Analysis of Display Cabinet Temperature and Humidity Condition for Fresh Fish Displayed

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Abstract: Fresh fish products are highly consumed and become very interesting local culinary to support tourism development. In nowadays, restaurants, cafes, and others food centre do not provide a cooling system for display cabinets. This condition causes an impact that the quality of fresh fish was not so good and hygienic for international standard food. Thus, this study aims to investigate the quality of fish products in display cabinets based on temperature and humidity during storage and compared with the investigation of the Coefficient of Performance (COP) of the cooling system dan frost condition. This research was conducted by experimental method. A display cabinet has been built with energy sourced from integration solar energy and the national grid electricity (PLN). The results showed that optimization of storage conditions is temperature of -0,6^{o}C and humidity of 95% that can keep the product quality fresh and hygienic. However, this prototype can reach the standard temperature very well but not to humidity which only reach in average 60%. In future will develop a specific humidifier with low energy and integrated with de-frost control dan infiltration control to get low energy display cabinet for storage fresh fish, so that operating costs can be reduced.

1 INTRODUCTION

The operation of the display cabinet still requires a lot of electrical energy so that the operational costs are relatively expensive. Because in general, display cabinets have a high infiltration of open display systems. Another condition is the electricity tariff (PLN) which continues to be more expensive in line with the depleting supply of fossil energy. So to maintain sustainability, as a tropical country, solar energy is a renewable energy in the future. At this time cooling in the display cabinet is done by soaking water and adding ice and certain preservatives, so that the quality of fresh fish is very bad for health.

Efforts for operational efficiency of display cabinets have been carried out in several studies in previous related studies. Chaomuang et al. (2019) and Manson et al. (2019) conducted an experimental study on the effects of operating conditions, including door opening frequency, ambient air temperature and product occupied volume, on the distribution of air and product temperatures in closed refrigerated display cabinets. From the results of this study, it was found that the position of the product in the cabinet is a determining factor for its temperature: high temperatures are observed at the front, especially at the top of the cabinet, and low temperatures are observed at the rear. Air infiltration due to door opening causes an increase in product temperature at the front and a decrease in temperature at the rear. Meanwhile, Santosa et al. (2021) has developed a dual humidifier system to maintain the humidity of the cooling room for storing fresh fruits and vegetables. Chaomuang et al. (2020a), Redo et al. (2019) and Chaomuang et al. (2020b) carried out air velocity measurements to study air flow patterns and analyzed that installing doors on open-air refrigerated display cabinets is a simple and effective way to improve cabinet performance because it can reduce air entry. warm and moist into the cupboard. Large unstable eddies develop in the mixing layer, thereby increasing the infiltration of larger external air. The model is then used to predict the effect of air infiltration through the door gap on the performance of closed display cabinets in both thermal and energy

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aspects. Applications in supermarkets were also observed that door opening is the main energy loss in display cabinets and in supermarkets a lot of waste is needed because many display cabinets are open. Gaspar et al. (2011) and Yu et al. (2009) stated that the thermal entrainment factor was analysed and compared with the total sensible and latent heat yields for experimental testing. From an engineering point of view, it is concluded that the thermal entrainment factor cannot be used arbitrarily, although its use is suitable for designing better cabinets under the same climatic class conditions.

In terms of the frost phenomenon that can cause a decrease in the performance of the cooling system, previous research has been carried out related to the control system of frost control on the evaporator. Malik et al. (2020) stated that freezing is the most detrimental phenomenon to the efficiency of the refrigeration system. Frost accumulation blocks airflow, worsening cooling capacity and performance coefficient. Tan et al. (2020) researched that frost dramatically worsens the operating performance of air source heat pump units and causes additional energy consumption. Zhang et al. (2017) conducted a study related to frost-free refrigerated display cabinets, in which freezing could be inhibited by removing moisture from the air before entering the display cabinet evaporator through a desiccant-coated heat exchanger and was found to significantly increase the COP by about 35%.

