

The Change of *Rastrelliger* sp. Quality in Samarinda Traditional Market Distribution Chain

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Abstract. Post-harvest handling is a crucial aspect of the distribution chain for fresh fish, as it ensures the safety and freshness of the commodity for consumers. The Indian mackerel (*Rastrelliger* sp.) is one of the primary marine protein commodities in East Kalimantan, Indonesia. The objective of the present study was to observe the quality change of indian mackerel fish during supply distribution in Samarinda City. The organoleptic quality, pH, total plate count (TPC), total volatile base (TVB) and water content of the fish were measured at four time points: 4 am in the fish handling facility (TPI Selili), 8 am, 11 am and 2 pm at the traditional market. The data were collected and compared with the National Standardization Body of Indonesia (SNI). The fish quality was found to change significantly at 11 am, with alterations being observed in the quality of the gills, eyes, mucus, aroma and texture of the fish. The TPC also indicated an increase in viable bacteria, exceeding the established standards. The pH level rises substantially due to the enzymes and microbes' activity, which accelerates the spoilage process. Meanwhile, the TVB of all samples remain categorized as safe to consume. The quick and right post-harvest handling is needed to preserve the quality of the fresh fish.

Keywords: fresh fish, organoleptic, post-harvest , total plate count, total volatile base

1 Introduction

Indonesia is tropical country that covered more than 60% of the ocean, marine fish resources become important commodity to be handled as one of the main protein sources to the community. One of the most popular aquatic consumed fisheries products was Indian mackerel (*Rastrelliger* sp.) that accounted for 373.499 tons in 2023 [1]. This number made the commodity becomes top 5 of marine fish in Indonesia. Indian mackerel, as marine fish, is categorized as highly perishable commodity which easily deteriorate during the handling [2]. Moreover, the characteristics of this commodity which contain high lipid that faster the quality degradation during distribution [3]. Quality of fresh fish

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becomes emerging problem in traditional market since three stages of supply chain that might forced into less proper food handling. Meanwhile in Samarinda, supply chain of fresh marine fish in traditional was categorized as 4 stages of supply chain that consist of distributors-wholesaler-seller-and the ultimate costumer that longer compared to the three stages of supply chain [4].

Therefore, the increasing number of consumers in fisheries product, also the highly perishable *Rastrelliger* sp., pose challenges to maintain the freshness during the supply chain. Moreover, in Samarinda, the fish in the retailer could stay during a day until the fish were purchased by the consumers. Quality monitoring is a crucial step to assure the commodity safety and maintain the safe and nutritious commodity until consume by the community [1], [2]. Highly perishable fish were easily deteriorating by either internal or external factor, several sign could be detected by human sensing, but others need to be observed in the laboratory. From the best of our knowledge, there is no data that supporting the quality of the Indian mackerel in Samarinda traditional market's supply chain. Hence, this study aimed to observe the quality change of *Rastrelliger* sp. in traditional market during distribution chain in the aspect of organoleptic quality, total plate count, total volatile base, pH and water content of the fish.

2 Methods

The research was conducted to observe the change of the quality of fresh *Rastrelliger* sp, using several parameters. The samples were obtained at 4.00 AM (W1) in wholesaler food handling facility (TPI Selili), and at 8.00 AM (W2), 11.00 AM (W3), and 2.00 PM (W4) at Traditional Market, Samarinda. The fish were immersed in crushed ice and placed in an open Styrofoam box during distribution. The fish were placed in ceramic table with the crushed ice in the top and once watered by cool water to maintain the freshness. The samples were taken in a cool box contained crushed ice 1:1 (w/w) and distributed to the Laboratory of Fisheries Product Technology, Mulawarman University.

2.1 Organoleptic quality

The organoleptic quality was observed based on SNI 01-2729-1-2006 [3] used of rating test of fish freshness by 9 scale categories. The 20 trained panellists were used to assess the quality of *Rastrelliger* sp., including the gills, eyes, mucus, aroma, and texture.

2.2 Water content and pH

The water content assessed by using thermogravimetric method (SNI 01-2354.2-2006) [4] based on fish wet based. The pH was measured by using pH meter. Both pH and water content were measured three times.

2.3 Total Plate Count (TPC)

The total plate count was using pour plate method based on SNI 2332.3:2015 [5]. As much 25 g of crushed fish were diluted 225 ml diluent. Then, the aliquots were centrifuged and diluted into serial dilutions and plated in Total Plate Count Agar on 10^{-5} , 10^{-6} , and 10^{-7} . The plates were triplicate in each dilution. The plate then incubated at 37°C 48 hours. The accounted colony was ranging from 30-300.

