Experimental study of a closed-cycle heat pump dryer for snakehead fish

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Abstract. Snakehead fish (Channa striata) is a type of fish that has economic value. Apart from that, it contains albumin which the human body needs. Albumin is a source of animal antioxidants which functions as a radical scavenger so that it plays a role in the process of cleaning and capturing ROS. Albumin is usually consumed in liquid form and has a fishy smell, therefore, an alternative is needed, namely a drying method. Albumin is a protein that is easily damaged by heat. Therefore, the drying process uses a vacuum dryer. In the drying process of albumin powder, drying temperature is a factor that influences the quality produced. The best drying temperature for albumin is 49°C and the reduction in albumin quality is at 60 ºC. Closed cycle heat pump dryers have the advantages of not being contaminated with dirt from the outside air, low and controlled drying temperatures, not depending on the weather, and relatively cheap equipment prices. This research conducted experimental tests on a closed cycle heat pump drying machine to analyze the performance and water content in drying snakehead fish samples and maintaining the drying temperature below 60°C to keep the albumin from being damaged. In this test, the range of 40.3 – 50.6 water content was achieved, namely 5% of the initial water content of 78.19, 0.619, a drying rate value of 0.619 kg/hour with a total performance value of 10.15. And the comparison value of steamed water with the energy required is SMER 0.47 kWh/kg and SEC 2.10 kWh/kg and the heat pump efficiency is 25%. With the results obtained, this closed cycle heat pump dryer is very suitable for use in the drying industry, especially in the snakehead fish drying industry.

1 Introduction

Snakehead fish (Channa striata) is a type of fish that has economic value. In Indonesia, its distribution includes Sumatra, Java, Kalimantan, Sulawesi and Papua. This species has a distinctive taste, thick and white flesh texture so the price is quite expensive both in fresh and dried form (salted fish). Apart from that, it contains albumin which is needed by the human body to overcome various diseases, especially those caused by reduced amounts of blood protein. Even though it has strategic potential and wide use in the food and pharmaceutical industries, it is still not widely cultivated in Indonesia because its cultivation techniques have not been mastered. Keeping tilapia fish together in ponds, using artificial feed mixtures rich in nutrients, and using aquatic plants in the spawning process are cultivation alternatives that need to be developed [1].

Albumin is a source of animal antioxidants which functions as a radical scavenger so that it plays a role in the process of cleaning and capturing ROS. Snakehead fish extract capsules contain abundant albumin which is able to work as trapping and scavenging against oxidants and free radicals as well as its ability to improve the body's immune function, especially in burns.

Albumin is a protein that is easily damaged by heat. Therefore, the drying process uses a vacuum dryer. In the drying process of albumin powder, drying temperature is a factor that influences the quality produced. Snakehead fish albumin extract is usually consumed in liquid form and has a fishy smell so not everyone likes it. For this reason, another alternative is needed, namely processing it using a drying method so that albumin is produced in powder form which is expected to be accepted by everyone.[2].

Drying can be done conventionally, but the conventional method has many disadvantages because it produces low quality products, is prone to contamination with impurities, requires a long drying time, depends on weather conditions, and requires large areas of land [3]. This drying problem can be overcome by using a closed cycle heat pump dryer.

Based on research results [2] shows that providing vacuum drying temperature treatment can have an influence on the quality of snakehead fish albumin powder. The best quality of snakehead fish albumin powder was obtained at a vacuum drying temperature of 49°C with an albumin content of 4.71%; protein content of 15.92%; yield 37.21%; water content is 4.23%, fat content is 2.07% and ash content is 1.30% and there are 16 amino acids contained in it.

A heat pump is a device that transfers heat from a low temperature medium to a high temperature medium. Most heat pump technologies move heat from a low-temperature heat source to a higher-temperature
location. The most common examples are refrigerators, freezers, air conditioners, and so on. A heat pump is the same device as a cooling machine (refrigerator), the difference is only in its final purpose. Meanwhile, the heat pump aims to keep the room at a high temperature (hot).

