Preserving the freshness of the quality of the fish caught on small fishing vessels: A comparative analysis between solar-powered chiller and conventional ice cooling

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Abstract. Fishers use various methods to preserve the freshness of the fish caught on fishing vessels. Some of these methods include the use of ice in the fish storage box and cooled seawater produced by a solar-powered chiller. This study aimed to compare the quality of fish stored in cooled seawater produced by a solar-powered chiller and icy storage boxes by applying the Indonesian National Standard 2729:2013, as a benchmark for the national standard for fish freshness. The study was conducted from February to August 2024. The results of the organoleptic tests of fish samples showed a significant difference between the performance of cooled seawater produced by a solar-powered chiller and an icy fish storage box (cool boxes with ice) particularly in the eyes, gills, body surface mucus, meat, smell, and texture. However, there was no significant influence of the panelist's observation on fish condition. Rather, the condition of the fish was primarily affected by the chosen cooling method.
Key Words: chiller, fish freshness, organoleptic test.

Introduction. Fish quality is one of the factors that determine its market price. The higher the quality, the higher the selling price of fish. Fresh fish do not undergo any preservation treatment, except for refrigeration. Therefore, ice cooling process of fish on board is crucial. Fish handling must meet the requirements of good fish handling practices, both regarding handling facilities and methods, including the use of ice as a cooling agent (Sakina 2022). The handling process preserves fish after being caught, to prevent spoilage, which can result in a decrease in the quality of organoleptic, chemical, and physical factors that affect the price (Irianto 2008). However, 69% of landed tuna is sold only in the domestic market because its quality does not meet export standards (Sakina 2022).

Proper handling of fish caught onboard is essential for preventing fish decay and preserving fish quality, so that the price remains high (Irianto 2008). Pondok Dadap Fishing Port in Sendang Biru, Malang Regency, falls within Fisheries Management Area (FMA) 573, based on Ministry of Marine Affairs and Fisheries regulation No. 18 of 2014 concerning Fisheries Management Area of the Republic of Indonesia. Pondok Dadap fishing port is a major landing place for fish with a large catch potential (Furqan 2017). The predominant fish in the area are tuna, mackerel tuna, and skipjack tuna (Firdaus 2018), as shown in Figure 1. The volume of tuna production at PPP Pondok Dadap, from 2017 to the end of 2021, reached a total 10,075 kg (Nasution et al 2023). Tuna products, the second largest exported Indonesian fishery commodities after shrimp, counted 14 percent of the total export value, contributing approximately 352 million USD, in 2009 (Lailossa 2015). Additionally, the other fish caught in the area is ribbonfish (*Trichiurus lepturus*). *T. lepturus* has become a high-value commodity in both domestic and export markets (Hermawan 2020).

Fish catch depends on the seasonality. In February, the catch primarily consisted of tuna and skipjack, whereas in June and the following months, ribbonfish also appeared. Tuna is among the predominant fish species caught in Sendang Biru Malang. Tuna fish belong to the family Scombridae and *Thunnus* species. One type of tuna commonly caught by fishers around fish aggregating devices (FADs) scattered in the waters off the south coast of Malang is *Thunnus albacares*. Mackerel tuna is also one of the predominant fish caught in Sendang Biru waters Malang. Similarly to tuna, mackerel tuna belongs to the Scombridae family, however it is classified under a different genus, *Euthynnus*. Mackerel tuna (*Euthynnus affinis*) lives in groups with a large number of members. Mackerel tuna is primarily caught by longline fishing. Mackerel tuna is an economically important fish with a fairly large export volume (Hapsari 2014). The other type of tuna in Sendang Biru Malang is the skipjack tuna (*Katsuwonus pelamis*). Skipjack tuna is a member of the Scombridae family and is the sole species within the genus *Katsuwonus,* which is a large pelagic fish that lives in groups. Skipjack tuna is a highly dynamic and migratory species, with a wide distributed both vertically and horizontally (Hidayat et al 2019). Tuna, mackerel tuna and skipjack tuna can be seen in Figure 1.

