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Feasibility of Air Conditioning (AC) Utilization as Heat Pump System for Fish Cracker Drying Machine

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Abstract: Fish crackers are one of the most popular snacks in Southeast Asian countries, including Malaysia. Traditionally, the process of fish crackers drying usually uses sun drying method. The problem of this method is uncontrollable weather conditions. Drying of fish crackers requires an alternative in the drying process. The heat pump is the most effective and controllable alternative dryer in reducing the moisture content of the material. Air Conditioning (AC) is one type of heat pump. The heat produced by the AC condenser can be used to dry fish crackers. In this study, the AC utilization as a heat pump system to dry fish crackers has an Evaporate Capacity (EC) of 1,838kg/h, a Specific Moisture Extraction Rate (SMER) of 1,998kg/kWh, and a Specific Energy Consumption (SEC) of 0.425kWh/kg of dry crackers. This drying machine is also economically feasible because it has an NPV> 0 which is RM28201.58 with an investment period of 1 year.

Keywords: Air Conditioning; Drying; Fish Cracker; Heat Pump.

Introduction

Fish crackers are one of the traditional Malaysian snacks (Hamid, et.al. 2020). Fish crackers are the most popular snacks in Southeast Asian countries (Chudasama, et.al., 2019). Fish cracker dough is made from a mixture of minced fish meat with several ingredients (Hamid, et.al. 2020). Some of these ingredients are flour and seasonings, such as sugar, garlic, pepper, salt, and MSG (Honglertkongsakul, et.al., 2018). The dough is molded into a cylindrical shape and steamed (Huda, et.al., 2010). After steaming, the dough is cooled to room temperature and sliced into thin sheets (Hamid, et.al. 2020; Honglertkongsakul, et.al., 2018).

Fish crackers are included in the type of processed seafood. This effort was made to increase the selling value of fish, especially demersal fish, such as Goldband Goatfish which has a low selling value compared to similar fish (Chudasama, et.al., 2019; Department of Fisheries Malaysia, 2015

As a demersal fish, the economic value of Goldband Goatfish is very cheap, ranging from RM2.0 – RM2.5/kg (Table 1). After being processed into crackers, the processed products can be sold at a price of RM20.0/kg (the selling price of fish crackers at Hakib's Industry). Besides increasing the economic value, the addition of fish meat to crackers changes the chemical properties of crackers because the protein content in fish can shrink the pores in the crackers in the frying process, this makes less oil absorbed and the cracker product will be healthier (Zulfahmi, et. Al. 2014). Before frying, thinly sliced cracker dough is usually preserved in order to increase durability so that it can be stored longer. One of the preservation methods commonly used for processed fish crackers is drying

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Drying preserves the product by lowering the water content in the material (Goh et al., 2011). The water content is lowered to the desired level to eliminate the activity of enzymes that break down the active substances contained in food ingredients, in this case fish crackers (Hall, 1980; Yahya, 2014). The process of removing water from the material is carried out by utilizing heat energy (Risdianti et al., 2016). Heat energy is applied in three ways, by convection, conduction, and radiation (Chen, 2008). Usually, for the drying process, heat is transferred by radiation. Like the transfer of heat from sunlight to the earth which is used to dry food such as fish crackers. Considered more practical and does not require large costs, this traditional method is still applied today.

Table 1. Golband Goatfish Prices by Month (RM/kg)

Jan	Feb	Marc	Apr	Mei	Jun	Jul	Agst	Sept	Okt	Nov	Des
2.16	1.94	2.16	2.19	2.19	2.14	2.25	2.25	2.21	2.15	2.03	2.34

(Malaysian Fisheries Department, 2015)

Although considered practical and does not require a large cost, sun drying requires a long drying time. Drying crackers under the sunlight takes 12 hours, because the drying process depends on weather conditions and during the rainy season, sunlight is very limited (Kusumaningrum, et.al., 2019). Drying in the open sun have uncontrollable of the air temperature and sunlight intensity, if the air temperature and sun intensity are too high, the quality of fish crackers will become very dry and break easily, if the air temperature and sun intensity are too low, it will take a long time to dry (Yahya, 2014).