2.4 Total Volatile Base (TVB)

Total Volatile Base (TVB) conducted in Conway Method based on SNI 2354.8:2009 [6].

3 Result and Discussion

3.1 Organoleptic Quality

Organoleptic testing is an approach to evaluating food product quality that involves observing human sensory responses as indicators, with subjective assessments by panelists. This method is also known as testing using the five human senses as the primary tool in assessing product characteristics. In assessing fish quality, organoleptic testing is conducted by assessing visual aspects such as the condition of the eyes, gills, and mucus on the body surface, as well as the characteristics of the meat, aroma, and texture. The fish handling process aims to maintain its freshness from capture to the time of purchase by consumers [7].

3.1.1 Appearance

Gills

Freshness of fish is an important indicator in determining its nutritional content, where a decrease in freshness is correlated with a degradation of nutritional value. Suboptimal handling of fish can affect its physicochemical characteristics and nutritional composition [8]. Organoleptic observations of the appearance of fresh mackerel were carried out at 4.00 AM at TPI (W1), 8.00 AM (W2), 11.00 AM (W3), and 2.00 PM (W4) at Traditional Market on the gills, eyes, and mucus on the surface of the mackerel's skin. The organoleptic score of the mackerel's appearance can be seen in **Fig 1**.

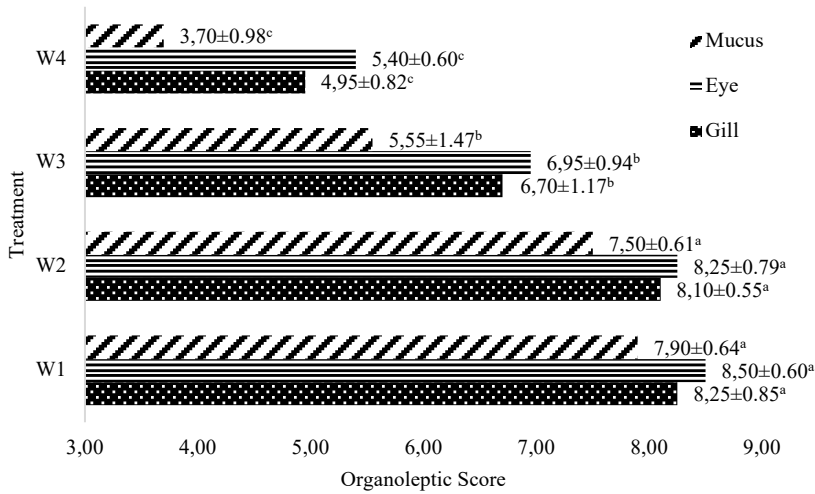


Fig 1. Organoleptic score of Indian mackerel appearance

*W1 (observation time 4.00 AM); W2 (8.00 AM); W3 (11.00 AM); W4 (2.00 PM). The alphabetic showed the significance level at p-value 0.05 based on Mann-Whitney post-hoc test

Based on the results of the Kruskal-Wallis and Mann-Whitney tests (**Fig 1.**), the organoleptic score for the gills of mackerel indicates a significant decline in quality as the observation time increases. At 4:00 AM (W1), the gill appearance score was 8.25, indicating that the gills were still a less vibrant red color, without mucus. This condition is typical of freshly caught fish. This gill condition was maintained until 8:00 AM (W2) with a score of 8.10. The consistently high score up to 4 hours after arrival at the Selili Fish Farm indicates that the physical quality of the mackerel gills, especially in terms of color appearance and surface cleanliness, is still in the very good category and has not experienced significant changes due to autolysis or microbial contamination.

However, at 11:00 AM (W3), there was a significant decrease in the score to 6.70, which was accompanied by a change in the color of the gills to a somewhat dull red, although no mucus was detected on the surface of the gills. This condition indicates a decrease in physiological quality, where the process of pigment oxidation and the beginning of tissue changes began to occur due to enzymatic and microbial activity that increased as the observation time increased. [9] Gills are a part of the fish's body that is rich in blood vessels and is an ideal place for the growth of putrefactive bacteria. The process of putrefaction in fish can occur when the number of bacteria in the gills increases significantly, thus triggering a degradation in the quality of the fish. Naturally, fish contain microbes that are concentrated in three main locations, namely the surface of the skin, gills, and stomach contents.

