

CHAPTER VI

RESULTS AND DISCUSSION

6.1 Experimental results and simulation model

6.1.1 Heat pump dryer without loop thermosyphon

Figure 6.1 shows the relationship between the recirculation air, airflow rate and specific energy consumption of the heat pump dryer without the loop thermosyphon. The variable parameters in this case are; airflow rates of 937, 1350 and 1620 m³/h, recirculation air ratios of 30, 35 and 40%. The control parameters for the computer program were: the by-pass air ratio of 15%, the ambient temperature of 30 °C, the relative humidity of 70% and the drying temperature of 75 °C for whole longan. It can be seen that for any condition of airflow rate, when the recirculation air increases, the specific energy consumption decreases. This is because recirculation air increase, it means that increase the recovery the waste heat. So, the specific energy consumption decreases. These results agree with the published research by Jolly *et al.* (1990), Jai *et al.* (1990), Praseartsan *et al.* (1996) and Achaiyaviriya *et al.* (2000).

From this study, it can be stressed that the suitable conditions for operation the heat pump dryer is the lower airflow rate but should not be lower than the limitation of the heat pump system, which in this system is 450 m³/h. The recirculation air ratio, which suitable conditions for operation the heat pump dryer are at the highest value but should not be higher than the limitation of the drying process. The mathematical model can be used to establish the values for these limitations.

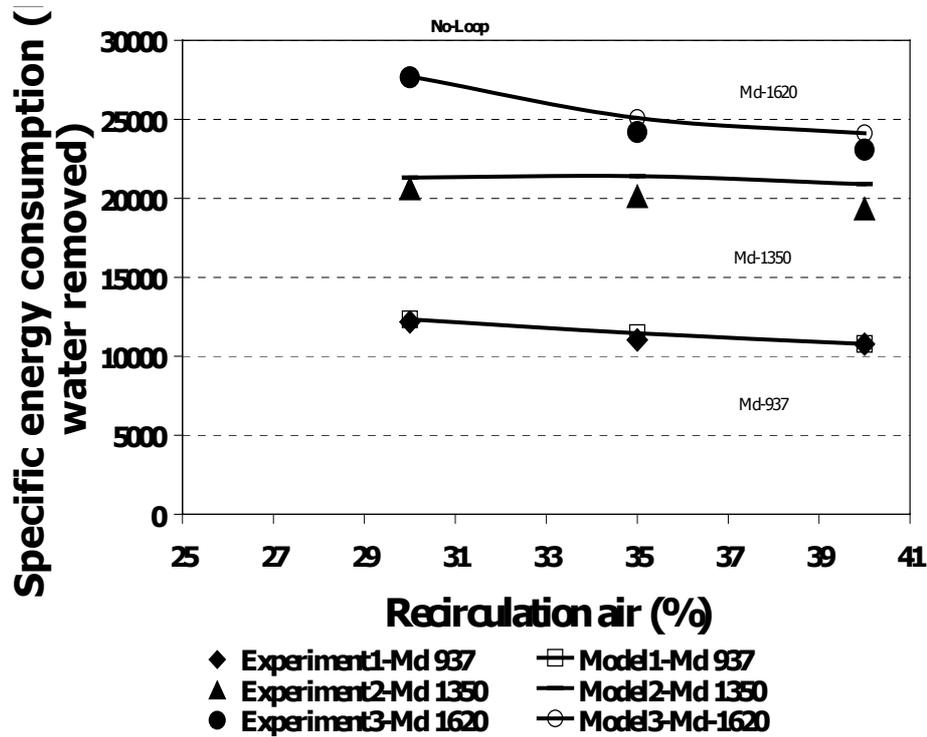


Figure 6.1 Effect of recirculation air and airflow rate on the specific energy consumption of heat pump dryer without loop thermosyphon.