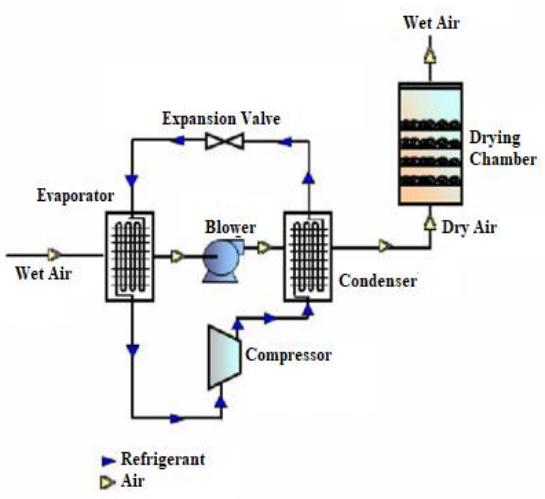

Figure 1. Scheme of heat pump drying system (Yahya, 2014)

To overcome these conditions, a drying machine is an alternative to drying fish crackers. In the drying process with a dryer, an important parameter that needs to be considered is the drying rate (Dina, et.al. 2018). The drying rate must be controlled and the drying process carried out in stages. Gradual drying aims to dry the material evenly by minimizing the difference in water content between the surface and the center of the material (Prasetyo, et.al. 2008). Based on these criteria, the heat pump system is a suitable alternative dryer for drying fish crackers.

The ability of heat pump dryers to control air temperature and humidity is an advantage of heat pump dryers (Ambarita et al., 2017). Heat pumps are an alternative to replace sun drying to improve product quality and quantity (Hamid, et.al., 2020). Compared to infrared drying, heat pump drying system has a more uniform water removal rate (Zhou, et.al., 2018). The heat pump drying system has the opposite working principle with a refrigerator. The refrigerant removes heat from the cooling chamber while the heat pump dryer transfers heat to the drying chamber (Mujumdar et al. 2008). The main components of a heat pump are compressor, heat exchanger (condenser and evaporator), and expansion valve (Sauer & Howell, 1983). This component makes the heat pump considered the most effective and most controllable in reducing the water content of the material. The heat pump can exploit hot air from the condenser and remove moisture in the air from the evaporator, so that the output air of heat pump becomes dry and hot (Naemsai, et.al., 2019).

In the evaporator component, the temperature becomes higher because of the refrigerant receives heat. The high temperature refrigerant then flows into the condenser through the compressor. The compressor serves to increase the pressure on the refrigerant, refrigerant that has a high temperature and high pressure flows into the condenser. In the condenser the heat will be released and applied to dry the material (Kusnendar, et. al. 2014).

One of the most commonly known heat pump system is Air Conditioning (AC). AC is usually used to cool the room. When the cooling process is carried out by the air conditioner, at the same time the air conditioner also produces heat from the work of the condenser (Widodo & Rubiono, 2021). This heat is an alternative energy source for drying materials (Husnawan, et.al., 2010). The air conditioning utilization

as a drying machine needs to be tested for its feasibility, both in terms of performance and economic feasibility

Method

To assess the feasibility of a heat pump dryer to dry fish crackers, a method with two analyzes was used. The first analysis is the analysis of the performance of the dryer. The second is an economic feasibility analysis based on production results. The performance of the heat pump dryer was analyzed based on the evaporated water capacity (EC), specific moisture extraction rate (SMER), and specific energy consumption (SEC). Economic feasibility is determined based on the Net Present Value (NPV) of the heat pump dryer.

