The Use of Showcase Chiller with Solar Panels as the Final Stage of the Cold Chain for Fish Sellers in Traditional Market

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Abstract. Fish as a commodity that easily and quickly decomposes requires fast, clean, careful, and cold handling. Thus the quality of the fish can be maintained from the time the fish is removed from the sea until the fish is marketed to consumers. Handling fish to maintain its quality to keep it fresh and hygienic can be done through the application of a cold chain system. A cold chain is a supply chain system that aims to maintain temperature so that fish products are maintained during the process of collection, processing, and distribution to consumers. Therefore, at the sales stage to the fish seller in traditional markets, it is necessary to apply a cold chain by applying refrigeration technology like a showcase chiller to keep the fish fresh and hygienic until it reaches the consumers. The showcase chiller requires an energy supply, where the solar panel system will use the energy source. This research was conducted to determine the cooling load of a showcase chiller with a capacity of 50 kg of fish, as well as to determine the capacity of the solar panels to be used. From the research conducted, the volume needed to store 50 kg of fish is 252 liters, so the selected showcase chiller has a volume of 260 liters with an input power of 203W. After testing for no-load and full-load conditions, the COP value for the no-load condition is 4.20, and for the full-load condition is 3.66. Meanwhile, the energy consumption is 43.4 kJ for no-load conditions and 43.8 kJ for full-load conditions respectively.

Keywords: Showcase Chiller; Solar Panels; Coefficient of Performance, Energy Consumption.

1. Introduction

Fish is one of the most popular sources of protein by the public because the protein content is high compared to other nutritional content (fat, carbohydrates, vitamins, and minerals). In addition, fish also has a taste that is quite tasty, easy to obtain, and the price is affordable. There are many nutritional values contained in the body of fish such as

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protein, omega 3, amino acids and so on which are good for brain growth, especially for children [1].

Fishery products have the main weakness in that they are prone to decay due to physiological, mechanical, physical chemical, and microbiological influences. Efforts to maintain the quality of fish so that it remains good requires a process of processing and preserving fish to extend the durability of its quality. Therefore, it is necessary to store fish by chilling or freezing it to reduce these losses. Bacterial growth below 10°C will be slower. The metabolic process itself is disrupted if there is a temperature change, so storage at low temperatures can extend the life span of the fish's internal tissues due to decreased respiration activity and micro-organism activity.

To evaluate the effectiveness of implementing the cold chain system at the level of fish sellers, and consumers, reference [2] has conducted research in the market in the city of Malang. The research was conducted using a qualitative descriptive method which was carried out using observation and interviews with respondents. The results of his research show that the cold chain system has not been implemented properly in traditional markets.

Research also shows there is a difference in the income between fishermen groups who apply for the cold chain and those who do not apply for the cold chain. In the three locations, fishermen who carry out cold chain fishing business obtain greater income and profits compared to those who do not apply cold chain. The payback period (PP) for fishing businesses using cold chains is also faster than for similar businesses that do not use cold chains [3].

The evaluation analysis of the development of a solar-powered refrigeration machine using conventional HFC134a refrigerant for use in rural and medical areas where there is no access to modern electricity sources has been carried out. The evaluation carried out is the performance of the refrigeration system that operates on solar energy as an alternative source of energy to increase the cooling effect, the coefficient of performance (COP). From the results of the study, it was found that the COP of the system increased by 8.67% when working with solar energy and reduced energy by 2.38% respectively [4].

Research to develop a Solar PV system that can run a refrigeration engine with a compression refrigeration cycle has also been carried out. Refrigeration systems with vapor compression cycles and Solar PV systems are designed by performing the necessary calculations from the derivative formula. A vapor compression refrigeration cycle was simulated in Aspen Hysys v11 software where the results obtained validated the design calculation results. The Matlab/Simulink model of the Solar PV Array was developed to simulate its performance according to radiation and temperature. From his research, it was found that the use of electricity generated from the Solar PV system saves monthly costs incurred for electricity bills. Solar PV systems help in eliminating CO_2 emissions when compared to electricity generated from coal-based power [5].

Research on refrigeration systems with solar power. A solar refrigerator is a cooling system that uses solar energy. Solar panels are equipped with photovoltaic cells that convert solar energy into electrical energy and store it in batteries. After conducting thorough research and analysis in the field of solar cooling systems, it was concluded that implementing a solar cooling system is one of the best ways to achieve efficiency and ensure that environmental preservation can be carried out [6].

A refrigeration system with Solar PV equipped with a cold bank for use at night has been studied. The refrigerator system is designed for a capacity of 150 liters. The electricity supply to run the AC compressor is provided by solar panels via an inverter. When the refrigerator is powered by Solar PV, the solution takes 3½ hours to reach -100°C under full load conditions. A 10-liter water solution can provide cooling for nearly 17 hours at full load without running the refrigerator [7]. Experimental study on the use of PV panels in chest freezers in hot climates. This study investigates the potential use of a PV power supply system for freezers in Indonesia a hot climate area The study results show that solar PV panels applied to freezers in hot climate regions are very prospective [8].