6.1.2 Heat pump dryer with Loop thermosyphon

Figure 6.2 shows the relationship between the recirculation air, airflow rate and specific energy consumption of the heat pump dryer with the loop thermosyphon. The variable parameters in this case are; airflow rates of 937, 1350 and 1620 m³/hr, recirculation air ratios of 30, 35 and 40%. The control parameters for the computer program were; the by-pass air ratio of 15%, the ambient temperature of 30 °C, the relative humidity of 70% and the drying temperature of 75 °C for whole longan. The parameter values are the same as for the heat pump dryer without loop thermosyphon. It can be seen that when the recirculation air increases, the specific energy consumption decreases. From this study, it can be seen that the suitable condition for operation of the heat pump dryer with loop thermosyphon is a low airflow rate, but it

should not be lower than the limit of the heat pump system. The mathematical program can be used to establish this condition. For the recirculation air ratios, suitable condition for operation of the heat pump dryer are at the highest value, but not exceeding the limit of the drying process.

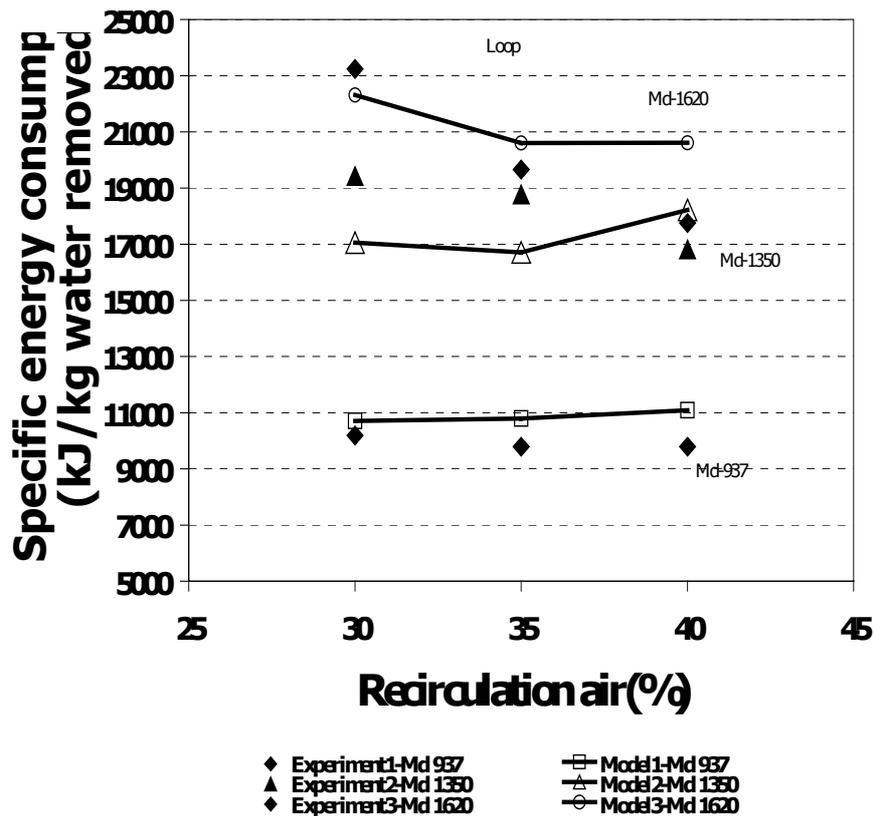


Figure 6.2 Effect of recirculation air and airflow rate on the specific energy consumption of the heat pump with loop thermosyphon.

6.2 Energy saving of loop thermosyphon

6.2.1 Effect of the recirculation air on the specific energy consumption

Figure 6.3 shows the relationship between the specific energy consumption at varying recirculation air ratios of the heat pump dryer with and without the loop thermosyphon. It can be seen that the heat pump dryer with loop thermosyphon has a

specific energy consumption lower than the specific energy consumption of the heat pump dryer without loop thermosyphon at all conditions of the recirculation air ratio. When comparing this result with the result of Waikual (1997) and Terdtoon *et al.* (1999), it can be seen that the results are in good agreement.

