \; x \; n1) + (0{,}1 \; x \; n2)] x \; d}$$

Explanation:

N = Number of colonies (/gr);
∑C = Number of colonies at all Petri dishes counted (/gr) ;
n1 = Number of Petri dishes at initial dilution was counted;
n2 = Number of Petri dishes at second dilution was counted;
d = Dilution factor.

The identification of *Salmonella* bacteria was based on the criteria set by the **National Standardization Agency (2006)**, which requires a negative result for every 25 grams of sample. The analysis process begins by identifying and enhancing a 25g sample in 225mL of lactose broth (LB). The sample was then incubated for 24 hours at a temperature of 35°C. For the enrichment stage, a 0.1mL sample was taken and added to a 10mL solution of rappaport-rassiliadis (RV) and tetrathionate broth (TTB). This mixture was then incubated in a water bath at a temperature of 42 (RV) and 43°C (TTB) for a period of 24 hours, with a tolerance of ± 0.2 (RV) and ± 0.5°C (TTB), and a time tolerance of ± 2 hours. *Salmonella* was isolated following the positive incubation of RV and TTB tubes, which was indicated by a change in color to cloudy. Each of the RV and TTB tubes were agitated and then used to inoculate hectoen enteric (HE), xylose lysine deoxycholate (XLD), and bismuth sulphite agar (BSA) media. Subsequently, the samples were placed in an incubator at a temperature of 35ºC ± 1ºC for a duration of 24 hours ± 2 hours. *Salmonella* colonies were discovered after a duration of 24 hours. The characteristic morphology of *Salmonella* resulted in the formation of colonies that were bluish green to blue, with or without the presence of black dots on the colonies. The

identification of *Salmonella* involved several biochemical tests, including the indole synthesis test, vosges proskauer test, methyl red test, citrate test, and fermentation tests for sucrose, lactose, and dulsitol.

The identification of *Escherichia coli* was determined according to the guidelines provided by the **National Standardization Agency (2015c)**, with a required quality of less than 3 most probable number (MPN) per gram. The procedure began by conducting an estimating test on a 25 grams sample in 225mL of Butterfield's Phosphate Buffered (BFP) solution. Subsequently, 1ml of the sample was added to a test tube containing 9mL of LTB solution and a durham tube. The *E. coli* prediction test involved transferring a positive LTB tube into a tube containing *E. coli* broth and a durham tube, in a quantity equivalent to one dose. The EC broth tubes were thereafter placed in a circulating water bath and incubated for a minimum of 48 hours, with a temperature of 45ºC ± 0.5ºC maintained. The *E. coli* broth tubes were examined at 24-hour intervals, with a tolerance of ± 2 hours, to detect the presence of any gas production. If no gas was produced, the process of incubation was repeated until a time period of 48 hours ± 2 hours elapsed. Additionally, the most likely number (MLN) was calculated by counting the number of positive tubes, and the total number of potential colonies werereported as MLN/gr fecal coliform using the MLN Table. Subsequently, confirmation tests, morphological tests, and biochemical testing were conducted.

5. Chemical analysis

The chemical parameters were analyzed by performing histamine tests using the spectrophotometer method, as described in **National Standardization Agency (2016a)**, with a quality standard limit of 100mg/ kg. The analysis of heavy metals included the usage of atomic absorption spectrophotometry to measure mercury (Hg), as stated in the **National Standardization Agency (2016b)** reference. The maximum acceptable level for quality was 1.00mg/ kg. The atomic absorption spectrophotometry method was employed to analyze lead (Pb) and cadmium (Cd), as stated by the**National Standardization Agency (2011)**. The method required a maximum quality limit of 0.40mg/ kg for Pb and 0.10mg/ kg for Cd.

6. Statistical analysis

The data were subjected to one-way ANOVA at a 95% confidence level (α=0.05). If the analysis yielded a statistically significant difference, further investigation was conducted using the Tukey HSD (High significant difference) test.

RESULTS AND DISCUSSION

1. Sensory characteristics of the fresh yellowfin tuna

The sensory evaluation results of the yellowfin tuna samples obtained from small-scale fishermen in Bone Bay and landed at the Lonrae fish landing site are presented in Fig. (1). The quality specifications assessed include: 1 (eyes), 2 (gills), 3 (body surface

mucus), 4 (color and appearance of meat), 5 (smell), and 6 (texture). The organoleptic value derived from each replicate are denoted in Figs. (2, 3, 4).