The decline in quality became more apparent at 2.00 PM (W4), with the gill score becoming 4.95. At this stage, the gills began to show discoloration (brownish red), and a little mucus began to appear. The change in color towards brown indicates the occurrence of hemoglobin oxidation and a simple Maillard reaction, while the presence of mucus is an early sign of the growth of spoilage microorganisms on the surface of the gills of mackerel. [8] The gills are the respiratory organs of fish that have a labyrinthine structure to filter dirt particles from the water entering the fish's body. In addition to being a respiratory organ, gills are also an important indicator in assessing the level of decline in fish quality. A change in gill color to brown indicates that the fish has experienced a decline in quality or a decay process.

Eye

Based on the results of the Kruskal-Wallis and Mann-Whitney tests, the organoleptic scores of the mackerel eyes showed a significant decrease in quality as the observation time increased. The eyes are one of the main indicators of fish freshness that consumers generally pay attention to when buying fresh fish [9]. The appearance of the mackerel fish's eyes can be seen in **Fig 2**.

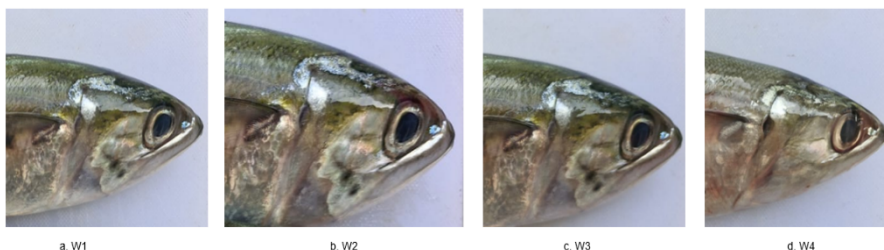


Fig 2. Appearance of Indian mackerel eyes

*W1 (observation time 4.00 AM); W2 (8.00 AM); W3 (11.00 AM); W4 (2.00 PM)

The appearance of the mackerel eyes experienced significant changes as the observation time increased. The mackerel eyes at 4.00 AM (W1) showed the characteristics of fish that were still very fresh (8.50). This was indicated by flat, bright eyeballs and clear corneas. This condition persisted until 8.00 AM (W2) with a score of 8.25, which indicated that the mackerel had not undergone any biochemical changes. Fish that are still in fresh condition generally have bright eyes, with protruding eyeballs (convex) and clear corneas. This condition occurs because there have not been many biochemical changes taking place in the fish's body, so the fish's metabolism is still running well and perfectly [10]. In the pre-rigor phase, the fish is still in a very fresh condition and has the same characteristics as when the fish was still alive, such as bright eyes and a clear cornea [7].

Changes in the quality of mackerel began to occur at 11.00 AM (W3), with a score of 6.95. This condition is indicated by the appearance of the cornea of the mackerel's eyes becoming slightly cloudy, slightly bright, and the color of the pupil becoming slightly grayish. The decrease in score is due to the mackerel having begun to experience a decline in quality. [10] Changes in the level of freshness of the fish will be clearly visible from changes in the brightness of the fish's eyes. The eye brightness parameter is one of the easiest to observe and is used as an indicator of fish freshness.

[7] In the rigor mortis phase, the appearance of the eyes in fish experiences changes, such as a slightly reduced brightness of the eyeballs. In addition, [11] changes in the brightness of the eyes of fish indicate the start of bacterial growth, which causes a decline in the quality of the fish.

At 2.00 PM (W4), the eye appearance score decreased significantly to 5.40. At this stage, the appearance of the mackerel's eyeballs began to shrink (sunken), the cornea became cloudy, and the pupil turned gray. This condition is a sign of deterioration in quality and an intensive process of oxidation and degradation of eye tissue. In addition, there was also the growth of microorganisms that accelerated the decay process. [7] In the post-rigor phase, the fish's eyeballs became slightly sunken, and the brightness of the pupil and cornea became cloudy and gray.

Mucus

Most fish produce mucus on their bodies, which acts as a protective layer that keeps the surface of the fish's body moist. The mucus is produced by goblet-shaped cells spread throughout the epidermis on the surface of the fish's body. When the fish moves, the mucus functions to reduce friction with the water by coating the uneven surface of the scales, making it easier for the fish to move in its natural habitat. Furthermore, the presence of mucus on the surface of the fish's body is also an indicator of freshness, where the formation of mucus indicates the beginning of the process of fish quality deterioration or the pre-rigor mortis phase is underway [12].

