

### 3.3 Results and Discussion for the Mathematical Model Section

#### 3.3.1 The first model in Figure 3.3 (Drying model)

For the mathematical model for 120-kg of whole longan, the initial and final moisture contents were 300% and 25% dry basis. Assuming the latent heat of water inside longan of 3000 kJ/kg (Klongpanich, 1991). We used the first period of the drying time interval for designing the specification of heat pump system. Because it has the highest drying rate and consumes highest energy for removing water from products. All energy used come from the condenser of heat pump, which it have step for calculation and the result as follow.

##### 3.3.1.1 Manual Calculation

The whole longan 120-kg, the beginning moisture content was 300 % dry basis or 75% wet basis. The mass of dry bone and water were 30 kg and 90 kg, respectively. The final moisture content was 25% dry basis or 20% wet basis, which have water 7.5 kg. So, the water removed from whole longan was  $90 - 7.5 = 82.5$  kg. This water used energy for evaporation of  $(3000 \times 82.5) = 247500$  kJ. We used the efficiency of heat transfer from condenser of heat pump 20% and the drying time 45 hours. So, the condenser, which used was  $[247500 / (45 \times 3600 \times 0.2)] = 7.6$  kW. The evaporator of  $7.6 / 1.4 = 5.3$  kW and the compressor of  $(7.6 - 5.3) = 2.3$  kW.

##### 3.3.1.2 The results from the mathematical model

From whole longan 120 kg, the moisture contents reduce from 300 to 25% dry basis. The condition were ambient temperature of 30 °C, relative humidity of 70%, drying temperature of 75 °C, recirculation air ratio of 10%, by-pass air ratio of 0%, the assumption as follow:

- Thermal equilibrium exists between moist air and whole longan.
- The wall of the cabinet dryer is adiabatic.
- The internal energy change of the cabinet dryer and whole longan are negligible.
- The drying air which exit the dryer have relative humidity less than 100%, if more than 100% the program will change the conditions

for drying.

From the results, it can be concluded that the condenser of 8 kW, the evaporator of 5.25 kW and the compressor of 2.75 kW. These values are close to the results from calculation. The experiment uses heaters to control the drying temperature at specific value such as 75 °C for whole longan. After this, we use the heat pump dryer model and the optimum heat pump dryer model for studying the effect of parameters on heat transfer characteristics of the heat pump.

### 3.3.2 The simulation result from the second and the third model

The rest further divided into two parts; first, we simulated for studying the effect of the variable characteristic of the heat pump dryer and selected the suitable condition for construction, secondly, to compare the experimental result with simulation result for verifying the program. Further establish the condition required for the design and construction of the loop thermosyphon.

