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Experimental review of cold storage for fishery products in Aceh Island using solar energy

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Abstract

Data from the Ministry of Maritime Affairs and Fisheries shows that Aceh Province, with a coastline length of 2666.3 km stretching from east to west, holds a variety of marine wealth, both fisheries and other natural resources. The province of Aceh has archipelagoes spread over Aceh Besar and Aceh Singkil. The archipelago areas in Aceh Besar are Aceh Island, Rice Island and Nasi Island. The availability of electricity in the archipelago, namely on the island of Aceh, is only at 18.00 - 22.00 and 5.00 - 8.00. Because of this, a study was carried out on using solar electricity to drive compressors in cold storage. This study aims to determine the solar energy capacity and photovoltaic area required for cold storage with a capacity of 100 kg of fish, determine the temperature of the cold storage when operating with and without load and determine the Coefficient of Performance (COP) of cold solar storage over time. This research was conducted experimentally to test the use of cold storage for storing fish. The results showed that the cold storage temperature was -15.9 ℃ with an average current of 0.87 A, a voltage of 226.02 V and a power of 124.72W when operating without load, while with a load, the temperature was -3.1 ℃ with an average current is 0.890 A, voltage is 225.88 V, and power is 127.96W. The ideal COP value is greater than the actual COP value (8.07 <2.69). To run cold storage using solar energy, a battery with a capacity of 120 Ah is required until it reaches a temperature of -3.1 ℃ lasts 2 – 3 days with 40% remaining battery usage and is recharged every day.

Keywords:
Cold Storage, Temperature, Solar Intensity, Solar Electricity

1. Introduction

Indonesia is a maritime country and a large part of the Indonesian population depends on the fishing industry for their livelihood. Indonesia's coastline stretches for 104,000 km, and controls 3,544 million square kilometers of sea, accounting for 70% of its territory [1].

Indonesia has a sea area of 5.8 million km2, which is divided into a territorial sea area of 0.3 million km2, and an area of 2.95 million km2 of archipelagic waters, as well as an area of the Indonesian Exclusive Economic Zone (ZEEI) of 2.55 million km2 [2].

Indonesia has a wealth of coral reefs with an area of coral reefs that has been mapped reaching 25,000 km2. Based on research by the Indonesian Institute of Sciences (LIPI), this number is divided into several conditions, namely: very good condition at only about 5.30%, good condition at 27.18%, quite good at 37.25%, and not good at 30.45 %. There are an estimated 8,500 species of fish, followed by 555 species of seaweed and 950 species of coral reef biota. The number of fish species in Indonesia constitutes 37% of fish species worldwide, with several types of fish species having high economic value, for example, shrimp, lobster, tuna, shellfish, reef fish, various types of ornamental fish, and grass sea [3]. The residents of Aceh Island who are in the district of Aceh Besar work as fishermen with a production capacity of 10-20 kg/day.

CGIAP and UNIDO report that 40% of Indonesian fishermen's catch (equivalent to US$7.28 billion/year) is unused or wasted. One of the reasons is improper storage of fish. Without adequate fish storage facilities, both fishermen and fish sellers must dispose of large amounts of spoiled fish [4], [5]. For island areas, electricity is available from 6 pm to 10 pm and in the morning from 5 to 8 am. It is a problem to use cold storage for cooling fish in island areas. This problem must be overcome by the use of solar electricity [6]. The challenge is not only the fish but also the electricity availability which is needed to provide fresh fish. The use of solar energy then is important to study to move the compressor in cold storage [7].

Likewise, the sea area of Banda Aceh, the capital city of Aceh province, has rich fishery potential because it is located at the northwestern tip of Indonesia and directly faces the Indian Ocean. Aceh fisheries data shows the total catch from Banda Aceh, Sabang and Aceh Besar in 2017 was 27,860 tons. Assuming that only 80% of this catch can be sold in local markets, then around 5,572 tons of fish per year (or 15 tons per day) would need to be frozen and stored [8]. However, the cold storage capacity in Banda Aceh is very limited and cannot meet this demand. Currently, there are two local government cold storage facilities in the city, but none are operational due to electrical and administrative issues [4].