Before conducting a feasibility analysis based on the performance of the dryer, it must first be known the amount of water content in the material to be dried. This analysis aims to determine the amount of water content in the material after drying to obtain a constant mass (Leviana & Paramita, 2017). Acorrding from Yahya (2014), calculating the water content on a wet basis is using equation 1.

$$M = \frac{W_A}{W_A + W_d} \quad (1)$$

$$EC = \frac{\Delta m}{t}, \text{where } \Delta m = m_0 - m_t \quad (2)$$

$$SMER = \frac{W}{E_{input}} \quad (3)$$

$$SEC = \frac{E}{m_t} \quad (4)$$

$$NPV = \sum_{i=1}^{n} \frac{NB}{(i+1)^n} \quad (5)$$

With:
- M : Water content (%)
- W_A : Water mass (kg)
- W_d : Material mass (kg)
- EC : Evaporate capacity (kg/h)
- Δm : Mass difference of material (kg)
- t : Drying time (h)
- m_0 : Mass of material before drying (kg)
- m_t : Mass of material after drying (kg)
- SMER : Specific moisture extraction rate (kg/kWh)
- W : The amount of evaporated water (kg/h)
- E_{input} : Total energy consumption during drying process (kW)
- NVP : Net Present Value
- NB Net Profit
- i Discount
- n Targeted n_{th} year

Analysis of drying performance based on the evaporation capacity of the dryer shows the ability of the dryer to evaporate water from the material in a certain time interval. Evaporation capacity is calculated by the equation 2. The specific moisture extraction rate (SMER) describes the amount of water content lost from the material compared to the amount of energy consumption (Yahya, 2014). For specific energy consumption is analyzed using equation 4. The second feasibility analysis is economic analysis using Net Present Value (NPV) which shown on equation 5. NPV determines the difference in the amount of profit received with costs incurred based on the current value of the commodity (Prasnowo & Nurdin, 2019). The assement critetia for NVP is shown on table 2.

Table 2. The assement critetia for NVP

NVP Result	Interpretation
NVP > 0.00	heat pump has economic advantage to dry fish crackers.
NVP < 0.00	heat pump has no economic advantage to dry fish crackers.

Result and Discussion

The heat pump drying system in this study utilizes two AC with a capacity of 1.5 hp. Drying chamber capacity of 20-25 kg of wet fish crackers. The design of Heat pump drying maschine is shown on Figure 2. The heat pump system dryer is operated to dry fish crackers twice. The first day of drying, there were 20 kg of wet crackers dried to determine the capacity of the dryer. The first day of drying produced 10.81 kg of dry crackers. The second day of drying aims to determine the performance parameters of the dryer. The drying process sets the system temperature constant at 55oC and the average drying chamber temperature is only able to reach 36oC-49^o C. On the second day of drying, the moisture content data obtained in a wet state of 51.61% and in a dry state of 11.76% with a decrease in water content based on time as shown in Figure 3.

The heat pump drying system dries fish crackers for 5 hours with an evaporation capacity of 1,838 kg/hour. This heat pump system dryer is capable of evaporating almost 2 kg of water every hour. Drying for 5 hours only consumes a maximum of 4.6 kWh of electrical energy with a specific moisture extraction rate of 1,998 kg/kWh. Every 1 kWh of electrical energy consumption by a heat pump dryer is able to reduce almost 2 kg of water from dried fish crackers. Figure 4 shows a graph of the specific moisture extraction rate based on drying time.

The curve of the graph on figure 4 is affected by the maximum temperature of the drying chamber. If the temperature is considered maximum, the AC installed as a heat pump drying system will turn off to save electrical energy which results in the slow rate of

moisture extraction of crackers. When the drying system is reactivated, the moisture extraction rate increases. The curve of the moisture extraction rate graph also shows the shape of the dryer's control in controlling the cracker drying process so that over-drying does not occur.