From this study, it can be concluded that the loop thermosyphon can save the specific energy consumption of the heat pump dryer.

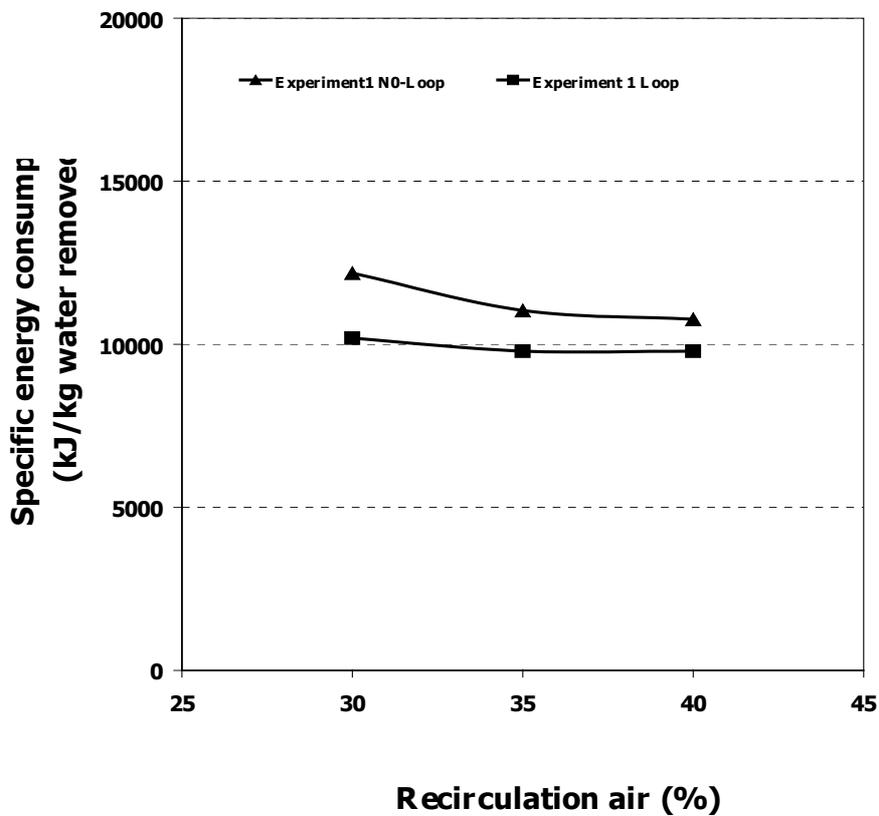


Figure 6.3 Comparison of the specific energy consumption of the heat pump dryer with and without loop thermosyphon.

6.2.2 Effect of the airflow rate on the specific energy consumption

Figure 6.4 shows the relationship between the specific energy consumption at varying airflow rates of heat pump dryer with and without loop thermosyphon. It can be seen that at all airflow rates when the airflow rate increases the specific

energy consumption increases and the heat pump dryer with the loop thermosyphon has a specific energy consumption lower than that of the heat pump dryer without loop thermosyphon. When comparing this result with the result of Waikual (1997) and Terdtoon *et al.* (1999), it can be seen that the results are in good agreement.

From these results, it can be stressed that the loop thermosyphon can reduce energy consumption of the heat pump dryer system.