Based on the results of the Kruskal-Wallis and Mann-Whitney tests, the organoleptic score on the mucus on the surface of the mackerel body showed a significant decrease in quality as the observation time increased. At 4.00 AM (W1), the mucus score on the surface was 7.90. This condition indicates that the fish is still in very fresh condition with a clear, transparent, bright mucus layer and no color changes. This condition persisted until 8.00 AM (W2) with a score of 8.25, where the mucus layer of the mackerel fish was still in good condition and functioned as a natural protector that maintains moisture and reduces friction. Based on SNI 01-2346-2006, fresh fish has an organoleptic value of 7-9. This is characterized by clear, transparent, and brightly shiny mucus on the surface of the fish [3], [13].

The score began to decline at 11:00 AM (W3) to 5.55, indicating that the mucus on the surface of the mackerel's body began to turn cloudy and thicken, which is an early sign of quality decline. [3] SNI 01-2346-2006, a score of 5 for fish freshness is characterized by thick, clumped mucus on the surface of the fish, and starting to turn white and cloudy. [14] Fish that have a thick, sticky, white layer of mucus indicate that the fish has experienced a decline in quality. This type of mucus condition is generally a sign that the process of quality decline or decay is underway. [9], [15] The mucus secreted by the fish's body consists mostly of glucoprotein and mucus, which provides an ideal environment for bacterial growth. The release of mucus is a natural response of fish entering a phase of quality decline, where the amount of mucus released can reach 1 to 2.5% of the fish's body weight, especially during the hyperemia stage, where mucus comes out of glands in the fish's skin and forms a thick, clear layer that covers the entire surface of the body.

Furthermore, at 2.00 PM (W4), the organoleptic score for mucus appearance decreased significantly again to 3.70. This condition describes the condition of mucus that is very cloudy, thick, and sticky, and is a sign of the active fish decay process.

The addition of excessive mucus is a natural response to tissue degradation conditions, as well as a clear indicator of a decline in the quality of mackerel. This is in accordance with SNI 01-2346-2006, where a score of 5 describes the condition of the surface mucus of the fish becoming thick, clumped, and starting to turn white and cloudy [3]. The decline in fish quality is caused by bacterial activity that utilizes the mucus found on the surface of the mackerel's body. Bacteria or microorganisms easily multiply on the outer surface of the fish's body, such as the skin, gills, and intestines. This bacterial activity contributes to the fish decay process, which results in a decline in the quality of fresh mackerel [16].

3.1.2 Odor

The odor or smell of fish can be an indication that the fish has experienced a decline in quality, which then influences consumer desire to purchase. Fish aroma can originate from the activity of spoilage microorganisms or chemical reactions such as fat oxidation [14]. The organoleptic aroma score for Indian mackerel can be seen in **Fig 3**.

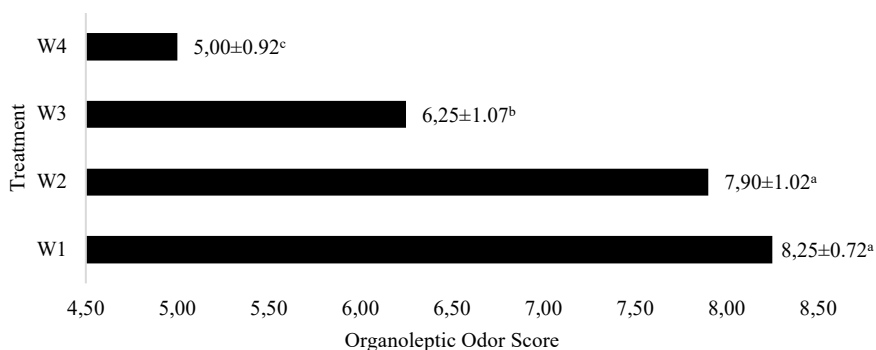


Fig 3. Organoleptic score of Indian mackerel odor

*W1 (observation time 4.00 AM); W2 (8.00 AM); W3 (11.00 AM); W4 (2.00 PM). The alphabetic showed the significance level at p-value 0.05 based on Mann-Whitney post-hoc test

Based on the results of the Kruskal-Wallis and Mann-Whitney tests (**Fig 3.**), the organoleptic aroma score of fresh mackerel showed a significant decrease in quality as the observation time increased. At 04.00 WIB (W1), the organoleptic aroma score of fresh mackerel was 8.25. This condition indicates that the fish is still in a very fresh condition. This is in accordance with SNI 01-2346-2006 [3], where a score of 8-9 organoleptic aroma of fresh fish indicates that the fish still has a fresh and specific smell of the fish type. This condition persisted until 8.00 AM (W2), where the aroma score of mackerel was 7.90.

