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# The Design of Refrigerated Portable Fish Storage Prototype for Small Scale Fisheries

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***Abstract*— Indonesia as one of the biggest capitals with fisheries industry have more than 90% small-scale fisher spread around the nation. Sadly, in some region, small scale fishers not really implement the proper fish storing method due to the lack of space in their vessel and limited technology. This issue has led to a new idea to build a portable cooling fish storage specifically for small scale fisheries. The aim of this studies is to build and test the performance of prototype of portable fish storage. The method used is direct testing by doing several tests such as power consumption test, temperature decreasing rate, and cost simulation efficiently with some condition and variables. The performance test resulted that power consumption of portable refrigerated fish storage around 374,94 - 651,93 watt with temperature decreasing rate of 0,5 C/minutes. In cost simulation, the portable refrigerated can save up to 90% rather than a traditional fish storage.**

*Keywords*— *cost efficiency, fish quality, portable mini fish box*

## I. Introduction

Fish is a perishable commodity that spoils quickly. The high water and protein content in fish, compared to other consumables, is believed to be the main reason for its susceptibility to bacterial growth [1]. This makes fish as product that cannot last long at room temperature without proper preservation [2]. Moreover, the maximum freshness of fish come only when it was landed on ship and will only decrease in the logistic process [3].

One critical element in fish handling process is the storage method used in post-capture process, especially when the fish still on the vessel board. The storage method on the vessel is key to determining the quality of fish in the further distribution chain. Traditionally, fishermen often choose ice as preservation method to maintain the quality of fish while on board. Unfortunately, using ice has several drawbacks. Large and coarse ice chunks can cause physical damage such as bruises and cuts on the fish's skin. These injuries can accelerate the decay procession by bacteria. Additionally, the use of ice take space on vessel's load and reduces the available space for storing fish. Not only that, but the use of ice can also only maintain storage temperatures for a short and limited period of time before it turns back into water [4]. This burden characteristic of ice have influent fishermen's decisions to bring ice during fishing operations, especially when given the unpredictability of catch quantities in each fishing trip [5].

The use of a refrigeration system can be one of the solutions to the problem of fish storage on board. This system, commonly found in devices like refrigerators and freezers. With refrigeration, the quality of the fishermen's catch can be maintained for longer periods. One innovative solution is portable fish storage, a small-scale cool box equipped with a refrigeration system powered by electricity. Previous research has focused on portable cooling solutions, such as [6] who developed an eco-friendly portable cooler prototype, [7] who designed an ice-making machine for boats, and [8] who innovated a fresh fish transportation tool for mobile vendors. However, there has been no development of a portable cooling hold that meets fishermen's needs and is ready for practical use. Thus, the portable mini fish box is needed. It is designed for small-scale fishermen, offering advantages like compact size, practicality, automatic power-saving features, and ease of use compared to permanent holds on fishing vessels.

## II. METHOD

The research was conducted from December 2022 to April 2023. The study activities consisted of the assembly and testing phases of the equipment. The assembly and testing of the portable fish storage prototype were carried out at the Faculty of Fisheries and Marine Sciences, IPB University campus. The research used data collected directly by the researcher through various trials.

The calculation of power requirements for the portable fish box was performed using an Arduino data logger, which recorded the current power consumption in watts and the total power requirement during operation in kWh. Power consumption was recorded with 7 repetitions over 360 minutes for two conditions: without load and with a 4 kg load. The effectiveness of the portable fish box performance was assessed based on the temperature changes of the electric fish storage. Experiments were conducted with two treatments under two different conditions. Each treatment in each condition was tested with 5 repetitions. In the first treatment, the portable fish storage was tested empty, while in the second treatment, it was tested with a 4 kg fish load.

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The cost efficiency calculation was based on the difference in operating costs between the electric-powered portable fish storage and conventional ice-based cooling. The efficiency calculation compared the monthly operational cost savings and the break-even point between the electric-powered portable fish storage and conventional cooling.