Figure 1. Fish caught in Sendang Biru (a) *Thunnus albacares*, (b) *Euthynnus affinis,* and (c) *Katsuwonus pelamis.*

The other commercially significant caught fish is ribbonfish. According to Sendang Biru fishers, ribbonfish (*Trichiurus lepturus*) are caught between June and August each year. Ribbonfish have the following morphological characteristics: a very long, flat body and a long tail like a whip. Its skin is not scaly, and its color is white like silver, and slightly yellowish (Figure 2). Ribbonfish is easily ruptured after being caught, especially if it is handled incorrectly.

Figure 2. *Trichiurus lepturus.*

One type of tuna fishing boat in Sendang Biru, Malang Regency, is a ≤5 gross tonnage (GT) with a length of approximately 11 meters. Under Regulation No. 5 of 2021 (The Government of the Republic of Indonesia 2021) concerning Risk-Based Business Licensing, the fishing boats are organized in small fishing vessel groups (The Government of the Republic Indonesia 2021). Fishers usually bring ice on board to preserve the freshness of the fish caught. The ice and the fish are placed together in the same box. However, the problem occurs when the fisher's catches are abundant. Fishers must release ice in the fish storage box for abundant fish. This can reduce the quality of fish.

Tuna, one of the predominant fish caught in Sendang Biru Malang, experiences an increase in body temperature after being caught. According to Irianto (2008), to maintain the freshness of tuna, the internal temperature of the fish must be immediately lowered by placing it in ice-cooled seawater for no more than 24 hours. The use of cooled seawater is an alternative method for fishers to substitute ice. According to Setiawan et al (2024), a cooled seawater chiller on a small fishing vessel can be produced using a solar-powered chiller, as shown in Figure 3.

Figure 3. Small fishing vessel with solar powered chiller on board.

The freshness of the caught fish can be determined by its physical appearance (Nasution 2010). One of the indicators of fresh fish quality is the Indonesia National Standard ~~SNI~~ number 2729 of 2013 (Badan Standardisasi Nasional 2013). The NSI provides a sensory or organoleptic test in Appendix A for the freshness of the fish.

This study aimed to analyze the performance of the caught fish preserved using ice in a fish storage box and cooled seawater produced by a solar-powered chiller on board, and the analysis was based on SNI 2729:2013.

Material and Method

Description of the study times and sites. This study was carried out from February to August 2024. Sampling activities took place along the East Coast of Pondokdadap Fishing Port, Sendang Biru, Malang, East Java, Indonesia, as illustrated in Figure 4.

