CHAPTER 8

CONCLUSIONS

Dried banana is an important product for the cottage-industry in Thailand. For example, in Bangkrathum, Phitsanulok, revenue from the sales of dried bananas alone is estimated to be more than 200 million bahts annually. Statistics from the Export Promotion Department, Bangkok, showed that the average export price of fresh bananas in 1997 was 12.05 Baht/kg compared to 276.16 Baht/kg for the dried product. These figures show conclusively the high value addition of dried bananas over the fresh commodity. Despite these encouraging data, the reality is that more than 90% of dried bananas in this country are still produced by the traditional open sun drying method. Adoption of more advanced solar drying technology has been relatively slow due to the perceived high capital cost, and a natural aversion to change and unfamiliar technology. Yet, it is a common knowledge in the industry that the main constraint to market expansion is the current method of drying. As consumers are becoming more discerning, the need for a more advanced method of producing dried products, including bananas, becomes more critical. Hence, the challenge is to design a solar dryer which can out-perform open sun drying in product quality, and at the same time user-friendly enough, so that the technology can be adopted by the industry eventually. In this study a mini-hybrid solar dryer has been designed and tested in an attempt to meet the challenge mentioned above.

a) Main Features of the Dryer:

In this thesis, the solar dryer designed is a shelf-type, indirect, forced-convection, with hybrid-mode capability, batch dryer.

1. The dimension of the dryer is 2.5 m (length) by 1.2 m (width) by 1.8 m (height).

2. The solar collector has an overall dimension of 2.4 m (length) by 1.2 m (width) and an effective area of 2.53 m^2. The collector assembly consists of one glass cover and an absorber made from corrugated galvanized sheet painted black. It is heat insulated by styrofoam on the sides and underside. The air-flow through the collector is under the absorber plate.

3. The drying chamber can hold three stainless-steel trays, each of dimension 1.2 m (length) by 0.5 m (width). The trays have a total area of 1.8 m^2 capable of holding 30 kg of peeled bananas per batch. A capacity of 30 kg is selected in order to limit the size of the dryer due to budget constraints. However, using the spreadsheet program presented in Appendix J, a new dryer can be re-configured to handle higher capacities, hence, up-scaling is possible.

4. The air delivery system consists of a centrifugal fan of capacity 10 m^3/min and an AC motor with a rating of 0.1 kW.

5. The auxiliary heating system uses LPG as fuel and it can be operated either manually or automatically. A built-in control system enables the desired drying temperature to be set when hybrid-mode is operated automatically.

b) Testing of the Dryer:

The dryer was tested under no-load and with-load conditions. The main findings are as follows:

i) No-Load Test

1. When the exhaust vent is opened 10% and 100%, the mass flow rates of air are found to be 0.067 kg/s and 0.102 kg/s respectively.

2. For vent opening 10%, the minimum and maximum instantaneous collector efficiencies are 29.7% and 64.7% respectively. For vent opening 100%, the minimum and maximum instantaneous collector efficiencies are 30.8% and 72.9% respectively. The average collector efficiencies are 54.8% and 59.9% for vent opening 10% and 100% respectively.

3. The temperature rise between collector inlet and outlet are 16.4°C and 11.9°C for vent opening 10% and 100% respectively.

4. For both vent openings, the efficiency curves and the temperature-rise curves appeared to vary in a similar manner with solar insolation, i.e. lower in the early morning and late afternoon and highest around mid-day.

5. The collector temperature-rise varies almost linearly with solar insolation when the collector inlet temperature is close to the ambient temperature. When the vent is fully opened, the empirical equation, $y = 0.0268x - 9.5926$, can be used to predict the outlet temperature for any time of the year with the help of available meteorological data, eg. insolation data and ambient temperatures.

6. It is found that when the air flow rate increased 52.2% from 0.067 kg/s to 0.102 kg/s; the average collector efficiency increased 5.1% from 54.8% to 59.9%, and the average rate of useful energy gained increased 9.1% from 1116 W to 1217 W, while the average temperature-rise decreased 27.4% from 16.4°C to 11.9°C. Hence, based on the above results, operating the dryer with the exhaust vent fully opened is preferred in view of the higher average efficiency achieved.

ii) With-Load Test

1. The mini-dryer is capable of drying 30 kg of bananas from an average initial moisture content of 66% wb to a final moisture content of between 22% - 25% wb in 5 days (40 hours) under varying insolation levels, regardless of weather conditions.

2. For 100% solar-mode with a load of 30 kg of bananas, the drying, pick-up and system efficiencies are found to be 39.7%, 34.3% and 17.6% respectively. The energy utilized, per kg of H_2O evaporated, per kg of fresh bananas and per kg of dried products are found to be 10.0 MJ/kg, 5.9 MJ/kg and 14.2 MJ/kg respectively.

3. For hybrid-mode with a load of 30 kg of bananas, the average drying, pick-up and system efficiencies are found to be 44.2%, 21.9% and 12.1% respectively. The average energy utilized, per kg of H_2O evaporated, per kg of fresh bananas and per kg of dried products are found to be 17.4 MJ/kg, 9.7 MJ/kg and 21.9 MJ/kg respectively.

4. For 100% LPG-mode with a load of 30 kg of bananas, the drying, pick-up and system efficiencies are found to be 38.7%, 20.2% and 18.3% respectively. The energy utilized, per kg of H_2O evaporated, per kg of fresh bananas and per kg of dried products are found to be 15.7 MJ/kg, 8.5 MJ/kg and 18.7 MJ/kg respectively.

5. The solar fractions calculated for hybrid-mode are 0.64 and 0.50 when the average insolation levels are 21.4 MJ/m^2day and 20.1 MJ/m^2day respectively.

6. The mass of LPG used during hybrid-mode ranges from 3 - 5 kg per drying period depending on the weather conditions. For drying at night (100% LPG), the amount used is 8 kg.

7. From the drying curves, it is observed that the mini-dryer and solar tunnel dryer take 5 days to attain the desired final moisture content of 22%- 25% (wet basis), compared to open sun drying which requires 7 days.

c) Product Quality Comparison:

1. The attributes (appearance, color, fragrance, texture, taste) in a sensory test are compared among the products from the tunnel dryer, mini-dryer and commercial open sun drying. Dried bananas from the mini-dryer are most preferred in terms of appearance, color and taste. Overall for the sensory test, the products from the mini-dryer and tunnel dryer seem to be similar but are superior to those produced by commercial open sun drying.

2. Moisture contents of dried bananas from mini-dryer and tunnel dryer are found to be 22.4% wb and 24.3% wb respectively compared to the product from commercial open sun drying which is higher at 28.1% wb.

d) Financial Analysis:

1. The value addition of dried bananas produced by the mini-dryer is estimated to be 10.8 Baht/kg fresh. If the value addition is considered based on the improved quality compared to open sun drying, the value addition of the product dried by the mini-dryer is found to be 4.3 Baht/kg fresh.

2. The simple payback period of the mini-dryer is found to be 2.5 years. Generally, this is comparable to the estimated payback of other solar crop dryers which are developed in Thailand.

3. On the whole, the financial viability of the dryer appears positive. If the dried products could be exported due to the improvement in quality, the value addition is believed to be even higher than it is currently.