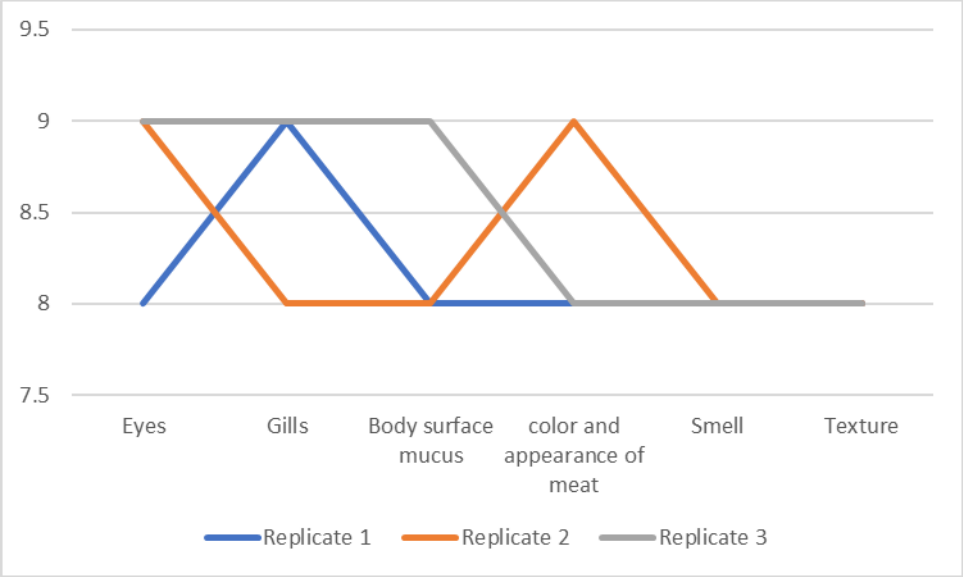

Fig. 2. Findings from the sensory evaluation of recently caught yellowfin tuna according to quality criteria

The quality specifications for the catch of the yellowfin tuna by small-scale fishers fall within the range of 8 to 9, suggesting that the catch is fresh and of a good quality **(Jeyasanta & Patterson, 2021)**. The value of 8 is assigned to each quality standard, which includes bright eyes, flat eyeballs, and clear corneas, as presented in Fig. (3). The gills have a less vibrant crimson hue, devoid of any mucus secretion. The body surface mucus exhibits a distinct, translucent, and luminous coating of mucus, without any signs of discoloration at present. The meat is in an excellent condition with a precise incision that reveals dazzling flesh. There is no evidence of milking along the spine, and the abdominal wall is unbroken. It exhibits a distinct and characteristic scent. The texture is slightly compact, exhibiting elasticity when pushed with fingers, and presents a challenge when attempting to separate the meat from the spine. A score of 9 out of the examined quality standards implies that the eyes are bright; the eyeballs are prominent; the corneas are clear, and the gills are of a beautiful red hue, with no presence of mucus. The mucus coating on the body surface is clear, translucent, and shining. The meat condition is characterized by a very distinct and species-specific incision, with no milking down the spine and an unbroken abdominal wall. The aroma of the fish is highly fragrant and distinct to its species, accompanied by a compact texture that is resilient when squeezed with a finger, making it challenging to separate the meat from the spine.

Fig. 3. Whole *T. albacares* and fresh meat

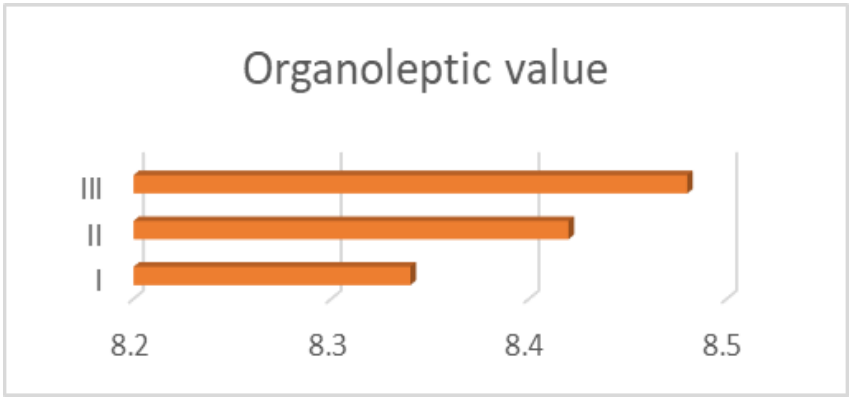

Fig. 4. Organoleptic value of fresh yellowfin tuna.

