Design of curcuma chips dryer by utilizing the waste heat of commercial refrigerator condenser

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Abstract. Curcuma is one of herb plant and also ingredients for cosmetic products. Curcuma can be dried by other heat source like the waste heat of commercial refrigerator condenser. The results showed the enthalpy heat the refrigerator condenser with the addition of fan is 96.53 kJ kg\(^{-1}\) and potential value is 5281.704 kJ hours\(^{-1}\). The capacity of the 2,4 kg day\(^{-1}\) with drying time 24 hour. Water content reach 8.26%.

1. Introduction
Curcuma is a multi-functional commodity that is currently proclaimed as a national health drink. Market prospects and opportunities for development are still open because of their nutritious chemical content. Currently it is incessant effort to promote healthy life by consuming herbal medicines and the use of herbal products that are safer and having side effects will be very minimal compared to chemical products [1].

Curcuma processing consists of slicing, drying and grinding. The drying process is the most important process, water content of the product exceeding 10% will reduce the quality of the product [2]. The most common method of drying is using solar energy and electric energy in the form of solar drying and oven drying. Each of these methods there is its own weakness. The weakness of solar drying is it needs a long time drying, large place to drying and less hygienic. The weakness of oven drying is it use high electricity. To overcome this problem here is another potential method that can be used for drying. This method is drying by utilizing waste heat. In reusing of waste heat, the quality of waste heat must be considered first. One example of waste heat sources that exist in daily life that is generally already in our homes is waste heat from both Air Conditioner (AC), refrigerator condensers, pumps and roasting ovens.

From the results of the study [3], it was found that the heat discharged from the commercial refrigerator condenser can reach a maximum of 42.12°C and the heat (energy) released is 108.688 kJ kg\(^{-1}\) with dryer efficiency of 100%. The use of potential heat from refrigerator condensers needs to be studied. The refrigerator functions as a food preservative with a cooling process, can function the same as a different process only by using waste heat produced without changing the refrigerator, only by adding components for the drying process. So the refrigerator can do its function in two ways, cooling and drying at once with one energy resource.

The purpose of this research is to design of curcuma chips dryer by utilizing the waste heat of commercial refrigerator condenser.
2. Materials and Methods

2.1. Experimental design

The experiment was conducted in Laboratory of Energy and Electrification Agricultural Faculty, University of Sumatera Utara, Medan. The material used is curcuma with thickness 3 cm. The dryer is tray dryer made of wood coated with Styrofoam and aluminium on the inside of tray dryer. The size of the tray dryer is length 128 cm, width 40 cm and height 40 cm. The air source of the dryer is waste heat of commercial refrigerator condenser AGA-300 RSA with a volume of 282 litres. Calculation of condenser heat value after adding fan

Heat value after fan installation $Q$ (kJ s$^{-1}$) is the difference of the air enthalpy after through condenser, $h_b$ (kJkg$^{-1}$) and air enthalpy before through condenser, $h_a$ (kJkg$^{-1}$) multiplied by difference of air flow rate, $V$ (m$^3$ s$^{-1}$) and specific volume of air $V_s$ (m$^3$ kg$^{-1}$). Air flow rate was calculated using Eq.2, where $v$ is velocity of air flow (m s$^{-1}$) and $A$ surface area of hopper (m$^2$) [4].

$$Q = \frac{V}{V_s} (h_b - h_a)$$  \hspace{1cm} (1)

$$V = v \times A$$  \hspace{1cm} (2)

Specific volume of air was calculated using Eq. 3, where $T$ is temperature of air dryer (°C) and $\omega$ is specific humidity (kg kg$^{-1}$) [5].

$$V_s = (0.082 T + 22.4) \times \left( \frac{1}{29} + \frac{\omega}{18} \right)$$  \hspace{1cm} (3)

Specific humidity was calculated using Eq. 4, where $P_v$ is actual vapour pressure (kPa) and $P$ is atmospheric air pressure (kPa) [4].

$$\omega = 0.622 \times \frac{P_v}{P - P_v}$$  \hspace{1cm} (4)

Actual vapour pressure was calculated using Eq. 5, where $e^o (T_{wet})$ is saturated vapour pressure at the wet ball temperature (kPa), $e^o (T)$ is saturated vapour pressure at air temperature (kPa), $\gamma_{psy}$ is psychrometric constant which value is 0.06738 at a pressure of 1atm and $T_{wet}$ is wet ball temperature of thermometer (°C) [4].

$$P_v = e^o (T_{wet}) - \gamma_{psy} (T - T_{wet})$$  \hspace{1cm} (5)