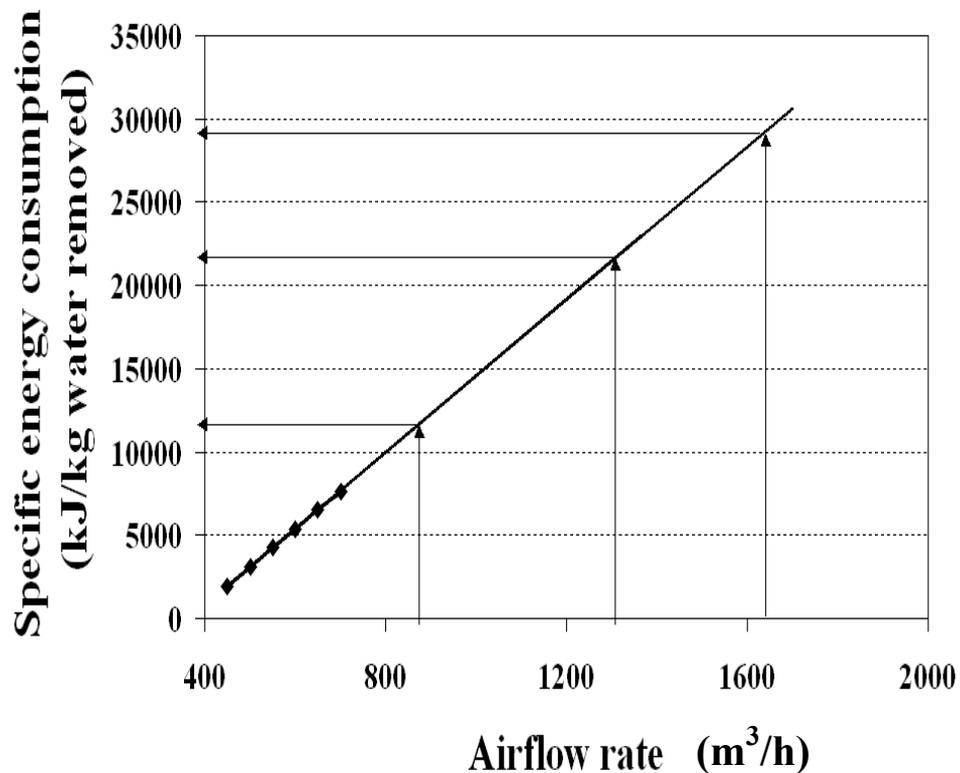
#### 3.3.2.1 Effect of airflow rate on the specific energy consumption

Figure 3.6 shows the relationship between of the specific energy consumption versus airflow rate with respect to the ambient temperature of 30 °C, relative humidity of 70%, 120 kg whole longan, recirculation air ratio of 40% and by pass air ratio of 10%. It can be seen that as the airflow rate increases from 450 to 750 m<sup>3</sup>/hr (simulated from 400 to 750 m<sup>3</sup>/hr), the specific energy consumption increase from 2000 to 7800 kJ/kg water removed. This is because the airflow rate increases the mix air before entering the condenser decrease. Figure 2.7 shows the relationship between the temperature of condenser work compression and power of compression. It can be seen that the compression work and power of compressor were reduced when the temperatures of air enter condenser decrease. This was affecting the specific energy consumption at the heater, which it was influenced directly to the specific energy consumption of the system. These results have agreement with the results of Jolly *et al.* (1990), Jai *et al.* (1990), and Prasertsan *et al.* (1996).

The airflow rate of 400 m<sup>3</sup>/hr can not be used in the experiment because this value is less than the minimum limit of the drying process. The limitation of the

drying process in this case triggers, when airflow rates decrease less than 450 m<sup>3</sup>/hr, the equilibrium moisture content occur in the system. The working air would have researched saturation and hence cannot absorb moisture from the product so the program stops by limiting time over condition (over 60 hrs). The limitation of heat pump system is; when the airflow rate less than 450 m<sup>3</sup>/hr the exit temperature at the condenser will be over the specified value. This program stops due to this condition (exit temperature of the condenser exceeds the specified value). Therefor, for the design and construction minimum value will have two, three and four times of the minimum value that will be used. So, the condition of airflow rate for experimental work are 900, 1350 and 1700 m<sup>3</sup>/hr. The equation and the extrapolation results are shown in Figure 3.6.

From this study, it can be concluded that the airflow rate conditions suitable for experimental work are 900, 1350 and 1700 m<sup>3</sup>/hr. The specific energy consumption was the function of airflow rate, which dependent on airflow rate.