Thus, this study aims to investigate the quality of fish products in display cabinets based on temperature and humidity during storage and compared with the investigation of the Coefficient of Performance (COP) of the cooling system and frost condition.

2 METHODOLOGY

This research is an experimental research by making a product/prototype of a display cabinet system for storing fresh marine fish and designing an integrated energy source from solar power and state grid electricity (PLN). A prototype display cabinet with a temperature that can be -5ºC with a precise control system and the storage volume is 118 litter (L). The research was carried out at the Refrigeration Lab, Bali State Polytechnic. Experimental tests have been carried out on the refrigeration system from the display cabinet and product quality tests (fresh marine fish). The solar power system used is an integrated system as shown in Figure 1.

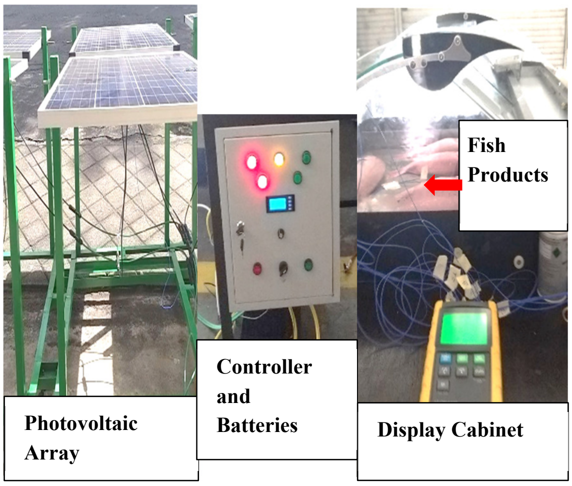

Figure 1: Prototype display cabinet with integrated solar energy and national grid (PLN) energy sources.

The data collection system was carried out with type K thermocouple with an accuracy of up to 0.3ºC and humidity was measured with a hygrometer with an accuracy of +-3% and pressure was measured with a pressure gauge. as shown in Figure 1. System performance data collection is carried out by measuring temperature (T) and pressure (P) in each condition (state) of the display cabinet refrigeration cycle, Temperature (T) and Humidity (RH) in the cabin and product. In terms of electricity, from solar energy sources and components, the electric power, current and input voltage are also measured carefully.

3 RESULTS AND DISCUSSIONS

In this results and discussions section, it consists of, 1) Review of display cabinet storage conditions, 2) Analysis of storage conditions for prototype display cabinet based on temperature and humidity, 3) Analysis of average COP (theoretical), 4) Visual analysis of frost and stored products. Where a detailed explanation is as follows.

3.1 Review of Storage Condition of Display Cabinet

The products stored in this display cabinet are fresh seafood products. Storage conditions based on ASHRAE (2014) that for fish products are shown in Figure 2a and for shellfish and shrimp products are shown in Figure 2b. Average storage temperature is -0.6 ºC to 2.2 ºC , and relative humidity ranging from 80% to 90% and between 95% RH to 100% RH with storage time in the display cabinet ranging from 7 days (for Menhaden products) to 18 days (for Halibut and Salmon products) while other products ranging from 8-14 days are still maintained freshness. Based on these data, the capacity of the designed display cabinet system is able to work up to a temperature of -5ºC. To achieve this temperature does not require high energy because it is a medium temperature, but to maintain high humidity, a special humidifier must be added which is most suitable for the system to be able to maintain hygiene. A suitable and energy efficient humidifier system will be developed in future research. The standard conditions for cold storage of fish products are shown in Figure 2a.

While the storage conditions for shellfish products (scallop meat, shrimp, lobster, oysters) are more varied in terms of storage temperature according to the type of product stored. The average storage temperature is from -0.6 ºC to a maximum of 10ºC. When compared to product fish, this product requires a higher temperature especially for lobster Oyster products (clams in shell). For humidity requirements in display cabinet storage, humidity (RH) is evenly distributed for all products between 95% to 100%, with a storage period of up to 16 days (lobster) and only 5 days for Oyster and between 8-14 days for products. other. Standard display cabinet storage conditions for shellfish are shown in Figure 2b.