Previous cold storage feasibility studies have been carried out mostly outside Aceh province. For example, analyzing the feasibility of building a cold storage facility with a capacity of 75 tons in Lingga Regency, Riau Islands, Indonesia. They find that the facility is feasible because the Net Present Value (NPV) is positive, the internal Rate of Return (IRR) is higher than the discount rate, and the net Benefit-Cost Ratio (BCR) is greater than 1 [5]. Also, studied the feasibility of an 80 ton capacity cold storage facility at the Lampulo Baru Fishery Port, Banda Aceh and also found that the project is feasible [4]. Similar studies have also found consistent results [9], [10].

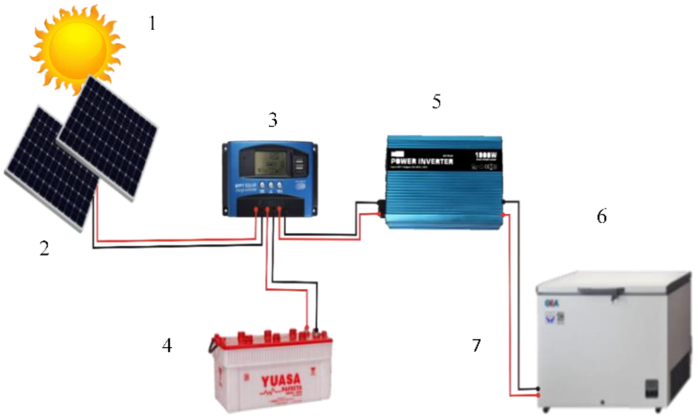
Research conducted by [11] explained that the analysis of the cooling load of cold storage for meat storage using the experimental method obtained an external cooling load of 11.6 kW, an internal cooling load of 138.8 kW and a COP of 2 while research conducted by [12] stated that it requires a voltage of 380 kV and the valve must be opened so that cold storage can circulate. The test results by [13] show that the ALREF system can be used as cold storage at -18°C, which allows it to be used as an alternative for fish storage which is not suitable for seawater cooling. The test results by [14] show that the cold room can accommodate up to 123.5 tons of frozen fish with a cold load of 82,717.32 Btu/hour.

This study aims to determine the solar energy capacity and photovoltaic area required for cold storage with a capacity of 100 kg of fish, determine the temperature of the cold storage when operating with and without load and determine the COP of solar cold storage over time.

2 Research methods

2.2 Research design

The principle of solar cold storage involves a refrigeration cycle, namely the vapor compression cycle, where the refrigerant is compressed using a compressor until a certain pressure and the temperature rises, then it is cooled in the condenser by blowing air into the condenser then the pressure decreases after going through the expansion valve and going to the evaporator and back to the compressor, the process is going on repeatedly. In this case the electricity generated via photovoltaic is forwarded to the solar controller as a means of stabilizing the incoming current from the photovoltaic and inverter as a compressor ac current converter to dc [15]. The test scheme for this study can be seen in Fig. 1.



1. The sun
2. Solar Panels
3. Solar Charger Controller (SCC)
4. Battery
5. Inverters
6. Cold storage

Fig. 1. Research scheme (design)

2.3 Research procedure

In this study, 100kg of tuna was cooled to a temperature of 0–(-10℃) in order to maintain the quality of the fish caught. Cooling technology using cold storage which requires electrical energy to drive the compressor work. The energy source comes from the sun which uses solar panels as a source of electrical energy. Electrical energy will flow into the battery, but before entering the battery the energy must be optimized using the Solar Charger Controller. The current that comes out of the DC current battery then the current is converted into AC current using an inverter. Then the AC current will be used as a source of electricity to the cold storage to drive the compressor and cool the fish.