The organoleptic values obtained from each test are 8.34, 8.42, and 8.48. These values are not significantly different from each other or the values obtained in other experiments ($P > 0.05$). The test value of the yellowfin tuna is less than 8.5, and all replicates generally show a value of 8, indicating that the condition of the caught fish is of a good quality. If the fish is not handled or stored correctly after being caught, the decay process will rapidly occur, marked by rigor mortis and subsequent changes in the fish after death. The spoilage process is characterized by the decomposition of different components and the creation of new compounds, resulting in changes in odor, taste, and texture. Deterioration happens rapidly due to various mechanisms activated by the metabolic activity of microorganisms, endogenous enzymatic activity (autolysis), and lipid oxidation **(Gram & Huss, 1996; Prabhakar *et al.*, 2020)**. The utilization of low temperatures is crucial in preserving the quality of fish following their harvest.

Refrigeration, super chilling, and freezing methods enable the extended preservation of fish without significant alterations in quality, ensuring economic advantages **(Shawyer & Medina, 2003)**. Ice cooling is a commonly employed technique utilized by small-scale fisherman to preserve the quality of their catches while on board.

2. Physical test parameters

The temperature and pH measurements obtained from the three repetitions indicate that the yellowfin tuna handling conducted by small-scale fishers aboard the boat was performed proficiently. This is demonstrated by the steady value of the average temperature of the yellowfin tuna from 1 to 1.5°C, with the average pH value in each replication of 5.7, 5.8, and 5.9 which can be seen in Fig. (5). No statistically significant difference was identified among all replicates or experiments ($P > 0.05$).

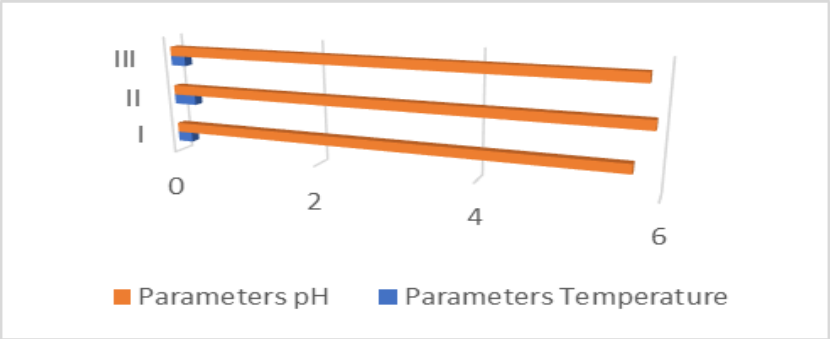

Fig. 5. Results of temperature and pH assessment in the yellowfin tuna

Refrigeration is the method of lowering the temperature of fish or fish products to temperatures near the point of ice melting. The purpose is to extend the shelf life by reducing the speed of physical and chemical reactions, as well as the growth of microorganisms and harmful enzymes **(Shawyer & Medina, 2003; Kaale *et al.*, 2011)**. Moreover, refrigeration helps preserve the sensory and organoleptic quality of the fish, making it appear fresh and appealing to consumers. The use of ice cooling can effectively preserve fish by keeping their temperatures near 0°C, hence extending their shelf life for up to 30 days. The duration of preservation depends on various aspects, including the water temperature (whether it is temperate or tropical) and the specific species of fish captured **(Shawyer & Medina, 2003)**. Small-scale fishers in Bone Bay effectively improve the quality of their yellowfin tuna catches by employing proper handling techniques. This includes the use of ice to maintain the desired fish temperature around 0°C and the removal of gills and entrails before storage **(Uddin *et al.*, 2017)**. The removal of gills and entrails in fish has a significant impact on the quality of preserved fish under different storage conditions. Simply removing the gills and entrails can extend the shelf life of fish, not only at low temperatures but also at room temperature. Bacteria in fish are typically found in the skin, gills, and digestive tract **(Austin, 2002)**. By removing the source of bacteria in fish, this treatment can slow down the decay process and stabilize the pH level of fresh fish. Fresh fish typically has a low acidity level, with a

pH range of 5.0 to 6.5 **(Comi, 2017)**. In the case of the fresh yellowfin tuna, the pH values range from 5.77 to 5.97 **(Silbande *et al.*, 2016)**.