However, at 11:00 AM (W3), a significant change in aroma occurred in fresh mackerel. This was indicated by a decrease in the score to 6.25, indicating the

disappearance or neutralization of the mackerel's specific aroma. The decrease in the aroma score indicates that the mackerel is entering the rigor mortis phase. [2] During the rigor mortis phase, a change in the fish's odor occurs. This condition will continue into the post-rigor phase. Based on SNI 01-2346-2006 [3], an organoleptic odor score of 7 in fresh fish indicates the fish has lost its specific aroma due to the onset of quality deterioration.

At 2:00 PM (W4), the organoleptic aroma score in fresh Indian mackerel decreased significantly to 5.00. During the observation process, the mackerel's odor increased, causing the organoleptic score to further decline. This condition was indicated by the emergence of an ammoniacal odor and a slight sour odor. [16] The sour odor in fish occurs due to the decomposition of chemical compounds by microorganisms. Compounds such as H₂S, ammonia, and histamine are produced by spoilage bacteria that decompose fish fat and protein, thus causing an unpleasant odor. In addition, the activity of proteins and protease enzymes from spoilage bacteria triggers oxidation that produces peroxides and hydroperoxides, which cause the foul odor in fish. This mechanism illustrates that microorganisms play an important role in the formation of the characteristic odor of fish spoilage through chemical reactions and biological decomposition. [15] Odor is an easy parameter to use to determine the freshness of fish, especially when purchased in the market. Fish quickly smell bad due to low glycogen levels, so the rigor mortis phase occurs more quickly.

3.1.3 Texture

Texture is a characteristic that describes the condition of the surface of the fish's body and can be observed through the sense of touch, so it can be used as an indicator of fish freshness. In addition, texture also includes structural elements of food products that can be physically felt by the sense of touch. Texture is one of the important parameters in organoleptic testing of fish quality and is the main aspect that influences consumer preferences for food products, so that texture can be interpreted as a parameter that reflects the physical quality of fish but also plays an important role in determining the level of consumer preference and choice of food products [12], [15]. The organoleptic score of fresh Indian mackerel texture can be seen in **Fig 4**.

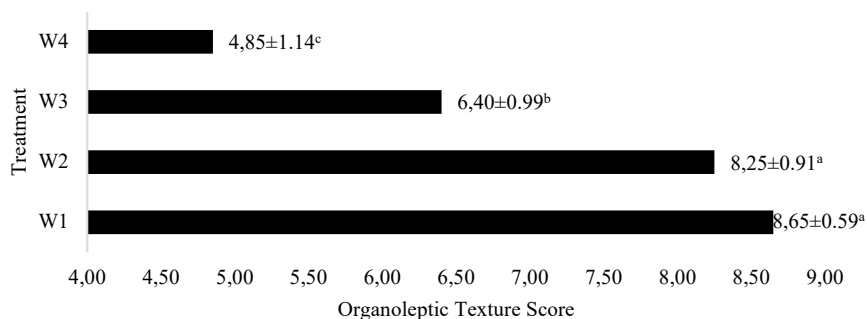


Fig 4. Organoleptic score of Indian mackerel texture

*W1 (observation time 4.00 AM); W2 (8.00 AM); W3 (11.00 AM); W4 (2.00 PM). The alphabetic showed the significance level at p-value 0.05 based on Mann-Whitney post-hoc test

Based on the results of the Kruskal-Wallis and Mann-Whitney tests (Figure 3.), the organoleptic texture score of fresh mackerel showed a significant decrease as the observation time increased. At 4.00 AM (W1), the texture of the mackerel meat was scored 8.65, which describes the texture of the mackerel meat as still dense and elastic, like a very fresh fish. However, at 8.00 AM (W2), the organoleptic texture score of the mackerel meat decreased slightly (8.25), and became somewhat dense and somewhat elastic. Based on SNI 01-2346-2006, an organoleptic score of 8-9 describes the condition of the texture of fresh fish meat, which is somewhat dense to dense, elastic when pressed with a finger, and the meat is difficult to tear from the spine [3]. Fish that have just died and are still in the pre-rigor mortis phase have a meat texture similar to that of live fish, namely chewy, elastic, and flexible. This is caused by the ongoing contraction and relaxation of the fish's muscles. Before death, the fish still has remaining ATP and products of anaerobic glycolysis, allowing its muscles to relax [17].

