

### 3.4.1 Experimental objective

For confirming that the mathematical model is accurate. Experimental results were used under different set of conditions. The objectives of the experiments are:

- To verify the simulation program
- To find the suitable condition for designing the loop thermosyphon
- To compare the specific energy consumption of the heat pump with and without loop thermosyphon.

### 3.5 Experimental result and discussion

The key parameter, which uses to consider performance of heat pump dryer is the total specific energy consumption of the heat pump system (SECT). It can be defined as:

$$SEC = SEC_h + SEC_{com.} \quad (\text{kJ/kg water removed})$$

$$SEC_h = \text{Energy consumption at the heater per kg of water removed from product. (kJ/kg water removed)}$$

$$SEC_{com.} = \text{Energy consumption at the compressor per kg of water removed from product. (kJ/kg water removed)}$$

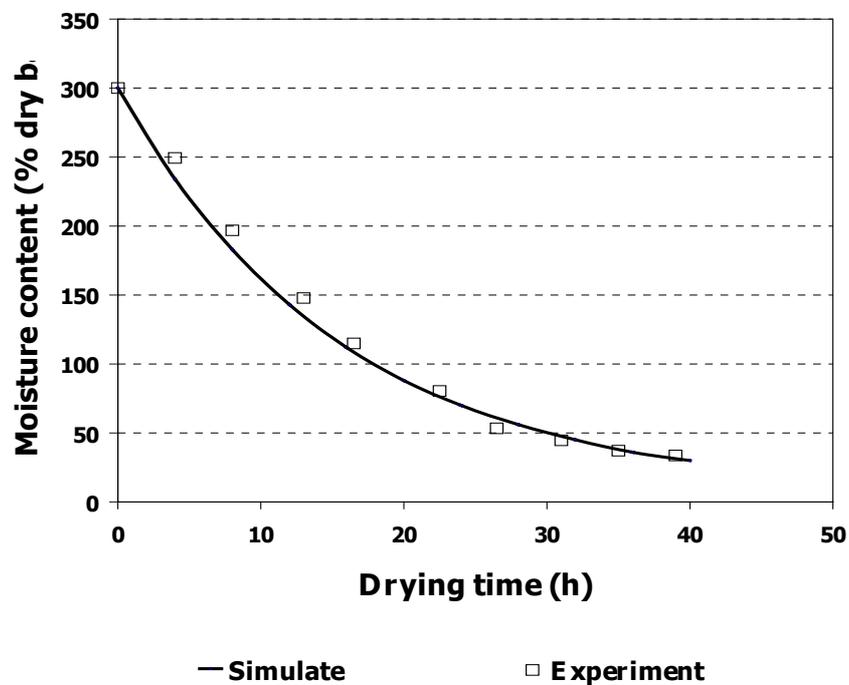
#### 3.5.1 Verification of the mathematical model

The experimental results were compared with the simulated results of the heat pump dryer model as shown in Figures 3.14, 3.15 and 3.16. The verification criteria were the moisture content of the whole dried longan, the exit air temperature from the condenser and the evaporator of the heat pump and the specific energy consumption of the heat pump dryer system.

Figure 3.14 shows the relationship of the moisture kinetics of whole longan with drying time. The open legends show the experimental data while the solid line shows the results from the models. It can be seen that the beginning of drying process, the moisture decreases rapidly, when the drying time increase it slightly decreases and

during final stages of drying the moisture is almost constant. This is because the beginning of drying process the evaporation of the water happen easily at the outside of products. The internal moisture of product is difficult to remove when the drying times increase especially the final period of drying. This is usually happen in the drying process. It is evident that the results of experiment and simulation are very well in agreement.