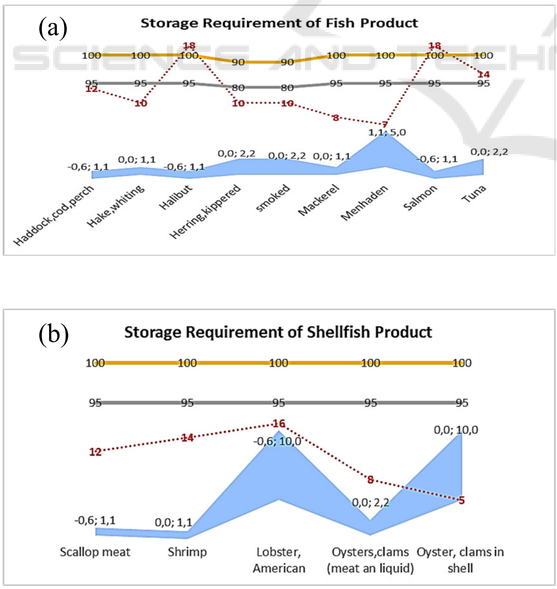

Figure 2: Standard storage conditions: (a). fish products and (b). shellfish products.

3.2 Analysis of Storage Conditions of Display Cabinet based on Temperature and Humidity

From the results of testing on temperature (ºC) and humidity (%RH) on the results of the prototype display cabinet design that was built, it was found that the operational characteristics of the display cabinet refrigeration system temperature were very good and in accordance with the desired settings as shown in Figure 3. Operational control temperature with on-off condensing unit system has been running very well which is controlled by a thermostat system. De-frost occurs at the 4th hour and it can be seen that during de-frost it can increase the maximum evaporating temperature by about 12ºC for a period of 12 minutes. De-frost is done by turning off the condensing unit (compressor and condenser fan), so that the ice melts naturally. While the condensing temperature has no effect, it is still the same as the de frost process. This shows that the balance of high and low pressure during de-frost is still maintained so that when the system starts again it does not require high energy in the compressor motor.

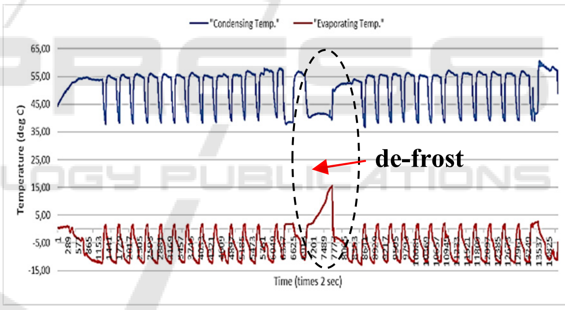

Figure 3: Condition of condensing temperature and evaporating temperature.

Figure 4 shows the characteristics of the cabin temperature and the product according to its placement, side 1 is a place near the evaporator and side 2 is a place in front close to the cabin door. There is a fairly high temperature difference at the different positions in the cabin of approximately 3.2 ºC and the difference in product temperature at the same time there is an average difference of 5.5 ºC. This is because the display cabinet is in a transparent condition, resulting in high heat transfer from the environment. When de-frost occurs, it is not accompanied by a significant temperature increase in cabin temperature and product temperature. This is because the operating temperature is almost the same as the frost temperature itself, which is around 0ºC and the prototype is still in a small capacity (compressor 1/2 Hp) so that the volume of the cabin space is not too large which results in not too high heat transfer from the environment. Besides that, the material in the cabin is made with good stainless-steel material to be able to store cold energy. Meanwhile, the average humidity condition in the cabin is 60% RH which of course is not enough to meet humidity standards to get a good product in accordance with ASHRAE (2014).