The energy requirement analysis will refer to the power usage of the portable fish storage prototype per unit of time. To determine the energy requirements, the formula from [9] can be use as follows:

$$P_{KWH} = P_{kilowatt} \times t / 1000 \quad (1)$$

with,
$P$ = Power Requirement
$t$ = Time Needed (hour)

The performance effectiveness analysis of the portable fish storage prototype will be conducted using a comparative performance method, which will measure the cooling time and the rate of temperature decrease. The formula used to determine performance is the temperature drop rate [10]:

$$V = \frac{\sum T_o - T_i}{t} \quad (2)$$

Where,
$V$ = Temperature Decrease Rate (Celcius/minutes)
$T0$ = Initial Temperature (Celcius)
$Ti$ = Temperature on-i minutes (Celcius)
$t$ = time (minutes)

The cost efficiency analysis refers to the calculation of operational and investment costs of the equipment. According to [11], the formula that can be used to calculate the efficiency savings between conventional ice-based cooling and the electric-powered portable mini fish box is as follows:

Savings Rate (%) = (OCp / OCe) x 100% (3)

with,
OCp = Operational cost of portable refrigerated storage per-month
OCe = Operational cost of conventional ice storage on per-month

Meanwhile, to determine the break-even point (BEP) in months, the calculation formula described by [12] is needed, as follows:
*BEP = cost savings / total cost difference* (4)

## III. Results And Discussion

### *A. The Portable Refrigerated Design Process*

The portable fish storage prototype operates based on the principles of a refrigeration machine. A refrigerator (cooling machine) consists of component series that are capable to lower the temperature on a specific space until its below its surrounding environment by forming a cooling cycle [13]. The process of creating the portable fish storage prototype begins with the technical drawing of the prototype, including front and side views, along with the measurements used.

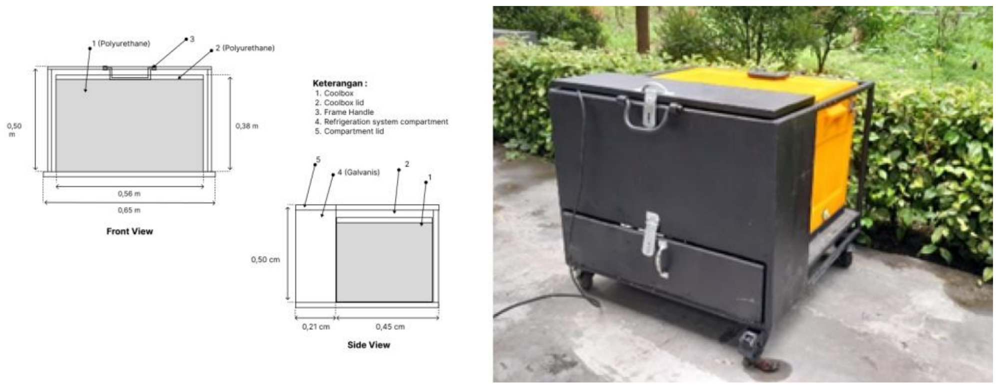

Figure. 1. The Design of Portable Refrigerated Fish Storage

One relevant size reference for a portable fish storage prototype suitable for small-scale fishermen is a coolbox with a capacity of 50 liters and dimensions of 56x45x38 cm. Based on these measurements, the design model for the portable fish storage prototype can be created using SketchUp software. This model integrates a coolbox, a steel frame, and a refrigeration system consisting of a compressor, condenser, evaporator, and capillary tubes.

The power usage testing of the portable mini fish box was conducted with 8 repetitions under two different variable conditions over 360 minutes (6 hours). These conditions included cooling without a load and cooling with a 4 kg load. This experiment measured the total power consumed, the lowest power required, and the highest power required for each condition.

### *B. Portable Refrigerated Energy Requirement*

The power usage testing of the portable mini fish box was conducted with 8 repetitions under two different variable conditions over 360 minutes (6 hours). These conditions included cooling without a load and cooling with a 4 kg load. This experiment measured the total power consumed, the lowest power required, and the highest power required for each condition.