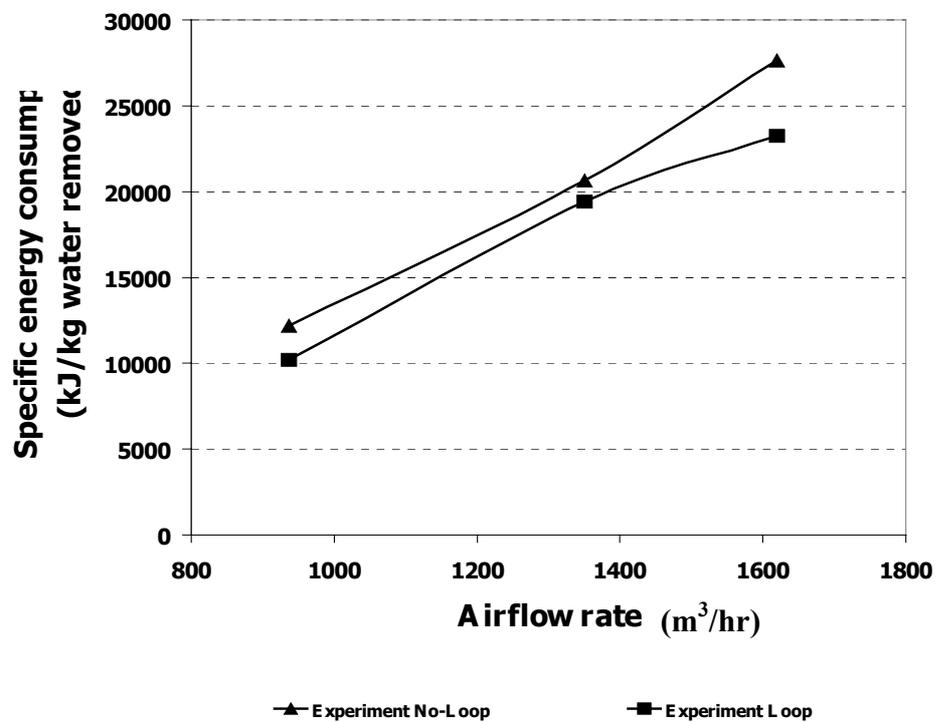


Figure 6.4 Comparison of the specific energy consumption versus airflow rate of the heat pump dryer with and without loop thermosyphon.

6.3 Effectiveness of the LTS

Figure 6.5 shows the effectiveness of the loop thermosyphon at varying airflow rates. It can be seen that when the airflow rate increase from 937 to 1620 m³/hr the effectiveness of the loop thermosyphon decrease from 0.25 to 0.15. When comparing this result with the result of Noie-baghban *et al.* (2000), it can be seen that the results are in good agreement.

From this study, It can be concluded that the lower the airflow rate the higher effectiveness but it is not be lower than the limitation of the heat pump operation and limitation of drying condition. The mathematical program can predict the mathematical program can predict both these limitats.