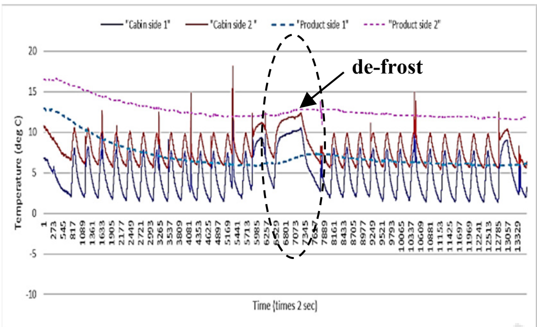

Figure 4: Cabin and product temperature characteristics.

The solar power system has also been able to work well and is integrated using the ATS (automatic Transfer Switch) system where energy will be transferred to the national grid energy source – (PLN) when battery charging drops below 30%. This transfer occurs at night and returns to normal conditions (connected to a solar energy source) during the day, with the system and planning carried out in this research the proportion of solar energy use and the national grid (PLN) 70% : 30%, respectively. Optimization analysis needs to be done to get the most efficient optimal condition between the proportion of solar energy and solar power between the energy produced and the investment required. In the next research, it will be developed to obtain the most efficient solar and PLN capacity proportion model for operating display cabinets.

3.3 Analysis of Theoretical Coefficient of Performance (COP)

The COP calculation is based on the average temperature conditions in the main state of the refrigeration cycle which includes: temperature point 1 at the compressor entry position, point 2 at the compressor exit position, point 3 at the condenser exit position and point 4 at the exit position of the capillary tube or entering the evaporator. From the calculation with the @Coolpack, the coefficient of performance (COP) is theoretically obtained at 4.8. From a comparison with other refrigeration systems, the theoretical COP is already very good. Thus, future developments will focus on humidifier and control systems to reduce the effects of infiltration and frost effects. The main condensing unit components of the prototype display cabinet covering, compressor, capillary tube and condenser which are shown in Figure 5 below.

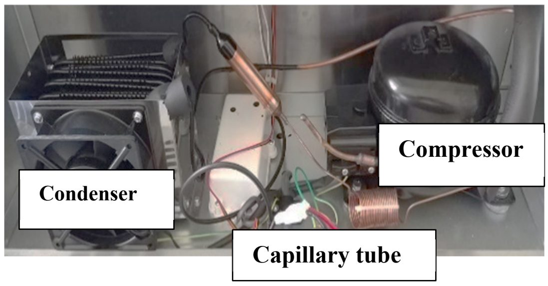

Figure 5: Main condensing unit components of display cabinet refrigeration system.

3.4 Frost and Product Visual Analysis

Figure 6. shows frost that occurs evenly on the entire surface of the evaporator and at the 4th hour has begun to be controlled the de-frost system works periodically by turning off the compressor system for 12 minutes. This frost occurs because the average temperature in the pipe and fin evaporator is around -5.3 ^{o}C with 60% humidity, so frost can easily occur. Testing the temperature of the product (fresh fish) and the stored space about 118 litter(L) is also shown in Figure 6.

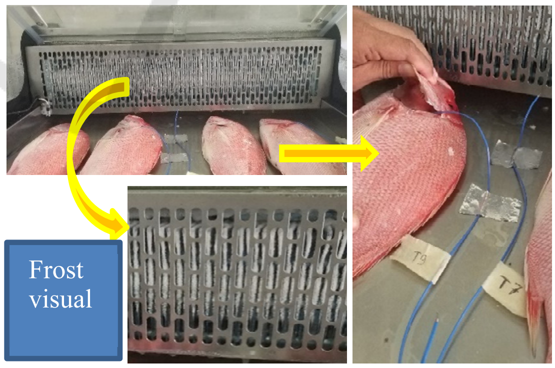

Figure 6: Visual frost condition and fish product quality.