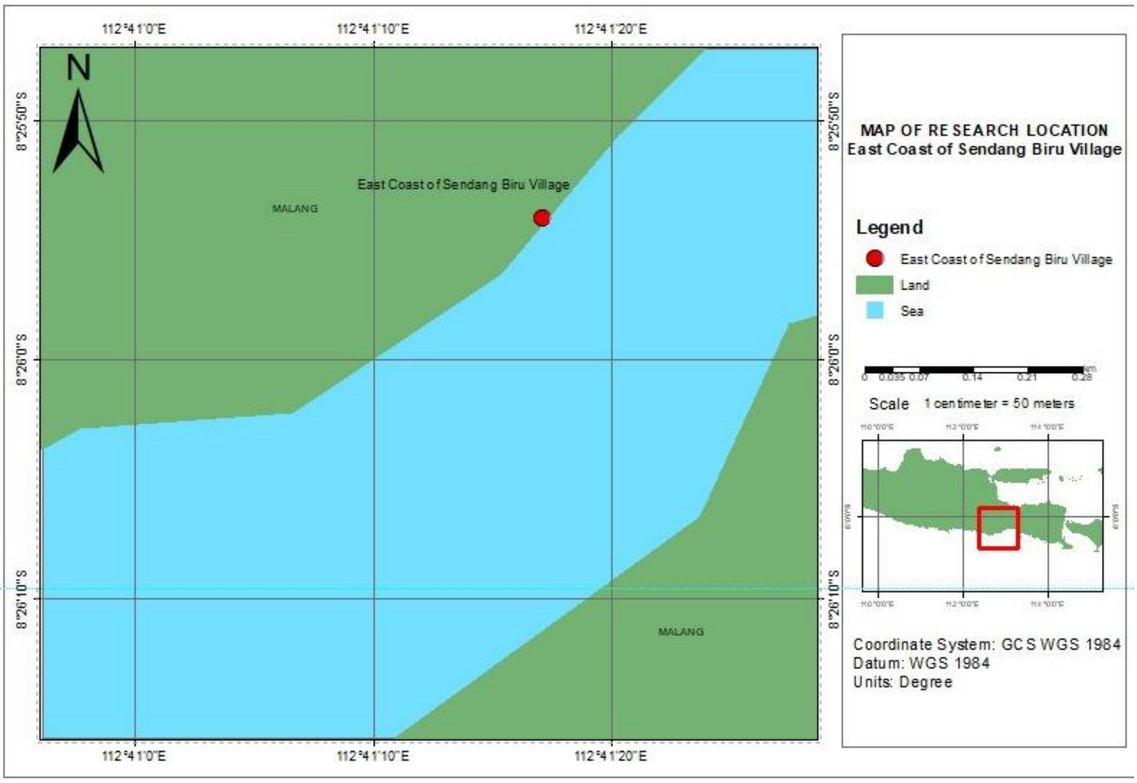

Figure 4. Sampling location.

Method. The method used in this study consists of comparing the physical appearance of fish stored in cooled seawater with those stored in iced coolboxes. The cooled seawater was produced using a seawater cooling engine on a small fishing vessel with a gross tonnage (<5 GT). After catching the fish, the fishers placed each caught fish in two boxes: one in a storage fish box containing cooled seawater and one in a storage fish box containing ice, as shown in Figure 5. Random sampling was carried out by taking 5 fish from the cooled seawater-fish storage box and 5 fish from the icy fish storage box when the fishers reached the fishing port. The samples were tested by six panelists in February 2024 using organoleptic (sensory) tests referred to the Indonesian National Standard (INS) number SNI 2729:2013 concerning fresh fish quality standard. The organoleptic assessment was performed on the eyes, gills, skin mucus, and smell using a scoring test (Sakina et al 2021; Amir et al 2024). Fresh fish will be classified as defective if the organoleptic observation value is less than 7 (Sakina 2021). In August 2024, organoleptic tests were conducted again with one panelist, and five ribbonfish from each sample were collected.

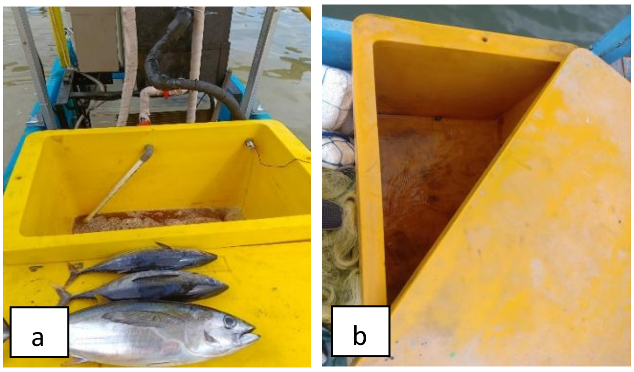

Figure 5. Boxes used for keeping fish fresh: (a) cooled seawater produced by solar-powered chiller, (b) ice.

Data analysis. The organoleptic (sensory) test was conducted by observing the physical characteristics of the caught fish, including the appearance of the eyes, gills, surface mucus, meat, smell, and texture. An organoleptic score sheet was used to identify the fish's quality. The score interval was between 1 and 9, and the minimum organoleptic quality requirement was 7.0. An organoleptic value <7 indicates that the product is of low quality and does not meet quality standards; when the value is >7, the quality of the fish is classified as good and worthy of being marketed. The organoleptic scoring sheets used are listed in Table 1.

