

## **CHAPTER VIII**

### **SUMMARY AND CONCLUSIONS**

This research focused on the application of loop thermosyphon as an energy saver in a heat pump dryer. The method involved design and construction of mathematical models. The mathematical model consists of a conventional heat pump dryer (without loop thermosyphon), loop thermosyphon model and heat pump dryer with loop thermosyphon as an energy saver. Construction of a physical model and test for the result verify the model. Economic analysis of loop thermosyphon for use in heat pumps dryer was performed.

#### **8.1 Developments of mathematical model of heat pump dryer.**

Firstly a mathematical models was developed for a heat pump dryer, which can be used to predict the heat transfer characteristic of the system. The amount of whole longan was 120 kg, the suitable condition and the specification of the heat pump dryer were airflow rates of 450 m<sup>3</sup>/h, the condenser of 8 kW, the evaporator of 5.25 kW and the compressor of 2.75 kW. It can be seen that the results of experimental data were comparable with the results of the model. It can be concluded that the model of the heat pump dryer without loop thermosyphon can be used to predict the heat transfer characteristic of heat pump dryer over the range of conditions. The limits of operation of the heat pump and drying process can also be calculated and predicted by the model. The requirements for minimum specific energy consumption were calculated for design and construction of the loop thermosyphon.

#### **8.2 Development of simulation model of loop thermosyphon**

The simulation program of the loop thermosyphon was used to simulate a range of sizes of the loop thermosyphon. For this research, the size of the loop thermosyphon used was 5.25 kW. From the results, it can be concluded that the loop thermosyphon model, which has been developed, can be used to design the loop thermosyphon well and the maximum effectiveness of the loop thermosyphon in this research was 0.25.

### **8.3 Applications of the loop thermosyphon as an energy saver in the heat pump dryer.**

The loop thermosyphon can be used in the heat pump dryer to reduce energy consumption. The results showed that the loop thermosyphon can reduce the specific energy consumption from 12 to 20%, depend on the operating conditions.

### **8.4 Economic analysis**

Application of the loop thermosyphon in the heat pump dryer is a good idea, because the economic results show that the pay back period is about 3 years and the internal rate of return (IRR) is about 30%. These results were obtained by operating the heat pump dryer at an airflow rate of two to four times the optimum value (optimum value is 450 m<sup>3</sup>/hr). If operated at optimum value of airflow, the value of energy saving will be more and the pay back period could be less than 2.8 years and the IRR will be higher than 30%.

### **8.5 Suggestion for future studies**

8.5.1 Application of the loop thermosyphon in a heat pump dryer must be considered at the optimum values; maximum heat transfer of the loop thermosyphon and minimum specific energy consumption of heater because the specific energy consumption of the heater influences the heat pump dryer. From this study, using airflow rates of two to four times the optimum conditions (450 m<sup>3</sup>/h) are recommended. If the airflow rate used is near optimum value, the specific energy consumption of the system can be reduced. The pay back period will be less than 3 year and the IRR will be higher than 30%.

8.5.2 The recirculation air ratio may be more significant at higher values and this should be studied. Example: using 20, 40, 60 and 80% may show differences that more clearly indicate the optimum point.

8.5.3 The effectiveness of the loop thermosyphon will be the highest when the heat pump dryer system operates at the lowest airflow rate. Therefore, studying the heat pump performance at low airflow rates should be considered but not lower than limits of the system.

8.5.4 Application of heat pump dryer with larger quantity of whole longan that used in this research (120 kg) should be considered. This can be done by recalculation of the heat pump size suitable for product using the mathematical model in Chapter III and the detail show in Figure 3.5 (Optimum heat pump dryer model). After that, the data of heat pump can be used to design loop thermosyphon using the program in Chapter IV and the detail shown in Figure 4.2 (Optimum loop thermosyphon model) and finally using the mathematical model of heat pump dryer with loop thermosyphon to simulate the minimum specific energy consumption.

8.5.5 Using this program with other product, which have different kinetics of drying, can be tested. The user must change the property equations of the product given in Chapter III, which has detail in Figure 3.3(Drying model). After that, simulation of the specifications of the heat pump can be found using the heat pump model shown in Figure 3.4.

8.5.6 The energy lost with exhaust hot air released to ambient is about 60%. If it possible to designs system for recovery of the waste heat in order to pre-heat the air before mixing with the recirculation air, which can save energy further.