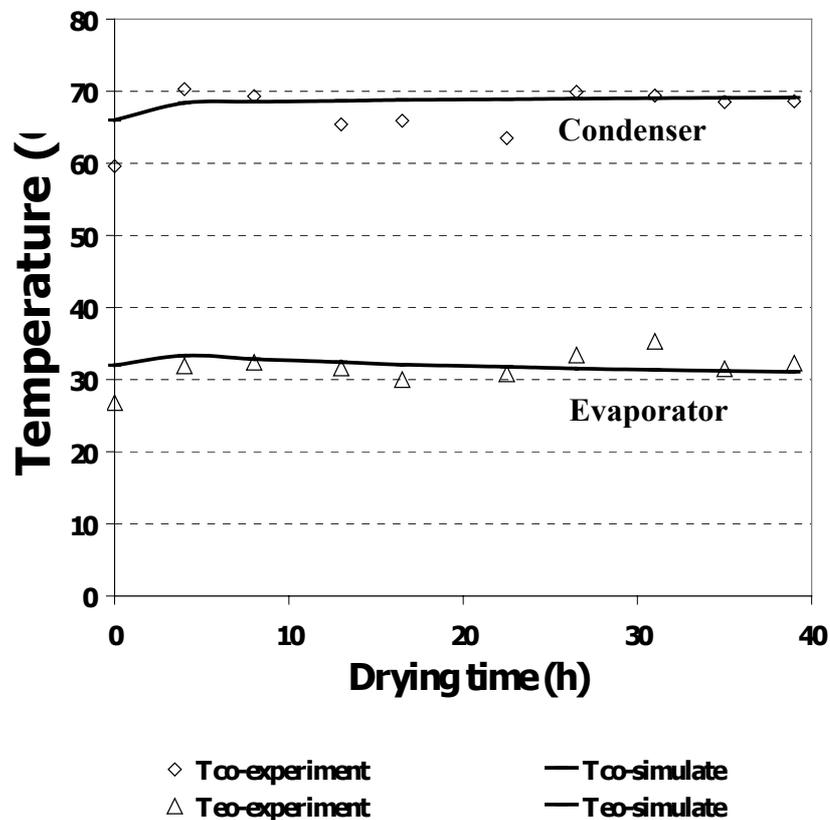
From this study, it can be concluded that the mathematical model can be used to predict the drying rate and drying time.



**Figure 3.14** Drying kinetics of whole longan using the heat pump dryer.

(Simulation condition:  $T_{di} = 75\text{ }^{\circ}\text{C}$ ,  $M_d = 937\text{ m}^3/\text{h}$ ,  $\text{RAR} = 40\%$ ,  $\text{BAR} = 15\%$ , The initial and final moisture content of product were 300 and 25 % dry-basis.).

Figure 3.15 shows the relationship of the exit air temperature from the condenser and evaporator of heat pump with drying time. Again the open legends show the experimental data while the solid line shows the results from the models. For the exit temperature at the condenser of heat pump, it can be seen that the beginning temperature from the experiment is lower than the simulation. This is because at the beginning the system was not at steady state. But as the drying time increases, heat pump was in steady state. It can be seen that the experimental data is in agreement with the simulated line. The exit temperature at the evaporator of the heat pump has values that follow similar trend as that of the temperature at the condenser.



**Figure 3.15** Comparison of the exit air temperature of the condenser and the evaporator. (Simulation condition were:  $T_{di} = 75\text{ }^{\circ}\text{C}$ ,  $M_d = 937\text{ m}^3/\text{h}$ ,  $\text{RAR} = 40\%$ ,  $\text{BAR} = 15\%$ , initial moisture content = 300% dry-basis, final moisture content = 25 % dry-basis,  $T_{co}$  = Temperature of exit air of the condenser,  $T_{eo}$  = temperature of exit air of the evaporator.).

From this study, it can be concluded that the mathematical model can be used to predict the temperature of exit condenser and evaporator of heat pump system to design the size of heater for controlling the specific drying temperature.

Figure 3.16 shows the relationship of specific energy consumption of the heat pumps dryer between simulation result and experimental result. It can be seen that effect of recirculation air ratio at any airflow rate to the specific energy consumption. When the recirculation air ratio increases the specific energy consumption decreases at any value of airflow rate. This is because increasing the recirculation airflow rate as the same as recovery of the waste heat to system, with the temperature of mixing airs before entering the condenser increase. So, the effect of the recirculation air ratio on the specific energy consumption is shown for different airflow rates. In Fig. 3.16 we can also see that the SEC decreases at all air flow rates. These results agree with the data of other researchers Jolly *et al.* (1990), Jai *et al.* (1990) and Prasertsan *et al.* (1996). Furthermore, the result from the simulation and experiments are nearly the same for all conditions.

From this study, we can suggest that the optimum condition for design and construction of a loop thermosyphon for the airflow rate as  $937 \text{ m}^3/\text{hr}$ . This condition was suggested because it has the lowest SEC. It should be noted that the recirculation air ratio to obtain this value of SEC is 40%. The other condition are by-pass air ratio of 15%, the drying air temperature for whole longan of  $75 \text{ }^\circ\text{C}$ , the ambient temperature and the relative humidity are  $30 \text{ }^\circ\text{C}$  and 70 %, respectively.