3. Microbiological test parameters

Microbiological analysis was performed for the yellowfin tuna using a total plate count (TPC) test, *Salmonella* test, and *E. coli* test, as shown in Table (1).

Table 1. Results of microbiological testing on the yellowfin tuna

No.	Parameter	Replication			Quality requirement
		I	II	II	
1.	TPC	1.5×10^4 Colony/gr	1.1×10^4 Colony/gr	1.1×10^4 Colony/gr	5.0×10^5 Colony/gr
2.	*Salmonella*	Negative/ 25 gr	Negative/ 25 gr	Negative/ 25 gr	Negative/ 25 gr
3.	*E. coli*	<3	<3	<3	<3 MPN/gr

Table (1) demonstrates that the yellowfin tuna caught by small-scale fishers in Bone Bay exhibits an excellent quality based on the analysis of three microbiological parameters. All values meet the quality standards, and no notable variations were identified among the replicates or experiments ($P > 0.05$).

The initial mechanism that exacerbates the condition of fish and thereafter impacts the quality of fresh fish is the microbial proliferation **(Boziaris, 2013)**. Microbial growth initiates in the fish muscle polluted by microbial populations present on the fish skin after the fish dies **(Comi, 2017)**. In tuna, the total quantity of bacteria is higher in the skin compared to the gills **(Kapetanovic *et al.*, 2017)**. The combination of high water activity, low acidity (pH > 6), and large levels of non-protein nitrogen compounds commonly found in fish leads to the rapid proliferation of microbes. This microbial growth causes unpleasant alterations in the look, texture, taste, and odor of fish, ultimately leading to a degradation in their quality **(Najih & Maskur, 2020; Tavares *et al.*, 2021)**. The presence of *Salmonella* and *E. coli* bacteria in tuna fish poses significant health risks. Contamination of tuna fish with these bacteria can lead to foodborne illnesses. Therefore, it is crucial to prioritize the safety of tuna products **(Rahayu *et al.*, 2021)**. Furthermore, it has been discovered that tuna can harbor several strains of *E. coli*, including enterotoxigenic *E. coli* (ETEC). This highlights the necessity of implementing monitoring and control strategies to effectively limit the proliferation and persistence of these harmful strains **(Sika *et al.*, 2020)**. Continuous monitoring, adherence to proper food safety practices, and the implementation of effective control measures are necessary to mitigate the risks associated with *Salmonella* and *E. coli* in tuna fish. These pathogens must be carefully handled on board to ensure the safety of the catch.

4. Chemical test parameters

The yellowfin tuna captures were subjected to chemical tests to detect the presence of histamine and heavy metals such as mercury, lead, and cadmium. The results of these tests can be found in Table (2).

Table 2. Results of chemical testing on the yellowfin tuna

No.	Parameter	Reiterate			Quality requirement
		I	II	II	
1.	Histamine	6.99	7.25	7.31	100 mg/kg
2.	Mercury	0.05 mg/kg	0.05 mg/kg	0.05 mg/kg	Maks. 1.00 mg/kg
3.	Lead	0.0166 mg/kg	0.0166 mg/kg	0.0166 mg/kg	Maks. 0.40 mg/kg
4.	Cadmium	0.0049 mg/kg	0.0049 mg/kg	0.0049 mg/kg	Maks. 0.10 mg/kg

Chemical analyses performed for the yellowfin tuna caught at the Lonrae fish landing site indicated that the values obtained were in accordance with the quality standards. The results validate that the catches made by small-scale fishers are of a high quality, and no noteworthy disparities were detected between each repetition or trial ($P > 0.05$).