The geometric dimensions of the front, right, left and rear walls, where: A is area (m2), P is length (m) and L is wide (m). Geometry area of cold storage eq. (1):

$$A = P \ x\ L \tag{1}$$

So, front side wall= 1,1 x 0,89 = 0,979m^2, Back side wall= 1,1 x 0,89= 0,979m^2, Left side wall= 0,62 x 0,89= 0,5518 m^2, Right side wall= 0,62 x 0,89= 0,5518m^2, Top side wall = 1,1 x 0,62= 0,682m^2, Bottom side wall= 1,1 x 0,62=0,682m^2

Cold storage volume geometry, eq. (2), where: V is Volume (m^3), P is Length (m), L is Wide (m) and T is High (m).

$$V = P \ x\ L \ x\ T \tag{2}$$

So, volume = 1,1m x 0,62m x 0,89m = 0,60698 m^3

The research location is in the archipelago. The flowing air is assumed to be at a speed of 10 km/hour and in the room the air moves very slowly so it can be assumed to be 0 km/hour. Data of Outer Airspeed: V_{out} is10km/h= 10km/h x 0,621mil/h= 6,21mil/h. Data of Room Airspeed: V_{in} = 0 km/h x 0,621mil/h = 0mil/h.

Expenses incurred as a result of fish products in cold storage. The cooling load from the product of the equation is as follows: Sensible Heat Gain eq. (3).

$$Q_s = m \ x\ c \ x\ \Delta T \tag{3}$$

Laten Heat Gain eq. (4),

$$Q_l = m \ x\ h_{lf} \tag{4}$$

where, Q_s is Load Sensible Heat Gain, Q_l is Latent Heat Gain Load m is mass (kg), Δt is Temperature Difference, c_p is Specific Heat and h_{lf} is Laten Heat.

The COP value is calculated using the eq. (5)

$$COP_a = Q_c/W = (h_1-h_4)/(h_2-h_1) \tag{5}$$

3. Results and discussion

Fig. 2. shows the cold storage test without using 100kg of fish. It shows that during data collection, from the time 13.00 to 15.00, the working current remained constant, namely 0.87A. Meanwhile, the power was initially 140 W, increased at 13.10 to 147 W, then decreased gradually until at 15.00 the power became 110 W.

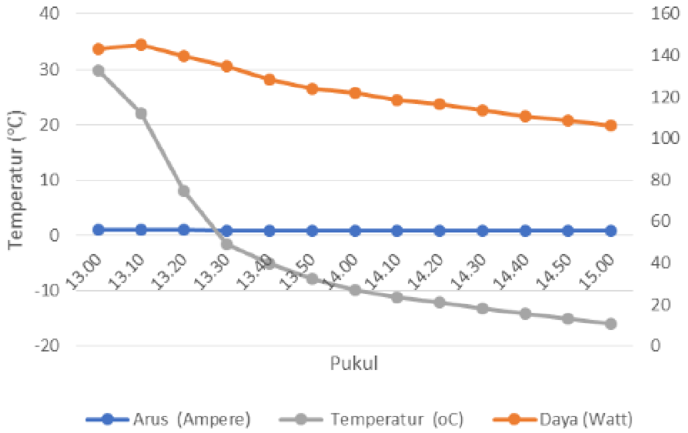


Fig. 2 testing cold storage without using fish.

Temperature decreased continuously, at 13.00, the temperature of 30℃ decreased drastically until 13.30 to -2℃, then gradually reduced until 15.00 to -15^{O}C. The decrease in power occurred because the required power was reduced when the cold storage had been operating for the first 10 min, while the temperature drop occurred because the temperature in the cold storage had become colder than the ambient temperature.

In Fig. 3, a cold storage test was carried out using 100kg fish, which can be seen below. It shows that during data collection from 13.00 to 15.00, the working current remained constant, namely 0.5 Amperes. Meanwhile, initially, the power was 130 Watt, increased at 13.10 to 145W, then the power decreased gradually until at 15.00 the power became 120W, while from 14.00–14.00, it experienced a sharper decline. While the temperature decreased gradually, at 13.00, the temperature of 32^{O}C decreased gradually until 15.00 became -5ºC. The decrease in power occurred because the required power was reduced when the cold storage had been operating for the first 10 min, while the temperature decrease occurred because the temperature in cold storage had become colder than the ambient temperature.