Table 1

Organoleptic test score sheet

Specification	*Mark*
1. Appearance	
a. Eyes	
Convex eyeballs, clear cornea and pupil, shiny specific to fish type	9
Flat eyeballs, clear cornea and pupil, slightly shiny specific to the type of fish	8
The eyeballs are flat, the cornea is slightly cloudy, and the pupil is slightly grayish, and slightly shiny, specific to the type of fish	7
The eyeballs are slightly sunken, the cornea is slightly cloudy, and the pupil is slightly grayish, and slightly shiny specific to the type of fish	6
The eyeballs are slightly sunken, and the cornea is cloudy. Pupils are slightly greyish, not shiny	5
Sunken eyeballs, cloudy cornea, grayish pupils, not shiny	3
The eyeballs are very sunken, the cornea is very cloudy, and the pupils are gray, not shiny.	1
b. Gills	
The gills are dark red or reddish brown, bright with very little transparent mucus	9

Specification	Mark
The gills are dark red or reddish brown, less bright with a little transparent mucus	8
The color of the gills is pink or light brown with a little slightly cloudy mucus	7
The gills are pink or light brown with slightly cloudy mucus	6
The color of the gills is pale pink or light brown with cloudy mucus	5
The color of the gills is gray or grayish brown with lumpy milky white mucus	3
The color of the gills is gray, or grayish brown with lumpy brown mucus	1
c. Body surface mucus	
Clear, transparent, bright shiny mucus layer	9
Clear, transparent, fairly bright mucus layer	8
The mucus layer starts to get a bit cloudy	7
The mucus layer starts to become cloudy	6
Mucus is quite thick, starting to change color	5
Thick mucus slightly lumpy, changes color	3
Thick, lumpy mucus that changes color	1
2. Meat	
The meat cut is very bright, type-specific, the meat tissue is very strong	9
Specific type of brilliant meat cut, strong meat tissue	8
Meat cut is slightly less shiny, and meat tissue is strong	7
Meat cuts are less bright, and meat tissue is slightly less strong	6
The meat cuts start to fade, and the meat tissue is less strong	5
Dull meat cuts, meat tissue is not strong enough	3
The meat cut is very dull, and the meat tissue is damaged	1
3. Smell	
Very fresh, specific strong type	9
Fresh, specific type	8
Fresh, less specific type	7
Neutral	6
Slight sour smell	5
Strong sour smell	3
Strong foul odor	1
4. Texture	
Dense, compact, very elastic	9
Dense, compact, elastic	8
Slightly soft, slightly elastic	7
A bit soft, a bit less elastic	6
A bit soft, less elastic	5
Soft finger marks are visible and very slow to disappear	3
Very soft, finger marks don't disappear	1

The organoleptic test observations of the samples were then analyzed. T-tests and analysis of variance were used for statistical analysis. A t-test was conducted to compare the effectiveness of the two fish cooling facilities based on the observation values of organoleptic tests (eyes, gills, mucus, meat, smell, and texture), with the hypothesis that there was no difference between the two cooling facilities. ANOVA or variation analysis was used to compare the differences in the values of the test samples based on variables (methods, fish samples, and panelists).

Results

Quality of caught fish. The fish-handling process on board plays a very important role in the fishing industry, because it can affect the quality of the processed catch. Once the fish are caught, preservation must be carried out as soon as possible through a fast and accurate cooling or freezing process. The better the handling technique, the better the quality of the fish. The panelists observed the quality of the fish and recorded it on an organoleptic score sheet. This method involved touching, pressing, and smelling the fish. First, the fish were observed as a whole, especially the eyes and gills, and the presence of mucus. Second, the panelists observed the condition of the fish by touching them, especially in the presence of mucus, and by assessing the elasticity of the fish. Third, the textures were assessed by pressing the fish meat. Fourth, the fish were smelled. The results of the statistical test (t-test) on sample observations in February were based on observations of the eyes, gills, mucus, meat, smells, and textures (Table 2). There were 6 panelists to observe 5 fish taken from chiller and 5 fish taken from icy fish storage. According to the t-test results, there was significant differences between fish taken from chiller and icy fish storage ($p<0.05$) based on eyes, gill, body surface mucus, meat, smell, and texture. The panelists of each group gave the same score for gill and texture of fish, which resulted in not available t values.