Microbial decay results in the production of volatile amines, biogenic amines, organic acids, sulfides, alcohols, aldehydes, and ketones, which contribute to an unpleasant and unacceptable taste **(Sperber & Doyle, 2010)**, Biogenic amines viz. histamine, cadaverine, tyramine, and putresin are formed when specific free amino acids undergo decarboxylation by microorganisms during storage. These amines can be used to assess the safety and quality of fish **(Biji *et al.*, 2016; Silbande *et al.*, 2018)**. Histidine is the naturally occurring free amino acid found in the scombroid fish, including the yellowfin tuna. The formation of histamine in fish is directly related to the amount of histidine present and the bacteria present in the fish. Heating and freezing methods are not effective in removing or eliminating histamine, as stated by **Tahmouzi *et al.* (2013)**. Histamine is one of the biogenic amines found in fish and is of toxicological importance. It is responsible for causing scombroid fish poisoning, as explained by **Hungerford (2010)**. Histamine production occurs when bacteria decarboxylate free histidine in raw fish due to improper temperature and duration, as highlighted by **Rawles *et al.* (1996)** and **Kim *et al.* (2000)**. The histamine levels in the fresh yellowfin tuna may fluctuate depending on factors such as storage conditions and processing techniques. At first, fresh tuna has very small amounts of histamine **(Ben-Gigirey *et al.*, 1998)**. However, it has been proven that proper storage methods such as keeping it in ice can effectively keep histamine levels under control. Studies have shown that histamine levels remain below 6.0ppm when stored correctly **(Rossi *et al.*, 2002))**. Therefore, it is appropriate to use temperature and time to control the formation of histamine in fish during handling and storage. **Food and Drug Admnistration (2022)** recommends storing fish on board at a temperature of 4.4°C (40°F) using either ice or refrigerated saltwater immediately after the death of fish. It is important to ensure that the fish is not maintained for longer than 12 hours.

The presence of heavy metals, including mercury (Hg), lead (Pb), and cadmium (Cd), in collected tuna is worrisome due to the potential health hazards they pose. The heavy metals mentioned **(Bernhoft, 2012; Gidlow, 2015; Ghenci *et al.*, 2020)** are the

most prevalent ones causing toxicity in humans. Tuna, being a carnivorous fish, has the highest concentration of heavy metals due to its position at the top of the food chain **(Ordiano-Flores *et al.*, 2011)**. As a predatory fish, it has a strong ability to accumulate metal pollutants **(Sharkawy *et al.*, 2020)**. The yellowfin tuna and bigeye tuna, both large predatory fish, have particularly high levels of mercury **(Kaneko & Ralston, 2007; Ordiano-Flores *et al.*, 2011)**. It is crucial to closely monitor and evaluate the levels of heavy metals in tuna to guarantee food safety and reduce the health hazards linked to heavy metal exposure **(Oktariani *et al.*, 2023)**. The detection of mercury, lead, and cadmium in harvested tuna gives rise to worries over the safety of the food and its impact on human health. Implementing continuous monitoring, evaluation, and remediation tactics is crucial in order to reduce the hazards linked to heavy metal pollution in tuna and guarantee the safety of consumers. Several factors can contribute to fluctuations in the levels of heavy metals found in fish, including the species, size, migration biology, and origin of the fish. While several studies have investigated the correlation between the size of tuna fish and the presence of heavy metals **(Drevnick *et al.*, 2015)**, it is crucial to consider the geographic origin of the capture or the habitat upon assessing mercury levels in fish of the same species **(Nicklisch *et al.*, 2017)**. Quality assessments help identify contaminants, ensuring that fish products are safe for consumption, building consumer trust and promoting public health. High-quality fish products often command better prices in the market, and this assessment can help producers identify and maintain quality standards, leading to increased profitability. In addition, evaluating fish quality encourages sustainable fishing practices.