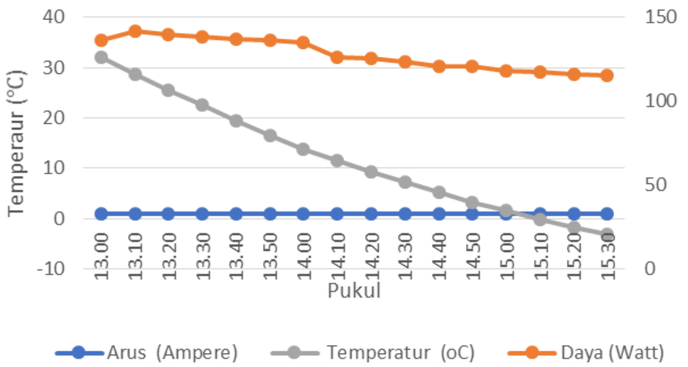


Fig. 3 cold storage using 100 kg fish at room temperature

Fig. 4 shows a comparison of cold storage without fish and using 100kg of fish. It shows that the temperature drops are very different. The temperature of the cold storage without a load decreased drastically from 13.00 to 13.30, while the temperature of the cold storage with a load of 100kg decreased gradually from 13.00 to 15.00.

To find the value of the coefficient of performance is calculated to get the value of the large ratio of heat absorption that occurs to the compressor work.

This value is also to measure the working ratio of the cooling system, eq. (5) and eq. (6):

$$COP_{ideal} = T_1/(T_2-T_1) \tag{5}$$

$$COP_{actual} = 1/3 \ x\ COP_{ideal} \tag{6}$$

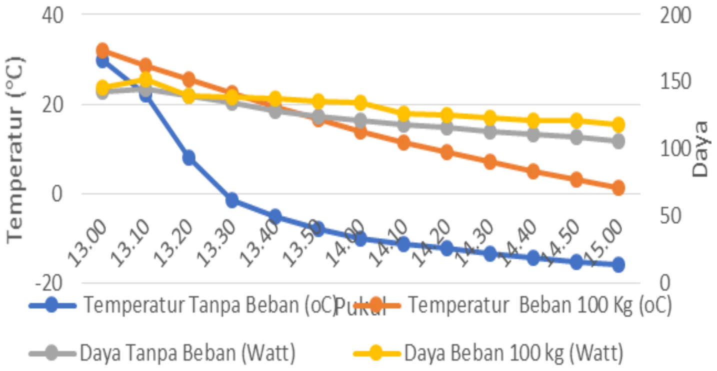


Fig. 4 Cold storage using load and no load

where: freezing temperature, T_1= -10°C = 263K; initial; temperature, T_2= 33,8 °C = 306.8 K, temperature, T_3= 0°C= 273K, Massa ikan, m= 100kg, specific heat c_p= 3,550kJ, Latent heat, h_{lf}= 227kJ

The heat that must be released in cold storage:

1. Heat is removed from the fish above the freezing point: Q_1= 100kg x c_p x (T_2-T_3)= 100kg x 3,555 x (306,8-273)=11999kJ
2. Heat is removed from the fish below freezing: Q2 = 100kg x Cp x (T_3-T_1)= 100kg x 3,555 x (273-263)= 3550kJ.
3. Fish in a latent state: Q_3= 100kg x 227= 22700kJ
4. Total heat released: Q_{total}= Q1 + Q2 + Q3= 11999 + 3550 + 22700= 38249 kj= 10,624 kW
5. Cold storage COP value: COP_{ideal}= 237/(306,8-273)= 8,07, COP_{actual}= 1/3 x 8,07= COP_{actual}=2,69
6. Compressor work: Wr= Qt/COP_{actual}= (10,624kw)/2,691= 3,947 kW= 236,87kJ/min
7. The heat dissipated by the product: Q_{produk} = COP_{actual} x Compresor work Q_{produk} = 2,691 x 10,624kJ/s= 28,58kJ/s= 1715,35kJ/min
8. Cold storage capacity, Capacity is1715,35/210=8,1 TR
9. The time it takes to reach cooling: T= Q_{total}/Q_{produk}= 38249kJ/1715,35kJ/min= 22,29min

4. Conclusion

In this study is found that total heat is 10.624kW, the ideal COP value is 8.07, the actual COP value is 2.69, the compressor work is 236.87kJ/min, the cold storage capacity is 8.1 TR and the time required to achieve cooling is 22.29min.

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