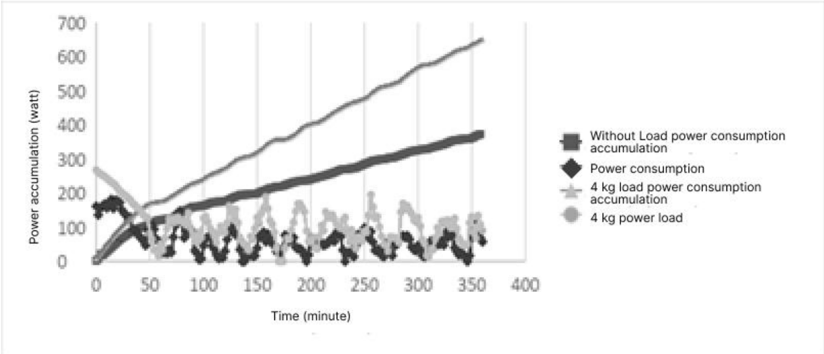


Figure. 2. Portable Fish Storage Power Consumption Diagram

In the power consumption test without load, it can be observed that power consumption fluctuates over time. The highest consumption reached 359.7 watts, while the lowest was only 16.22 watts. The cumulative consumption steadily increased, reaching 374.94 watt-hours by minute 360, equivalent to 62 watts per hour. Meanwhile, in the test with a 4 kg load, power consumption tends to have a wider range compared to the no-load condition. However, power consumption with the 4 kg load is generally more stable, with a minimum of 101.27 watts and a maximum of 285.21 watts. Over 360 minutes, the cumulative power consumption for the loaded cooler amounted to 651.93 watt-hours. This translates to approximately 108.565 watts per hour. Compared to the cumulative power consumption without load, this represents an increase of 1.7 times.

One of the factors contributing to differences in power consumption, according to [14], is the varying cooling loads used. The cooling load affects the duration required to lower the cooler's temperature to the desired level, thereby impacting the total electricity consumption per unit of cooling time. The larger the load that needs cooling, the greater the total electricity consumption. Another factor influencing power usage is the thermal insulation performance of the cooler. Thermal insulation systems consist of modules or materials used to prevent heat penetration into the refrigerated space [15]. The choice of materials and insulation thickness in a cooler significantly affects energy consumption. As noted in research by [16], opening the refrigerator door every 5 minutes imposes heavier compressor workload compared to opening it every 10 minutes.

*C Portable Refrigerated Prototype Performance*

Based on the test results, it can be observed that the conditions and the amount of cooling load affect the cooling rate of the cooler. The greater the load to be cooled, the longer it takes to lower the cooler's temperature. Comparing the experiments under cloudy conditions without load and with a 4 kg load, in the unloaded condition, it took 34 minutes to reach 5°C, whereas with a 4 kg load, it took 58 minutes starting from an average initial temperature of 25°C. The difference in cooling time between these two variables indicates that the cooling load significantly affects the time required to cool the coolbox. The respective times required to reach 5°C under hot conditions without load and with a 4 kg cooling load were 68 minutes and 76 minutes, respectively. For instance, the portable fish storage can decrease coolbox temperature with 0,5C$^{o}$/minutes rate or around 30$^{o}$C/ hour.

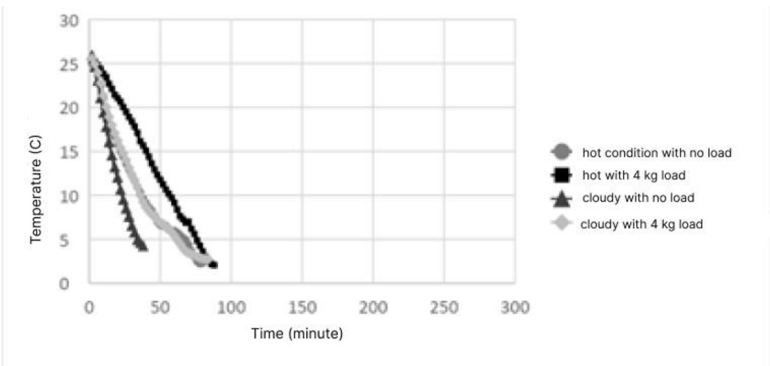


Figure. 3. Temperature Decreasing Rate Diagram of Portable Fish Storage

In this scenario, it is evident that the cooling load affects the time required to cool the coolbox. This is supported by [17], who states that cooling time increases with higher cooling loads. Further calculations reveal that the temperature reduction rates in each condition also exhibit varying tendencies. Sequentially, The variation in cooling rate is influenced by several factors, including the cooling load, electrical voltage supply, and environmental temperature differences. The cooling load directly impacts the cooling calorie requirement to achieve a specific temperature, as formulated in the laws of thermodynamics governing heat transfer, where heat transfer is directly proportional to the mass to be cooled—meaning the cooling calorie requirement increases with the cooling mass [18]. The electrical voltage source affects the refrigeration system's performance by determining voltage, current, and power input. Power fluctuations resulting from machine performance and other device usage on the same electrical system affect the power input into the refrigeration system. This is influenced by the constant value of the current used in the refrigeration system, which was not controlled in this study [18]. Environmental temperature also plays a crucial role in heat transfer during the cooling process. In hot conditions, the ambient temperature ranges from 30–36°C, whereas in cloudy conditions, it ranges from 23-30°C. These environmental differences affect the amount of environmental heat entering the mini fish box. Higher ambient temperatures lead to increased heat influx, thereby prolonging the time required for the storage space to reach a specific temperature [19].