Table 2

Result of organoleptic t-test

No	*Test*	*Mean of cooled seawater – solar-powered chiller group*	*Mean of icy fish storage group*	*Statistics (level of confidence 95%)*
1	Appearance			
a	Eye	9	6.93	t-test: 31.00, p=0.0000, df=58
b	Gill	9	7	there is no t test result, all panelist gave same score for each method
c	Body surface mucus	9	6.93	t-test: 44.62, p=0.0000, df=58
2	Meat	9	6.73	t-test: 23.84, p=0.0000, df=58
3	Smell	9	7	there is no t test result, all panelist gave same score for each method
4	Texture	9	6.8	t-test: 29.62, p=0.0000, df=58

The ANOVA test showed the effect of cooling method (chiller and icy fish storage) and panelists observation to eye, gill, body surface mucus, meat, smell, and texture of fish, as shown in table 3. The result indicated that the cooling method significantly influenced the eye, gill, body surface mucus, meat, smell, and texture of fish ($p<0.05$). However, there was no significant influence of the panelist's observation on fish condition.

Table 3

Result of ANOVA test

No	*Sensory test*	*ANOVA method*	*ANOVA panelists*
1	Appearance		
a	Eye	F=909.52, p=0.0000	F=0.38, p=0.8612
b	Gill	All panelists gave same score	All panelists gave same score
c	Body surface mucus	F=2214.48, p=0.0000	F=2.30, p=0.0574
2	Meat	F=589.12, p=0.0000	F=1.43, p=0.2298
3	Smell	All panelists gave same score	All panelists gave same score
4	Texture	F=961.95, p=0.0000	F=2.12, p=0.0773

Based on the statistical test, the method of cooling using seawater produced by solar powered chiller had a significant influence on the quality of the caught fish. It can be seen from the eyes, gill, body surface mucus, meat, smell and texture of fish, which were in better conditions than in fish preserved in the icy storage.

The results of the test showed that the quality of fish stored in a cooled seawater box was better than that of fish stored in icy storage boxes, as shown in Figure 6.

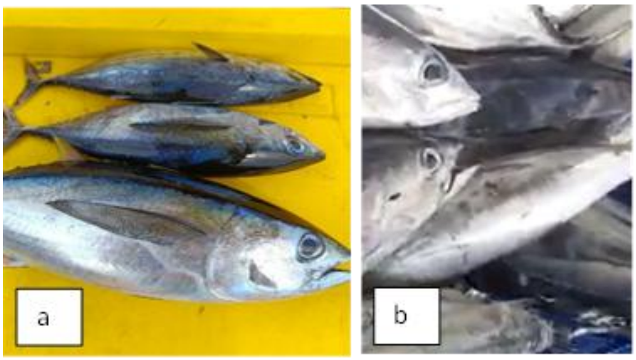

Figure 6. The appearance of eyes of fish keeping in (a) cooled sea water and (b) icy storage box.

Table 4 shows the appearance of the eyes, gills, skin surface layers, and fish meat from organoleptic tests.

Table 4

The appearance of caught fish stored in a seawater cooling machine

SNI 2729:2013 *Noted*	*Organoleptic test results* *Fish in cooled seawater – solar powered chiller*
Eyes Convex eyeballs, clear cornea, and pupil, shiny, specific to the type of fish	
Gill The color of the gills is blood red or brownish red with a thin layer slightly of cloudy mucus.	
Body surface layer Clear, transparent, shiny, bright mucus layer	
Meat The cut of the meat is very bright, the meat tissue is very strong.	

In August, organoleptic tests were performed once again to verify whether the results were the same as those of previous tests and also because it was the ribbonfish's (*Trichiurus lepturus*) season. Ribbonfish has a different body type from tuna; thus, to obtain more data, an organoleptic test should be performed. Sensory observations were performed by a panelist according to SNI 2729:2013. The results of the observations showed a significant difference in the values between fish stored in the seawater-cooled fish storage box and those in the icy storage box, suggesting that the seawater-cooled storage box is organoleptically superior to the icy storage boxes. Fish stored in cooled seawater had better quality than those which stored in icy storage boxes. The results of the organoleptic observations of the catch in August are shown in Table 5.