At 11:00 AM (W3), a significant decline in the organoleptic texture of the mackerel meat began to occur, reaching 6.40. This condition is illustrated by the texture of the fish, which began to change to become somewhat denser and somewhat elastic. This change in texture indicates that the mackerel began to experience a decline in quality as the observation period progressed. [15], [17] Immediately after being caught, physical and chemical changes occur. If the fish is not handled properly, its quality will rapidly decline. This decline in quality is caused by changes in muscle tissue due to enzymatic processes, which disrupt blood circulation carrying oxygen for metabolism. The texture of the fish meat, which was initially chewy, elastic, and flexible, gradually hardens because the remaining energy is insufficient to separate actomyosin into actin and myosin. As a result, the fish muscles begin to stiffen and harden. The formation of actomyosin from the binding of actin and myosin causes the fish meat to become stiff and tough. The texture of the fish meat becomes hard, indicating that the fish has entered the rigor mortis phase.

Changes in meat texture occurred again at 2.00 PM (W4), with a decrease in the organoleptic score to 4.85. This condition is characterized by the texture of the mackerel meat changing to a slightly softer and less elastic texture. This characteristic indicates that the mackerel meat has entered the post-rigor mortis phase. [17] The texture of the fish meat returning to being soft after previously being hard is caused by increased enzyme activity that degrades the fish meat tissue. These enzymes come from within the fish meat or are released by the surrounding microbes. The breakdown process by these enzymes produces alkaline compounds, thus causing an increase in pH. This is also supported by SNI 01-2346-2006 [3], an organoleptic score of 5, indicating the texture of the fish meat is slightly soft, less elastic when pressed with a finger, and it is quite easy to tear the meat from the spine. [10], [15] Autolysis is a process of tissue breakdown that occurs independently due to enzymes originating from within the fish's body. This process occurs when the fish enters the post-rigor mortis phase, characterized by the fish's flesh starting to decay and losing

its elasticity. When pressed with a finger, the flesh takes a long time to return to its original shape. Furthermore, during autolysis, the fish's muscles relax again, resulting in uncontrolled bacterial and enzyme activity, which leads to the degradation of the fish's muscle proteins.

3.2 Moisture content and pH

Based on the results of the study, data on the average moisture content (using the gravimetric method) of Indian mackerel meat at 4:00 AM (W1); 8:00 AM (W2); 11:00 AM (W3); and 2:00 PM (W4) can be observed in **Fig 5**. The moisture content of mackerel showed a significant upward trend during the storage period, from 70.23% at 4:00 AM to 72.96% at 2:00 PM, an increase of 3.89%. Statistical analysis showed that storage duration had a significant effect on the increase in moisture content ($p < 0.05$). This change in moisture content is an important indicator in evaluating the freshness of fish, because high moisture content makes fish susceptible to spoilage after being caught, which causes loss of nutrients and a decline in fish quality.

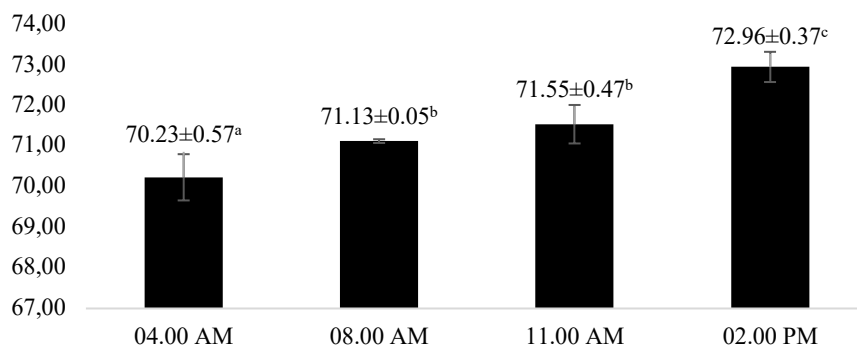


Fig 5. Moisture content of Indian mackerel

*W1 (observation time 4.00 AM); W2 (8.00 AM); W3 (11.00 AM); W4 (2.00 PM). The alphabetic showed the significance level at p-value 0.05 based on Tukey post-hoc test