CONCLUSION

The yellowfin tuna caught by small-scale fishermen in Bone Bay and landed at the Lonrae fish landing site has an excellent catch quality, as determined through sensory, physical, microbiological, and chemical testing conducted on the catch. The findings indicated a sensory score of 8, fish pH ranging from 5.7 to 5.8, fish temperature near 0°C, average total bacterial counts of 1.1 x 10^4 colonies/g, with no presence of *Salmonella* or *E. coli* <3 MPN/gr. The histamine value ranged from 6.99 to 7.31. The levels of heavy metals were measured as follows: mercury at 0.05, lead at 0.0166, and cadmium at 0.0049mg/ kg. Periodic evaluation of the quality of fish resources, particularly tuna, is needed to ensure consumer health and increase economic value. This requires cross-sector cooperative cooperation such as fishermen, academics, and related agencies.

REFERENCES

Akande, G. and Diei-Ouadi, Y. (2010). Post-harvest losses in small-scale fisheries. Food and Agriculture Organization of The United Nations, Rome. 1-89 p.

Austin, B. (2002). The bacterial microflora of fish. Scientific World Journal, 2: 558-72. https://doi.org/10.1100/tsw.2002.137.

Ben-Gigirey, B.; Craven, C. and An, H. (1998). Histamine formation in albacore muscle analyzed by AOAC and enzymatic methods. J Food Sci, 63(2): 210–214. https://doi.org/10.1111/j.1365-2621.1998.tb15711.x

Bernhoft, R.A. (2012). Mercury toxicity and treatment: A review of the literature. J Environ Public Health, 1-10. https://doi.org/10.1155/2012/460508

Biji, K. B.; Ravishankar, C.N.; Venkateswarlu, R.; Mohan, C.O. and Gopal, T.K. S. (2016). Biogenic amines in seafood: a review. J Food Sci Technol, 53(5): 2210-2218. http://dx.doi.org/10.1007/s13197-016-2224-x

Boziaris, I.S. (2013). Introduction to seafood processing—assuring quality and safety of seafood. Seafood Processing: Technology, Quality and Safety, 1-8. https://doi.org/10.1002/9781118346174.ch1

Comi, G. (2017). Spoilage of meat and fish. The Microbiological Quality of Food, 179-210. https://doi.org/10.1016/B978-0-08-100502-6.00011-X

Dainty, R.H. (1996). Chemical/biochemical detection of spoilage. Int J Food Microbiol, 33(1): 19-33. https://doi.org/10.1016/0168-1605(96)01137-3

Drevnick, P.E.; Lamborg, C.H. and Horgan, M.J. (2015). Increase in mercury in Pacific yellowfin tuna. Environ Toxicol Chem, 34(4): 931-4. https:// doi.org/10.1002/etc.2883

Food and Drug Admnistration. (2022). Fish and fishery products hazards and controls guidance. Center For Food Safety and Applied Nutrition, 1-553 p.

Genchi, G.; Sinicropi, M.S.; Lauria, G.; Carocci, A. and Catalano, A. (2020). The effects of cadmium toxicity. Int J Environ Res Public Health, 17(11): 1-24. https://doi.org/10.3390/ijerph17113782

Ghaly, A.E.; Dave, D.; Budge, S. and Brooks, M.S. (2010). Fish spoilage mechanisms and preservation techniques. Am J Appl Sci, 7(7): 859-877. https://doi.org/10.3844/ajassp.2010.859.877

Gidlow, D.A. (2015). Lead toxicity. Occup Med (Chic Ill), 65(5): 348-56. https://doi.org/10.1093/occmed/kqv018

Gram, L. and Huss, H.H. (1996). Microbiological spoilage of fish and fish products. Int J Food Microbiol, 33(96): 121-137. DOI: 10.1016/0168-1605(96)01134-8

Hungerford, J.M. (2010). Scombroid poisoniag: a review. Toxicon, 56(2): 231-243. http://dx.doi.org/10.1016/j.toxicon.2010.02.006

Ikape, S. I. (2017). Fish spoilage in the tropics : a review. Octa J Biosci, 5(2): 34-37.

Jeyasanta, I. K. and Patterson, J. (2021). Impact of traditional and dip in-freezing in the refrigerator on the quality of sardines. Frontiers of Agriculture and Food Technology, 11(2): 001-009.