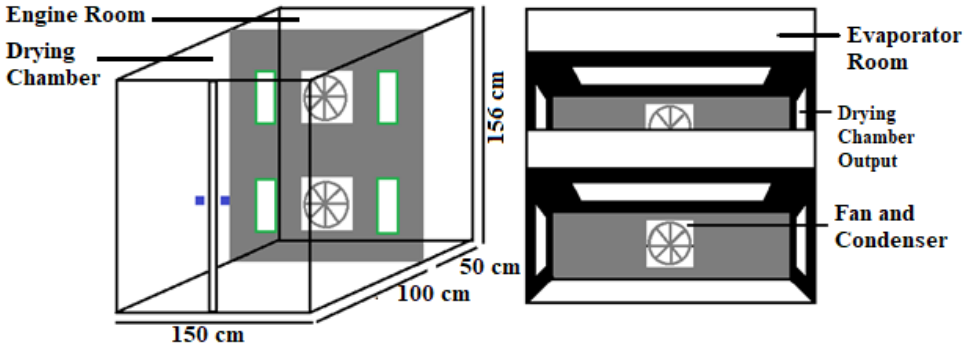

Figure 2. Design of Heat Pump Drying Machine

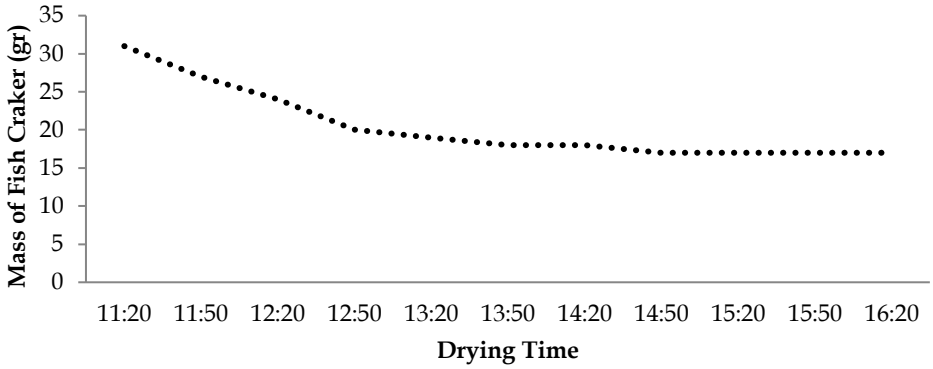

Figure 3. The amount of moisture lost during the drying process

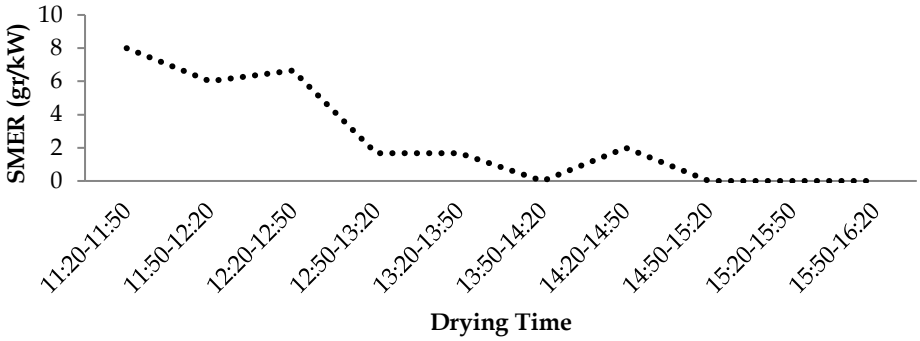

Figure 4. Specific Moisture Extraction Rate

Similar to the specific moisture extraction rate, the specific energy consumption also depends on the capacity of the drying chamber. The drying chamber in this study was able to produce 10.81 kg of dry crackers. This means that the heat pump drying system consumes specific energy of 0.425 kWh of electrical energy to produce 1 kg of dry crackers.

The achievement of the dryer above is able to provide a net income of RM108.1/day and RM39,456.5/year with a profit of RM10/kg of dried fish crackers. This amount of income is the basis for determining the feasibility of using AC as a heat pump system to dry fish crackers. The feasibility test is given from the results of the net present value (NPV) analysis with a total discount of 3.285% (based on the number of Malaysian discounts 2018). With the investment value in the heat pump system dryer of RM10,000 and an investment target of 1 year, the current net value (NPV) is RM28201.58. Because the NPV value is greater than zero (NPV> 0), the heat pump system dryer has

economic advantages and suitable as a fish cracker dryer.

Conclusion

Based on the results of the research and discussion, it can be concluded that the computational thinking approach has the potential to be integrated into physics learning. This is marked by the many previous studies that were able to integrate it in various learning devices and media. In addition, it was found that learning with a computational thinking approach is closely related to students' problem-solving abilities so that physics learning media based on a computational thinking approach has great potential as a means of increasing students' problem-solving abilities.

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