Table 5

Organoleptic t-test results of ribbon fish

Parameters	*Cooled sea water - solar powered chiller*	*Icy fish storage*
Mean	8.9	6.8
Variance	0.012	0.048
Observations	6	6
Pooled variance	0.03	
Hypothesized mean difference	0	
df	10	
t Stat	21	
P(T<=t) one-tail	6.6564E-10	
t Critical one-tail	1.812461123	
P(T<=t) two-tail	1.33128E-09	
t Critical two-tail	2.228138852	

Furthermore, based on ANOVA test results, the organoleptic tests indicate that the cooling method significantly affected the caught fish condition, as shown in Table 6.

Table 6

Organoleptic ANOVA test results of ribbon fish

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Method of cooling	68.6667	9	7.6296	79.2308	1.34E-24	2.0957
Sensory to be tested	1.3333	5	0.2667	2.7692	0.0289	2.4221
Error	4.3333	45	0.0963			
Total	74.3333	59				

Discussion. Based on the results of organoleptic tests, the use of a cooled seawater fish storage box effectively preserves fish freshness, maintains the quality of fish in good condition, and prevents damage and decay. The damage mainly occurs in the physical condition of the fish: a protruding stomach, a loose head, and a bruising which can accelerate the decomposition process of fish, thus affecting the level of buying, selling, and consumer acceptance of fish. However, the use of a cooled seawater storage box contributes to preserve fish freshness. A ruptured stomach is a form of damage observed in the organoleptic test of ribbonfish in August 2024. Fish that experienced a ruptured stomach (pp) and were stored in an icy fish storage box were more damaged, with 25 kg or 25% of the total fish caught, than the fish stored in cooled seawater fish storage boxes, that were only 8 kg or 11% of the total fish caught (Table 7). Fish in the icy storage box, being directly exposed to physical contact with ice, were subjected to pressure and damage (Lestari et al 2015).

Table 7

Comparison of the number of fish experiencing stomach rupture

No	*Fish size (kg)*	*Price (USD)*	*Fish kept in cooled seawater – cooling engine*		*Fish kept in icy fish storage box*	
			Quantity (kg)	*Total price (USD)*	*Quantity (kg)*	*Total price (USD)*
1	3	1.9	16	30.4	25	47.5
2	2	1.29	38	49.02	35	45.15
3	1	0.61	9	5.49	15	9.15
4	Stomach rupture	0.36	8	2.88	25	9
	Total		71	88	100	111

The decline in fish quality also affects the price of the caught fish, as shown in Table 7. Fish of various sizes, that experience a ruptured stomach, are sold for only USD 0.36 (equivalent IDR 6,000.00). In contrast, the fish with a size of more than 3 kg and good quality conditions are sold for USD 1.9 (equivalent to IDR 31,000.00). Conventional fish cooling processes using ice cubes have limitations in terms of storage mechanisms and cooling times. The limitations of the storage mechanism are in the form of placing the caught fish in piles and direct contact with the ice. This affects the skin and meat surfaces of the fish. In addition, storage using ice cubes reduces the freshness over time (Herawanty et al 2021). The use of a cooled seawater fish storage box is more effective in maintaining the quality of fish caught because cold seawater will moisten the entire body the fish, both on the surface of the skin and inside the body. This aligns with Irianto (2008), who stated that to preserve the freshness of tuna, it is recommended to rapidly reduce its internal temperature by immersing it in ice-cooled seawater, ensuring full and direct exposure to the cooling medium. Good and appropriate fish handling methods produce high-quality products that are safe for consumption and not easily damaged. There are three keys to preserving fish quality: proper handling, rapid cooling, maintaining the cold chain and good sanitation (Beverly 2011).

Conclusions. The results of the organoleptic tests of fish samples showed a significant difference between the performance of a cooled seawater produced by solar powered chiller and an icy storage box (coolboxes with ice). There were significant differences in the eyes, gills, surface layers, meat, smells and textures between caught fish kept in cooled seawater and in icy storage. However, there was no significant influence of the panelist’s observation on fish condition. The differences in fish quality were primarily influenced by the cooling method rather than by a subjective evaluation of the panelist.

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

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