In this research, snakehead fish dryers will be tested using a closed cycle heat pump using R32 refrigerant which has good heat conductor efficiency and is environmentally friendly. R32 refrigerant is highly recommended because it has a GWP (Global Warming Potential) value of 677 below the standard RAC gas usage limit of 750 and an ODP (Ozone Depletion Potential) of zero. So the use of R32 refrigerant creates an AC that is environmentally friendly and has a better cooling level. Same with R32. In this test, a temperature, humidity and weight sensor will be installed on the drying machine to determine the ongoing drying conditions.

2 Method

This test was carried out by drying the snakehead fish using a closed cycle heat pump with the working fluid, namely R32 refrigerant, with the desired water content of the snakehead fish being 5%.

Compressor work

Where to get the Wk value of the heat pump using the following equation [4]:

\[ W_k = h_2 - h_k \]  

Heat released from the condenser

To find out the heat value released by the condenser, you can use the following equation[4]:

\[ q_k = h_2 - h_j \]  

Heat absorbed by the evaporator

The amount of heat absorbed by the evaporator can be calculated using the following equation [4]:

\[ q_e = h_j - h_k \]  

Total Performance

The total performance of drying can be calculated using the following equation [5]:

\[ TP = \frac{q_e + q_j}{W_k} \]  

Water content

To calculate the final water content and final weight of the material, you can use equation [6]

\[ K_{a,w} = \frac{W_i}{W_f} \times 100\% = \frac{W_f - W_e}{W_f} \times 100\% \]  

Drying Rate

The amount of drying rate work is calculated using equation [7]:

\[ \dot{m}_d = \frac{W_e - W_f}{t} \]  

Value of SpThe effective Moisture Extraction Rate can be calculated using equation [7]:

\[ SMER = \frac{\dot{m}_d}{W_e + W_f} \]  

SEC Specific Energy Consumption is calculated using equation [7]:

\[ SEC = \frac{1}{SMER} \]  

Drying Efficiency

Drying efficiency can be calculated using equation [8]:

\[ \eta = \frac{Q}{q_a} \times 100\% \]  

For the design scheme for carrying out testing, we can look at the following experimental set up:

Fig. 1. Design results of heat pump dryer system

The circulation system in the closed cycle heat pump dryer above uses a forced convection system, namely air is flowed from bottom to top where the blower acts as a fan and sucks in air which is released by the condenser into the drying room. The air duct is a connection between the drying room and the engine where the air will return to the engine room and will be fanned by a fan before the evaporator and circulation continues as long as the heat pump engine is turned on.

Fig. 2. Experimental set-up scheme

3 Results

Some of the sensors used to obtain the values of the required parameters are load cells, Arduino Uno, DHT2, 34970A data logger, and laptop. The setup for testing can be seen in the image below:
In the picture it is known that the sensors have been installed where the load cell is to see the decrease in the mass of snakehead fish, the DHT21 as a humidity meter in the drying room and machine, the data logger as a temperature reader which is measured by the thermocouple, and the Arduino Uno as a sensor connector to the laptop for reading and data recording during testing. Where in the test the compressor work result was 44.22 kJ/kg, the heat absorbed by the condenser was 166.49 kJ/kg, the heat absorbed by the evaporator was 264.22 kJ/kg.

Based on the working value of the compressor, the heat released by the condenser, and the heat absorbed by the evaporator, we can find out the value of the total drying performance of 10.15 with an average reduction rate of water content of 0.619 kg/hour. In testing 5 kg of snakehead fish with a water content of %, the final mass of snakehead fish was 1.286 kg with a SMER value of 0.475917 kWh/hour and an SEC value of 2.101207 kWh/hour and a drying efficiency of 25%.

The drying temperature in the test was in the interval 40.3ºC- 50.6ºC, including this drying temperature which would not damage the albumin content of snakehead fish.

3.1 Performance of heat pump drying machines
Captions Overview of the temperature and humidity of the engine room and drying room of a closed cycle heat pump.

3.2 Test result
Below in the picture are the results of drying snakehead fish meat.

4 Conclusion
The conclusion of this research is that the total drying performance value is 10.15, the drying rate is 0.619 kg/hour. The level achieved was 5% with a mass of 1.286 kg from an initial mass of 5 kg. The SMER value was 0.475917 kWh/hour and the SEC value was 2.101207 kWh/hour. With temperatures below 60ºC, snakehead fish albumin would not be damaged. Drying efficiency is 25%.

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References