Study the problem of integration of energy requirements from operating display cabinets with renewable energy sources with solar power, so that the energy sources and systems developed can be guaranteed to be well sustainable. Preliminary studies to make a product/prototype of a freezer display cabinet system for storing fresh meat or fish and design integration of energy sources from solar power. From the results of the initial study research obtained in the form of feasibility and optimization of the use of photovoltaic systems for display cabinet drive system applications, it was found that the solar power system with photovoltaic circuits achieves optimal current output results with a slope angle of 15 degrees and north direction [9].

2. Study Of Literature

2.1 Vapor Compression Refrigeration Cycle

The showcase chiller uses a vapor compression refrigeration cycle. The main components of the vapor compression refrigeration cycle are the compressor, condenser, expansion device, and evaporator. The expansion device used is the capillary tube type and is wound on the compressor suction pipe to form a heat exchanger. The important performance parameters of the vapor compression refrigeration cycle are the coefficient of performance (COP), and energy consumption (Ec).

Fig. 1. Sliding Glass Showcase Chiller

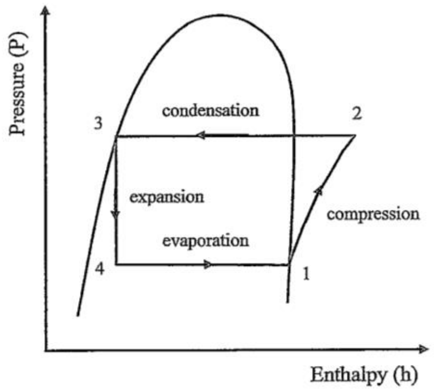

Fig. 2. Pressure–enthalpy diagram of vapor compression refrigeration cycle

Coefficient of Performance

The coefficient of performance (COP) is the amount of useful energy, namely the effect of refrigeration divided by the work required by the system, namely the work of compression [10]. Mathematically, COP is expressed by the formula:

$$COP = (h_1 - h_4) / (h_2 - h_1) \quad (1)$$

Where:

h = refrigerant enthalpy (kJ/kg)

Energy Consumption

To calculate the energy consumption (E_c) is used the formula:

$$E_c = [(V \times I \times Cos\ \varphi) \times t \times 60] / 1000 \quad (kJ) \quad (2)$$

Where:

V = electrical voltage (Volt)
I = electric current (Ampere)
t = time (minute)
$Cos\ \varphi$ = power factor

2.2 Research Methods

This research carried out experimental tests on a showcase chiller machine with an energy source from a solar panel system. This showcase chiller has a storage capacity of 50kg of fish. It is planned to use the showcase chiller for 8 hours a day. This showcase chiller works at a cabin room temperature of 2°C. The door of the showcase chiller is at the top, made of glass and the opening is sliding type. The selection of this showcase chiller is based on the volume needed to store 50kg of fish. With a storage capacity of 50kg of fish, the required volume is 252 liters. From this volume, a showcase chiller machine will be selected to be used in this study. The total input power from this showcase chiller will be used to determine the solar panel capacity.

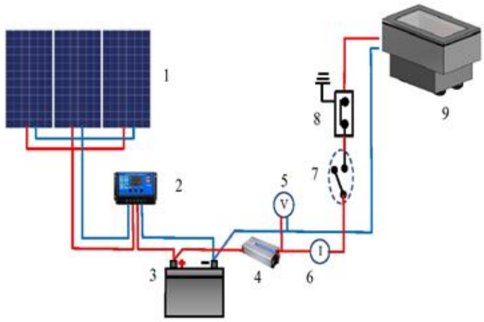

Fig. 3. Showcase chiller design with solar panels

Table 1. Legend

No	Parts
1	Solar panels
2	Solar charge controller
3	Battery
4	Power inverter
5	Volt meter
6	Ampere meter
7	ON-OFF switch
8	Thermostat
9	Showcase chiller

After the components of the solar panel system are assembled, the refrigerant is filled into the system with the optimum mass according to its working pressure. After the system works normally, it will be tested to determine its performance and energy consumption. The test is carried out by measuring the refrigerant temperature at 6 set-points using a type K thermocouple and temperature display while AC voltage and current are measured at the input cable to the system.

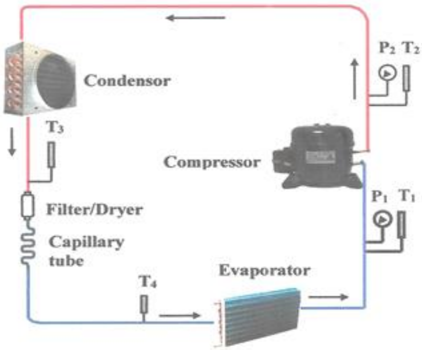

Fig. 4. Piping diagram of vapor compression refrigeration cycle

Legend:

P = pressure gauge; T = temperature sensor

1, 2, 3, 4 = measurement point

3. Results And Discussion

With a fish capacity of 50kg, a cold storage space of 252 liters is required. With such a large volume, a showcase chiller was then chosen which had a cabin volume of 260 liters. The input power of the showcase chiller is 203Watt and the refrigerant used is HFC-134a. The solar panels used have a total capacity of 300WP consisting of 3 solar panels each with a capacity of 100WP. The solar charge controller is used with a capacity of 20A, while 2 batteries are used, 12V and 300Ah. To convert DC to AC, a pure sine wave power inverter with technical specifications of 12V and 4000W is used. To set the cabin temperature in the showcase chiller, the Elitech ETC-200+ temperature controller is used. The cabin temperature is set at 2°C.