*D Portable Refrigerated Prototype Cost Efficiency*

Cost calculations are based on investment costs, fixed costs, and operational costs of the portable mini fish box compared to conventional refrigeration. For the cost calculation of the portable mini fish box, the reference electricity cost is based on the electricity tariff per kWh under the R1/TR 2,200 VA tariff in 2023, valued at Rp1,447.00 per kWh. This tariff is chosen because households of fishermen typically have electrical inputs ranging from 1,300 to 2,200 VA.

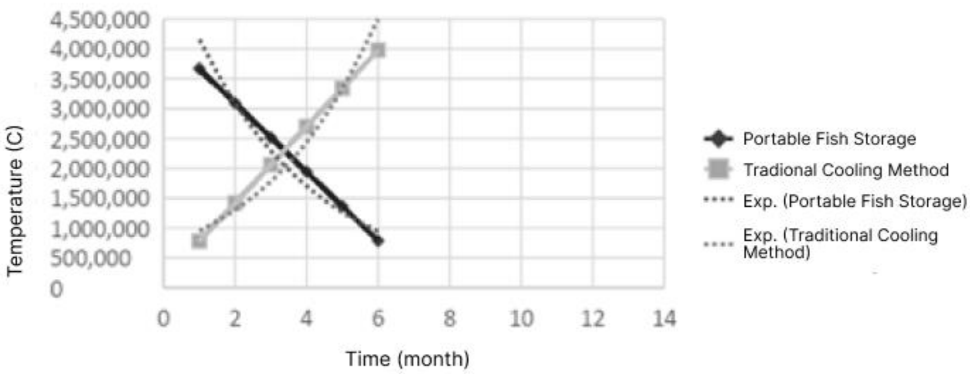


Figure. 4. Total Cost Consumption Comparison Diagram

Based on the results of the tests, operating the portable mini fish box to cool 20 kg of fish over 6 hours requires an average total power of 1.76 kWh. If this amount is converted into Indonesian Rupiah by multiplying it with the electricity tariff per kWh, the operational cost of the portable mini fish box is Rp2,555.00 per single fishing trip. When accumulated over a month, the operational cost of using the portable mini fish box amounts to Rp63,882.00 per month. In comparison, the total operational cost for cooling on the ship using conventional methods is Rp640,000.00 per month. Therefore, the difference in costs incurred is:
Cost difference = pre-savings cost - post-savings cost = Rp640,000.00 - Rp63,882.00 = Rp576,118.00

When calculated, the portable mini fish box can save up to 90% of the costs incurred by conventional cooling methods. This savings rate can be used to predict the break-even point of the costs used to assemble the portable mini fish box using the BEP formula by [12]:
BEP = (Savings Application Cost) / (Cost Difference) = Rp4,246,000.00 / Rp576,118.00 = 7.3

From this calculation, it can be seen that the investment cost spent on implementing the portable mini fish box can be recovered after 7.3 months, equivalent to 7 months and 9 days. In the further calculation, the use of portable fish storage can save up around 90% of operational cost compare to the traditional one.

Thus, the cost per kg of ice for the portable mini fish box and conventional cooling for a maximum storage capacity of 20 kg are Rp127.00 and Rp2,560.00 respectively. These costs take into account the storage space efficiency where the portable mini fish box can hold 20 kg of fish, whereas the conventional cooler can only accommodate 10 kg of fish and 10 kg of ice.

## IV. CONCLUSION

Based on the specific requirement, the prototype of portable fish storage prototype build with 56x45x38 cm ideal dimension. The performance test resulted that portable refrigerated fish storage consume load power around 374,94 - 651,93 watt with temperature decreasing rate of 0,5 C/minutes. The different result can outcome because of the environment condition and storage load affect the power needed by the portable fish storage. In cost simulation, the portable refrigerated can save up to 90% rather than a traditional fish storage.

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