To calculated saturated vapour pressure at the wet ball temperature use Eq. 6 [6]

$$e^o (T_{wet}) = 0.6010 \exp^{17.27 T_{wet}} \frac{T_{wet} + 237.3}{273}$$  \hspace{1cm} (6)

Air enthalpy before and after through the condenser was calculated using Eq. 7 [7].

$$h = 1.005 T + \omega (2501.3 + 1.82 T)$$  \hspace{1cm} (7)

2.2. Calculation the amount of heat for curcuma drying

Heat value for curcuma drying (Qd) can use Eq. 8, where $Q_t$ is energy to heat material (kJ), $Q_w$ is energy to heat water material (kJ) and $Q_l$ is material water to evaporate energy (kJ). Energy heat material was calculated using Eq. 9, where $C_p$ is value of curcuma specific heat (kJ kg$^{-1}$°C$^{-1}$), $T_a$ is
initial temperature of the material \(^\circ\text{C}\), Td is average temperature of drying air \(^\circ\text{C}\) and mt is mass water of curcuma (kg) \[8\].

\[
Q_d = Q_t + Q_w + Q_l
\]  (8)

\[
Q_t = m_t \cdot C_p (T_d - T_a)
\]  (9)

Energy heating water material was calculated using Eq. 10, where \(C_p\) water is specific heat value of water (kJ kg\(^{-1}\)\(^\circ\text{C}\)) and mat is initial water mass (kg) \[8\].

\[
Q_w = m_a \cdot C_p \text{ of water} (T_d - T_a)
\]  (10)

Evaporation energy of water was calculated using Eq. 11, where \(h_{fg}\) is latent heat of water (kJ kg\(^{-1}\)) and mah is lost mass of water (kg) \[8\].

\[
Q_l = m_a h_{fg}
\]  (11)

3. Result and discussion

Result of calculation condenser enthalpy value after adding fan is 96,53 kJ kg\(^{-1}\) with heat potential is 5281,704 kJ hours\(^{-1}\) and calculation amount of heat for drying 1 kg curcuma is 2086,99 kJ with 6 hours of drying time and drying efficiency of 16,63 % \[9\] the mass of dried curcuma 2,4 kg.

This dryer has an inner dimension of space with a length of 128 cm, width of 40 cm and height of 40 cm and the distance between shelves is 10 cm. The output air shaft uses a parabolic wire with dimensions of 50 x 50 cm. The output air can exit freely, because it will affect the compressor performance and causing it to be quickly damaged when it is closed. Curcuma chips which are sliced with a thickness of 3 cm dried for 24 hours drying time.

Figure 1. Curcuma chips tray dryer
Important components in drying is temperature. The highest drying temperature was 44°C and the lowest was 29 °C. The highest temperature is on first tray, then second tray and third tray. The dryer temperature is high at 18 hour of drying time, because the refrigerator works the most of time.

Generally drying curcuma with conventional methods takes 3-5 days. Conventional drying results in 3 days obtained 22.61% water content with an initial water content of 80.33%. Standard water content of curcuma is <10%.
Figure 3. (a) chart of water content on first tray, (b) chart of water content on second tray (c) chart of water content on third tray.

From Fig. 3a the water content from 0 to 18 hours at areas A and B has decreased quite high. In Figure 3b it can be seen a chart of curcuma water content at area B lower than areas A and C. Where at area B has a lower initial water content compared to areas A and C. Curcuma water content on second tray is lower than first tray can be seen in Figures 3a and 3b. This is influenced by the position of the tray in the second tray that is parallel to the fan. Because of the small of air velocity from the second tray caused the evaporation of moisture is more optimal. The water content on second tray at area B with value 8.26% met the standard water content. Chart of water content on third tray has similarities with first tray.

Area C on each shelf is always higher than areas A and B. That is because the temperature of area C is the farthest from the heat source. Can be seen on each temperature chart at area C. The drying rate will slow down when the water content has reached or approached the equilibrium water content [10] from Fig. 3 the water content of the samples from all trays slowing down after 12 hours drying time and almost stagnant from 18 to 24 hours of drying time, because water content of the material almost reach its equilibrium moisture content.

4. Conclusion
The results showed the enthalpy of the refrigerator condenser with the addition of fan is 96.53 kJ kg\(^{-1}\) and potential value is 5281.704 kJ hours\(^{-1}\) and drying capacity was 2.4 kg. Curcuma tray dryer has an inner dimension of space with a length of 128 cm, width of 40 cm and height of 40 cm with 3 trays. The highest drying temperature was 44\(^\circ\)C and the lowest was 29 \(^\circ\)C. Water content that would conform with the standard in this research is the second tray area B 8.26%.

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