Changes in moisture content during storage can be explained through several mechanisms. This study shows an interesting phenomenon where the moisture content of mackerel increases during the distribution process from the fish auction after capture to sale at the market, where storage temperature is difficult to control. This is different from the general expectation that moisture content should decrease under these conditions. The deterioration in fish quality involves complex changes, including structural changes in muscle tissue that can affect the muscle's ability to retain water. [18], the processes of autolysis and enzyme activation break down proteins, causing damage to connective tissue and muscle cells, which may cause an increase in water content with longer storage and transportation times in the supply

chain. Microorganism metabolism in fishery products can also produce extracellular enzymes that contribute to the degradation of tissue structure and the release of bound water into free water, thereby increasing water content [19].

Acidity (pH) is an indicator used as a chemical indicator of fish freshness. pH is defined as the negative logarithm of the hydrogen ion (H^+) activity in solution. In fresh fish, the pH is generally near neutral. The pH of live fish is around 7.0, and after death, it decreases to 5.8-6.2 [13]. pH of Indian mackerel can be seen in **Fig 6**.

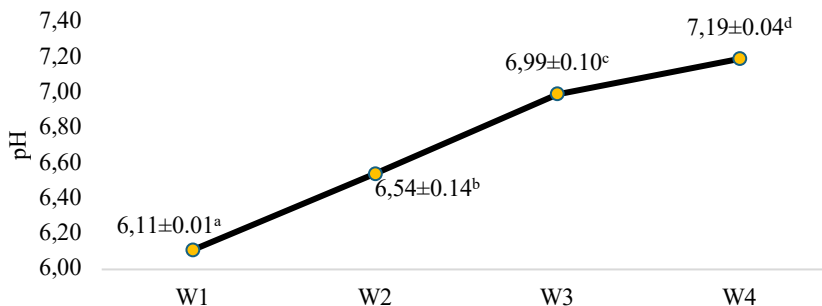


Fig 6. pH of Indian mackerel

*W1 (observation time 4.00 AM); W2 (8.00 AM); W3 (11.00 AM); W4 (2.00 PM). The alphabetic showed the significance level at p-value 0.05 based on Tukey post-hoc test

Fig 6. shows that treatments W1 to W4 significantly increased the pH value of mackerel. The pH value increased gradually from 6.11 (W1) to 6.54 (W2), 6.99 (W3), and 7.19 (W4). This indicates that the longer the observation period, the higher the pH value of the mackerel. This pH indicates a change in conditions from a slightly acidic initial state to a more neutral state. [20], the pH value of fresh fish generally ranges from 6.4 to 6.6, approaching the neutral pH of 7. Changes in pH in fish flesh affect the spoilage process, where glycolysis occurs through the breakdown of glucose into lactic acid, and the accumulation of lactic acid causes changes in the pH of the fish.

At W1 and W2, mackerel fish are in the pre-rigor mortis phase, then at W3, the fish begins to enter the rigor mortis phase, and at W4, it enters the post-rigor mortis phase. [12] In general, after the fish dies, the pH of the fish approaches neutral, which is around 6.8 to 7 (neutral). Fish quality is categorized as very good if the pH value of the meat is in the range of 6-7, considered good if the pH is less than 6, and declared poor if the pH is more than 7. Fish meat that has a high pH is caused by the formation of alkaline compounds, such as ammonia, trimethylamine, and other volatile compounds that can reduce the organoleptic value of the product. The process of glycolysis, controlled by enzymes, plays an important role in the formation of lactic acid, but the accumulation of this lactic acid is slower, so that the decrease in fish pH also occurs slowly. During storage, the protein in fish meat undergoes decomposition into alkaline compounds, including ammonia, through the activity of proteolytic enzymes and the help of microbes. This is also supported by the organoleptic odor

score value (Figure 2.) in Indian mackerel, where in the pre-rigor mortis phase, the odor/aroma of the fish is still specific to the species, and when entering the post-rigor mortis phase, the odor/aroma changes to an ammoniacal and slightly sour odor.