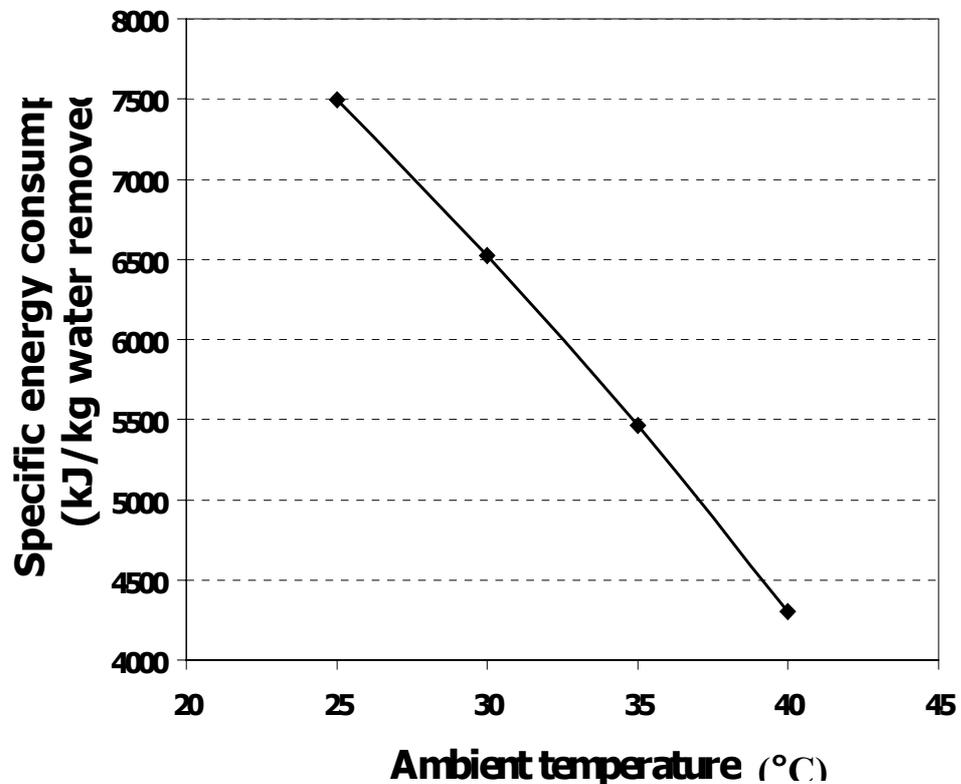
**Figure 3.6** Effect of airflow rate on the specific energy consumption of the heat pump dryer. (Simulation condition:  $T_a=30^\circ\text{C}$ ,  $T_{di}=75^\circ\text{C}$ ,  $RH = 70\%$ ,  $RAR = 40\%$  and  $BAR= 10\%$ . The initial and final moisture content of product were 300 and 25 % dry-basis)

### 3.3.2.2 Effect of the ambient temperature on the specific energy consumption

Figure 3.7 shows the relationship between the specific energy consumption versus the temperature of air. The other data are: relative humidity of air 70%, 120 kg whole longan, recirculation air ratio of 40% and by pass air ratio of 10%, the air flow rate of 650 m<sup>3</sup>/hr. It can be seen that as the ambient temperature increases from 25 to 40 °C, the specific energy consumption decreases from 7500 to 4300 kJ/kg water removed. This is because the temperature of ambient air increases the temperature of mix air before entering the condenser increase. Figure 2.6 show the relation ship of work compression and evaporator temperature. It can be seen that the

work compression and power of compressor decreases when the evaporator temperature increases. The evaporator absorbs more heat from hot and humid air exiting the dryer to the condenser. So the energy consumption at the heater and the compressor decreases. This result corresponded with the result of Achariyaviriya *et al.* (2000).

From this study, It can be mentioned that the ambient temperature affected the specific energy consumption of the heat pump dryer. But during the season of drying longan (rainy season) the average ambient temperature is usually at 30 °C.



**Figure 3.7** Effect of ambient temperature on the specific energy consumption of the heat pump dryer. (Simulation condition:  $M_d=650 \text{ m}^3/\text{hr}$ ,  $T_{di}=75^\circ\text{C}$ ,  $\text{RH} = 70\%$ ,  $\text{RAR} = 40\%$  and  $\text{BAR} = 10\%$  The initial and final moisture content of product were 300 and 25 % dry-basis)