To determine the COP of a showcase chiller with solar PVs, the CoolPack application program is used. The input test data includes refrigerant type, evaporation temperature, condensation temperature, super-heat degree, sub-cooled degree, and isentropic efficiency. Meanwhile, to determine energy consumption, the existing formulas are used.

3.1. Variation Of Cabin Temperature, Coefficient Of Performance, Energy Consumption, And Cooling Time At No-Load Condition

From Fig. 5 below it can be seen that the graph for Coefficient of Performance (COP) from the 10th to the 30th minute tends to experience a significant decrease. From the 30th minute to the 62nd minute, the decrease in COP value was very small. Furthermore, the COP value tends to be constant, namely 4.2 until the 76th minute where at that time the cabin temperature (Tc) has reached 2°C according to the set temperature. Meanwhile, the cabin temperature has decreased from 26.5°C to 2°C (setting temperature) which takes 76 minutes.

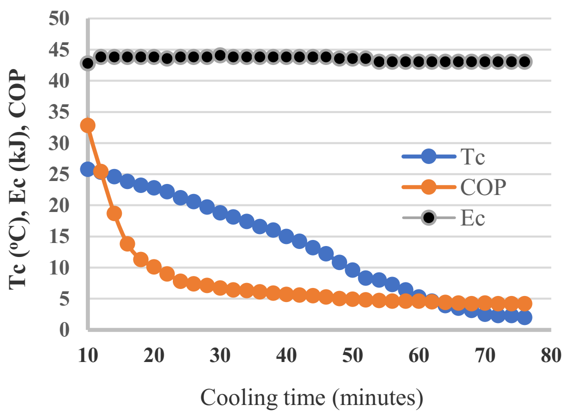

Fig. 5. Variation of cabin temperature, COP, Energy Consumption, and cooling time on no-load condition

When the cabin temperature reaches 2°C, the thermostat cuts off power to the compressor. The compressor will restart when the cabin temperature rises to 5°C. As for the energy consumption (Ec), from the graph, it can be seen that during the test until the setting temperature is reached at 2°C, the value is the same, namely 43.4 kJ.

3.2 Variation Of Cabin Temperature, Coefficient Of Performance, Consumption Energy, And Cooling Time At Full Load Condition

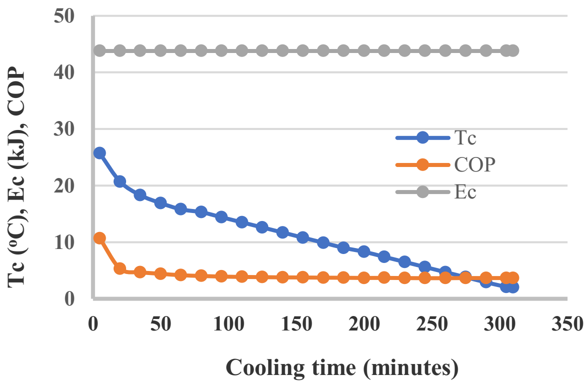

Fig. 6. Variation of cabin temperature, COP, energy consumption, and cooling time on full load condition.

From Fig. 6 above it can be seen that for the showcase chiller test with a full load (50 kg of fish), it takes 305 minutes to reach a cabin temperature of 2°C. Please note that 160 grams of HFC-134a refrigerant is loaded into the showcase chiller system. As for the COP value, a drastic decrease occurred from the 5th to the 20th minute. Then from the 20th to the 95th minute, the COP value was very small, from 5.3 to 4.03. From the 110th minute to the 305th minute, the COP value tends to be constant, namely 3.66, where the cabin temperature has reached 2°C (setting temperature). Henceforth it is the same as in the no-load test, once the cabin temperature reaches 2°C, the compressor will turn off, and when the temperature rises to 5°C, the compressor will turn on again. In the test with a full load, during the decrease in cabin temperature, until it reaches the setting temperature of 2°C, the energy consumption value is almost the same, namely 43.8 kJ. In the full load test, the energy consumption is 0.4 kJ greater when compared to the no-load test.

4. Conclusion

Application of cold chain to fish traders in traditional markets is very important to keep fish fresh and hygienic. For this reason, a cooling machine such as a showcase chiller is needed, which uses a solar panel system as an energy source. The showcase chiller has a storage volume of 260 liters for 50 kg of fish. The capacity of the solar panels used is 300WP. The refrigerant used was HFC-134a with a mass of 160 grams. The time needed to reduce the temperature to 2°C is 76 minutes for no load and 305 minutes for a full load. The COP value for the chiller showcase without load is 4.20, and for full load is 3.66. As for the energy consumption, in the no-load test, it was 43.4 kJ, and in the full-load test, it was 43.8 kJ.

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