From the analysis of fish products stored for 6 days in a display cabinet in general, it can be seen that the fish is still fresh with good quality (from the color of the gills, the smell and the condition of the flexibility of the meat). However, the upper fish skin is a little dry because of the lack of moisture in the display cabinet cooling chamber. This will be the focus of attention in further research, namely by developing a humidifier system that is suitable for display cabinets for storing fresh fish.

4 CONCLUSIONS

Based on the tests and analyses that have been carried out, it can be concluded that this display cabinet system has operated very well with a fairly high performance with theoretical COP approximately 4.8. However, it is still not able to produce sufficient humidity for fresh fish storage standards. The required humidity ranges from 80% to 90% and between 95% RH to 100% RH. With a natural method by manually opening regularly every 1 hour with an opening duration of 10 seconds, it is only able to produce 60% humidity. With evaporator setting temperature of -5^{o}C and humidity in average of 60% naturally, at evaporator fin and tube surface already occur a frost evenly. So that for future research development, a humidifier system, de-frost control and infiltration control from the display cabinet system will be developed so that it can produce product storage with excellent quality and energy saving.

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REFERENCES

ASHRAE. (2014). *ASHRAE Handbook of Refrigeration*. ASHRAE, Inc., Atlanta, 749 pgs.

Chaomuang, N, Denis, F, Denis, A, Laguerre, O. (2019). Influence of operating conditions on the temperature performance of a closed refrigerated display cabinet. *International Journal of Refrigeration*, 103,32–41.

Chaomuang, N, Denis, F, Denis, A, Laguerre, O. (2020). Experimental and numerical characterization of airflow in a closed refrigerated display cabinet using PIV and CFD techniques, *International Journal of Refrigeration*, 111, 168-177.

Chaomuang, N, Laguerre, O, Flick, D. (2020). A simplified heat transfer model of a closed refrigerated display cabinet, *Thermal Science and Engineering Progress*, 17, 100494.

Gaspar,P,D, Gonçalves, L,C, Pitarma, R,A.(2011). Experimental analysis of the thermal entrainment factor of air curtains in vertical open display cabinets for different ambient air conditions. *Applied Thermal Engineering*, 31, 961-969.

Malik, A, N, Khan, S, A, Lazoglu, I. (2020). A novel hybrid frost detection and defrosting system for domestic refrigerators. *International Journal of Refrigeration,* 117, 256-268.

Månsson, T., Rukundo, A, Almgren, M, Tsigas, P, Marx, P, Ostermeyer, Y. (2019). Analysis of door openings of refrigerated display cabinets in an operational supermarket. *Journal of Building Engineering*, 26,100899.

Redo, M, A, Ohno, K, Giannetti, N, Yamaguchi, S, Saito, K. (2019). Seasonal performance evaluation of CO_2 open refrigerated display cabinets. *Applied Thermal Engineering*, 163, 114354.

Santosa, I, D, M, C, Waisnawa, I, N, G, S Sunu, P, W, Wirajati, I,G,A,B. (2021). Investigation of optimization of solar energy refrigerator with natural humidifier. *International Journal of Thermofluid Science and Technology*, Vol. 8, Issue 2, Paper No. 080201.

Tan, H, Xu, T, Liu, Z, Tao, T, Xu, G. (2020). Investigation of ultrasonic array defrosting method based on synergism of standing wave intermittent phase-stagger and multi-frequency for finne d-tub e evaporator. *Energy & Buildings*, 218, 110054.

Yu, K, Ding, G, L, Chen, T, J. (2009). A correlation model of thermal entrainment factor for air curtain in a vertical open display cabinet. *Applied Thermal Engineering*, 29, 2904–2913.

Zhang, L, Fujinawa, T, Saikawa, M. (2017). Theoretical study on a frost-free refrigerated display cabinet. *International Journal of Refrigeration*, 74, 95-104.