Kaale, L.D.; Eikevik, T.M.; Rustad, T. and Kolsaker, K. (2011). Superchilling of food: a review. J Food Eng, 107(2) : 141-6. DOI: 10.1016/j.jfoodeng.2011.06.004

Kaneko, J.J. and Ralston, N.V.C. (2007). Selenium and mercury in pelagic fish in the central North Pacific near Hawaii. Biol Trace Elem Res, 119(3): 242-54. https:// doi.org/10.1007/s12011-007-8004-8

Kapetanović, D.; Smrzlić, I.V. and Valić, D. (2017). Culturable microbiota associated with farmed Atlantic bluefin tuna (*Thunnus thynnus*). Aquat Living Resour, 30: 1-

8. https://doi.org/10.1051/alr/2017029

Kim, S.H.; Ben-Gigirey, B.; Barros-Velázquez, J.; Price, R.J. and An, H. (2000). Histamine and biogenic amine production by *Morganella morganii* isolated from temperature-abused albacore. J Food Prot, 63(2): 244-51. DOI: 10.4315/0362-028x-63.2.244

Muhammed, M. and Al-Taie, B. (2024). Isolation and identification of aquatic fungi from some water samples in Mosul City. Egyptian Journal of Aquatic Biology & Fisheries, 25(5): 793-804. DOI: 10.21608/ejabf.2024.380430

Najih, M.R. and Maskur, M. (2020). The quality of yellow tail fish (*Caesio cuning*) with mobile sales system at Makassar City. IOP Conference Series: Earth and Environmental Science, 1-10 p. https://doi.org/10.1088/1755-1315/584/1/012027

National Standardization Agency. (2006). Microbiological test methods - part 2: determination of *Salmonella* in fishery products. Indonesian National Standard, 01-23322, 1-29 p. (In Indonesian)

National Standardization Agency. (2011). Chemical test methods - part 5: determination of heavy metal levels of Lead (Pb) and Cadmium (Cd) in fishery products. Indonesian National Standard, 23545, 1-10 p. (In Indonesian)

National Standardization Agency. (2015a). Guidelines for sensory testing of fishery products. Indonesian National Standard, 2346, 1-23 p. (In Indonesian)

National Standardization Agency. (2015b). Microbiological test methods - part 3: determination of total plate count (TPC) in fishery products. Indonesian National Standard, 23323, 1-16 p. (In Indonesian)

National Standardization Agency. (2015c). Microbiological test methods - part 1: determination of coliforms and *Escherichia coli* in fishery products. Indonesian National Standard, 23321, 1-23 p. (In Indonesian)

National Standardization Agency. (2016a). Chemical test methods - part 10: determination of histamine levels by spectrophotometry and high-performance liquid chromatography (HPLC) in fishery products. Indonesian National Standard, 235410, 1-18 p. (In Indonesian)

National Standardization Agency. (2016b). Cara uji kimia - Bagian 6 : Penentuan kadar logam berat merkuri (Hg) pada produk perikanan. Indonesian National Standard, 23546, 1-15 p. (In Indonesian)

Nicklisch, S.C.T.; Bonito, L.T.; Sandin, S. and Hamdoun, A. (2017). Mercury levels of yellowfin tuna (*Thunnus albacares*) are associated with capture location. Environ Pollut, 229: 87-93. https://doi.org/10.1016/j.envpol.2017.05.070

Nurilmala, M.; Abdullah, A. and Matutina, V.M. (2019). Chemical, microbiology changes and detection of HDC gene on longtail tuna *Thunnus tonggol* during chilling temperature storage. J Ilmu dan Teknol Kelaut Trop, 11(2): 285-96. (In Indonesia)

Oktariani, A.F.; Sudaryatma, P.E. and Ramona, Y. (2023). Heavy metals content in fresh tuna and swordfish caught from Hindian and Pacific Oceans: Health risk

assessment of dietary exposure. Vet World, 16: 858-68. DOI: 10.14202/vetworld.2023.858-868

Ordiano-Flores, A.; Galván-Magaña, F. and Rosiles-Martínez, R. (2011). Bioaccumulation of mercury in muscle tissue of yellowfin tuna, *Thunnus albacares*, of the eastern Pacific Ocean. Biol Trace Elem Res, 144(1-3): 606-20. https://doi.org/10.1007/s12011-011-9136-4

Prabhakar, P.K.; Vatsa, S.; Srivastav, P.P. and Pathak, S.S.A. (2020). Comprehensive review on freshness of fish and assessment: analytical methods and recent innovations. Food Res Int, 133: 1-17. DOI: 10.1016/j.foodres.2020.109157