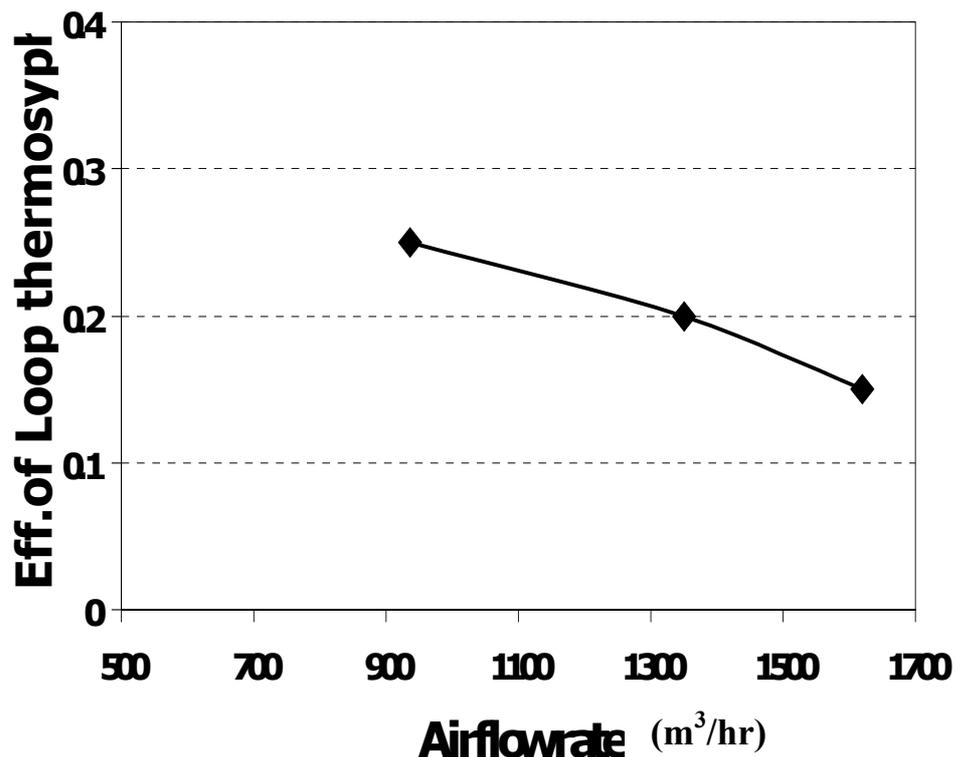


Figure 6.5 Effectiveness versus airflow rate of LTS.

6.4 Comparison of the percentage energy saving for the heat pump dryer with and without the loop thermosyphon from the experiments and simulation results

The experimental results were compared with the simulation results, for assessing the energy saving aspects of a heat pump dryer. Tables 6.1, 6.2 and 6.3 show the percentage of energy saving produced by the loop thermosyphon.

Table 6.1 Compares the specific energy consumption and percentage energy saving in a heat pump dryer with and without loop thermosyphon at an airflow rate of 937 m³/h. The values shown in the table are the results from the experiments and the models. It can be seen that the result from experiment is 9.6 % and the simulation is 13.2 % energy saving. The results from the experiment and model agree quite well. The discrepancy between these results could be caused by the assumptions in the model. For example, in the model the temperature of ambient air taken as constant; but in the experiment the actual temperature of the air is not constant. This is a possible reason that the percent energy saving of the experiment is more than that of the model.

Table 6.2 shows the specific energy consumption and percentage energy saving in a heat pump dryer with and without loop thermosyphon at the airflow rate of 1350 m³/h. It can be seen that the percentage energy saving of the experiment is 15.8 % and the model is 19.9 %. Again, the results from the experiment and the model agreed fairly well. The discrepancy between these results could also have come from some of the assumption made for the model as indicated earlier.

Table 6.3 compares the specific energy consumption and percentage of energy saving in a heat pump dryer with and without loop thermosyphon. The values shown in the table are the results from the experiments and the models at the airflow rate of 1620 m³/h. From the experiment energy saving is 20.4 % and from the model the percent of energy saving is 19.5 %. These results are nearly the same value. It can be concluded that the loop thermosyphon device can be used as an energy saver in the heat pump dryer. The amount of the energy saved depends on the condition of operation.

And from all the results, it can be seen that a percentage energy saving of 12 to 20 % is possible depending on the operating conditions.

Table 6.1 Comparison of specific energy consumption of experiments and simulation of a heat pump dryer with and without the loop thermosyphon.(Airflow rate of 937 m³/hr).

%RAR	Experimental results			Simulation result		
	No-loop	Loop	% Energy saving	No-loop	Loop	%Energy saving
	(kJ/kg water removed)			(kJ/kg water removed)		
30	12137	10973	9.6	12337	10707	13.2

Table 6.2 Comparison of specific energy consumption of experiments and simulation of a heat pump dryer with and without loop thermosyphon. (Airflow rate of 1350 m³/hr)

%RAR	Experimental results			Simulation result		
	No-loop	Loop	% Energy saving	No-loop	Loop	%Energy saving
	(kJ/kg water removed)			(kJ/kg water removed)		
30	20496	17248	15.8	21313	17056	19.9

Table 6.3 Comparison of specific energy consumption of experiments and simulation of a heat pump dryer with and without loop thermosyphon. (Airflow rate of 1620 m³/hr)

%RAR	Experimental results			Simulation result		
	No-loop (kJ/kg water removed)	Loop (kJ/kg water removed)	% Energy saving	No-loop (kJ/kg water removed)	Loop (kJ/kg water removed)	%Energy saving
35	26929	21426	20.4	27725	22310	19.5