3.3 Total Plate Count (TPC)

The numbers of viable bacteria could be detected by using Total Plate Count that showed the number of total bacteria of the fish. The result showed that the overall TPC was still acceptable based on Indonesian National Standards (SNI) which the values under 5.0×10^7 (**Table 1.**) The condition of viable bacteria at 4.00 AM (W1) and 8.00 AM (W2) were not significantly different, the number was still under 4 logs of bacteria that showed the freshness both in the wholesaler and beginning of retailer. The primary number of bacteria could be affected by the polluted water or due to secondary contamination during handling or that probably comes from the psychotropics bacteria that could perform under low temperature [21], [22]. Meanwhile, the activity of bacteria was significantly increase at 11.00 AM (W3) into 5.63×10^5 that can be affected by the gradual increase of spoilage bacteria such as *Pseudomonas* by the increasing temperature due to the melted ice crush [23]. The increasing pH also chance for halophilic bacteria to increase at 2.00 PM (W4) with the total number 2.06×10^6 . Thus, the total plate count result was still permissible to consume since the number under the SNI guidelines [24].

Table 1. Total Plate Count data of fresh fish during supply chain

Sampling time	TPC
4.00 AM	1.50×10^4 (a)
8.00 AM	4.34×10^4 (a)
11.00 AM	5.63×10^5 (b)
2.00 PM	2.06×10^6 (c)

*The alphabetic showed the significance level at p-value 0.05 based on Tukey post-hoc test

3.4 Total Volatile Base (TVB)

The results showed a significant increase ($p < 0.05$) in the TVB value of mackerel (*Rastrelliger* spp.) during a 10-hour storage period at room temperature (**Fig 7.**) The TVB value increased significantly from 10.47 mg/N at 4.00 AM (W1) (hour 0) to 16.01 mg/N at 2.00 PM (W4) (hour 10). This increase reached 52.9% of the initial value, indicating a significant deterioration in fish quality. This consistent pattern of TVB increase is in line with studies conducted by [25], [26], which state that TVB is a reliable indicator for evaluating the rate of fish quality deterioration during storage. According to European Union standards (EC No. 2074/2005), the maximum TVB

limit for fresh fish is 25-30 mg/100 g, so the results of this study indicate that mackerel is still in the category of fit for consumption until the end of the observation period.

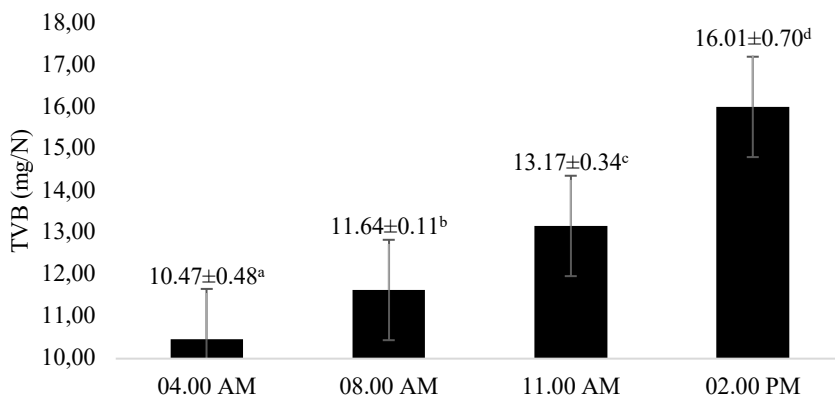


Fig 7. TVB of Indian mackerel

*W1 (observation time 4.00 AM); W2 (8.00 AM); W3 (11.00 AM); W4 (2.00 PM). The alphabetic showed the significance level at p-value 0.05 based on Tukey post-hoc test

The increase in TVB levels is caused by the activity of microorganisms and endogenous enzymes that break down proteins and other nitrogen compounds in fish into volatile nitrogen compounds, mainly ammonia, triethylamine, and dimethylamine [27], [28]. This decomposition process is accelerated by room temperature conditions that are optimal for mesophilic bacterial growth. [29] shows that the activity of *Pseudomonas* spp., *Shewanella putrefaciens*, and *Enterobacteriaceae* bacteria is the main cause of volatile nitrogen compound formation in fish stored at uncontrolled temperatures. The rate of increase in TVB in this study was 0.55 mg/100g per hour, which indicates a relatively high rate of deterioration compared to fish stored at cold temperatures. Storage at low temperatures can slow down or even stop the activity of microorganisms and enzymes in fish, thereby reducing the rate of formation of volatile base compounds that cause deterioration in the quality of fresh fish [30].

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