Rahayu, N.E.; Pratama, R. I.; Gumilar, I. and Rostini, I. (2021). Hazard analysis and critical control points in handling frozen tuna steak (case study at PT. Awindo International, Jakarta, Indonesia). Asian J Fish Aquat Res, 14(4): 1-9. DOI: 10.9734/ajfar/2021/v14i430300

Rawles, D.D.; Flick, G. J. and Martin, R.E. (1996). Biogenic amines in fish and shellfish. Adv Food Nutr Res, 39(C): 329-65. https://doi.org/10.1007/s13197-016-2224-x

Rossi, S.; Lee, C.; Ellis, P.C. and Pivarnik, L.F. (2002). Biogenic amines formation in Bigeye tuna steaks and whole Skipjack tuna. J Food Sci, 67(6): 2056-2060. https://doi.org/10.1111/j.1365-2621.2002.tb09500.x

Sharkawy, A.A.; El-Sayed, A.M. and Ali, M.A.M. (2020). Heavy metals content in canned tuna fish marketed in Assiut city, Egypt and its related human health risk assessment. Assiut Vet Med J, 66(165): 1-20. DOI: 10.21608/AVMJ.2020.166364

Shawyer, M. and Medina, P.A.F. (2003). The use of ice on small fishing vessels. FAO. Fisheries Technical Paper, 116 p.

Sika, A.E.; Ouattara, L.; Yoro, D.T.; Nevry, R.K. and Djé, K.M. (2020). Growth and survival of enterotoxigenic *Escherichia coli* (ETEC) isolated from tuna loins produced in Côte D'ivoire. Int J Pathog Res, 4(4): 1-11.

Silbande, A.; Adenet, S. and Chopin, C. (2018). Effect of vacuum and modified atmosphere packaging on the microbiological, chemical and sensory properties of tropical red drum (*Sciaenops ocellatus*) fillets stored at 4°C. Int J Food Microbiol, 266: 31-41. https://doi.org/10.1016/j.ijfoodmicro.2017.10.015

Silbande, A.; Adenet, S. and Smith-Ravin, J. (2016). Quality assessment of ice-stored tropical yellowfin tuna (*Thunnus albacares*) and influence of vacuum and modified atmosphere packaging. Food Microbiol, 60: 62-72. DOI: 10.1016/j.fm.2016.06.016

Sperber, W.H. and Doyle, M.P. (2010). Compendium of the microbiological spoilage of foods and beverages. Food Microbiology and Food Safety Series, 376 p.

Tahmouzi, S.; Ghasemlou, M.; Aliabadi, F.S. (2013). Histamine formation and bacteriological quality in skipjack tuna (*Katsuwonus pelamis*): effect of defrosting temperature. J Food Process Preserv, 37(4): 306-313. DOI: 10.1111/j.1745-4549.2011.00650.x

Tavares, J.; Martins, A.; Fidalgo, L.G. (2021). Fresh fish degradation and advances in preservation using physical emerging technologies. Foods, 10(4): 1-20. DOI:

10.3390/foods10040780

Uddin, W.; Rasul, M.G.; and Hossain, M.M. (2017). Effect of gill removal and gutting on the quality of tilapia (*Oreochromis niloticus*) under different storage condition. J Appl Biol Biotechnol, 5(5): 30-35. DOI: 10.7324/JABB.2017.50505

Visciano, P.; Schirone, M.; Tofalo, R. and Suzzi, G. (2012). Biogenic amines in raw and processed seafood. Front Microbiol, 3: 1-10. DOI: 10.3389/fmicb.2012.00188

Visciano, P.; Schirone, M.; Tofalo, R. and Suzzi, G. (2014). Histamine poisoning and control measures in fish and fishery products. Front Chem, 5: 1-3. DOI: 10.3389/fmicb.2014.00500

Waileruny, W.; Wiyono, E.S.; Sarimane1, S. and Matrutty, D.D.P. (2024). Evaluation of applied tuna-jacket, a post-harvest technology of tuna handlines in Maluku Waters, Indonesia. Egyptian Journal of Aquatic Biology and Fisheries, 28(5), 743-754. DOI: 10.21608/ejabf.2024.380422