

## The Solar Macaroni Dryer <sup>#</sup>

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### ABSTRACT

“Solar energy is free but not cheap”. That thought has driven research at Nong-Lam University to design, fabricate, and test a macaroni dryer using solar energy as the heat source; the aim being to be competitive with the drying costs of fossil fuels.

The dryer is based on the air reversal principle as presented at ICCHP '03. The machine has 3 components: 1/ a two-stage axial-flow fan; 2/ a drying bin containing 500 kg of macaroni, wherein the airflow can be set upwards or downward; and 3/ a solar collector consisting of two parallel 25 m-long horizontal cylinders, made from heavy polyethylene (PE) transparent sheet, with black PE sheet inside as heat absorbers. In this case the solar collector replaces the coal furnace of an existing macaroni dryer, which used to consume 6 kg of coal per hour for a drying a batch in 5 hours.

Drying tests in March 2006 with solar insolation ranging from 500 to 900 W/m<sup>2</sup> showed that the drying temperature reached 37- 52° C, averaging 14 kelvin above ambient temperature, over 5-hour drying time. The collected power was about 44 kW, and the collector efficiency was 40 %. In the rainy days of April-June 2006, drying from solar energy alone was confirmed, although the drying time stretched out to 6 - 8 hours.

By substituting coal with solar energy, the collector has saved US\$120/month; compared to its initial cost of US\$900 and the US\$50 replacement cost for PE tube after every 7 months; the pay-back period is less than one year. Use of clean solar energy meets the hygienic requirements for food drying. There are indications that greater investment cost reductions for the collector are possible.

Keywords: *Solar dryer, Solar collector, Food drying, Macaroni.*

### INTRODUCTION

Mechanical drying is a better way than sun drying on the pavement to ensure food hygienic requirements, to be independent of the rainy weather, and to save labor. However, using machine requires fuels such as coal or oil, which entails high drying cost, and which is the factor impeding the acceptance of the machine itself.

Solar energy is an inexhaustible source for drying. But as a popular saying “solar energy is free but not cheap”, research on solar drying resulted in numerous dryers, but very few among these brought economic profits on long-term operation at production scale (Kamaruddin 2003; Sukhatme 1996). That thought has driven research at Nong-Lam University to design, fabricate,

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and test a macaroni dryer using solar energy as the heat source; the aim being to be competitive with the drying costs of fossil fuels.

## MATERIALS AND METHODS

Works started with a laboratory dryer for about 5 kg of drying material per batch. The data on the solar collector was used to design and fabricate a full-scale 500-kg macaroni dryer. After testing the latter, ways to reduce the cost for the solar collector were explored.

### *The laboratory dryer*

Construction of the 5-kg laboratory dryer is shown in Figure 1 (Nguyen M. Hoang, 2005).

The drying chamber consists of six trays of 0.39 m \* 0.39 m. A 12-watt fan with an airflow of  $\approx 0,02 \text{ m}^3/\text{s}$  draws the heated air from the solar collector and blows through the trays. The collector is a 3 m<sup>2</sup> polyethylene tube, with black absorber inside. To estimate the heat power of the collector, comparison was made with a variable electric resistor which produced the same temperature increase under the same airflow and ambient temperature. Measurements were repeated in several days with different insolation.



Figure 1: The laboratory dryer  
1/ Solar collector; 2/ Suction fan; 3/ Air duct; 4/ Drying chamber; 5/ Trays

### *The macaroni 500-kg dryer*

Based on data obtained from the laboratory dryer, a 500-kg macaroni solar dryer was designed, tested, and applied by a food company in Ho Chi Minh City.

The dryer is based on the air reversal principle (Fig.2), which had been applied widely for paddy in the Mekong Delta and Viet Nam since 2001 (Phan Hieu Hien et.al. 2003). The machine has three components: 1/ a two-stage axial-flow fan; 2/ a drying bin containing 500 kg of macaroni, wherein the airflow can be set upwards or downward; and 3/ a solar collector consisting of two parallel 1-m diameter, 25 m-long horizontal cylinders, made from heavy polyethylene (PE) transparent sheet, with black PE sheet inside as heat absorbers (Fig.3). In this case the solar collector replaces the coal furnace of an existing macaroni dryer, which used to consume 6 kg of coal per hour for a drying a batch in 5 hours.

Drying tests were conducted while ambient conditions were recorded, with the solar radiation monitored by a Daystar solarimeter.

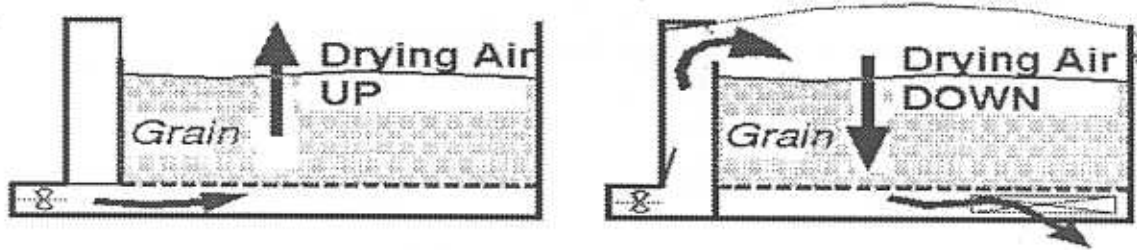


Figure 2. Principle of air reversal drying

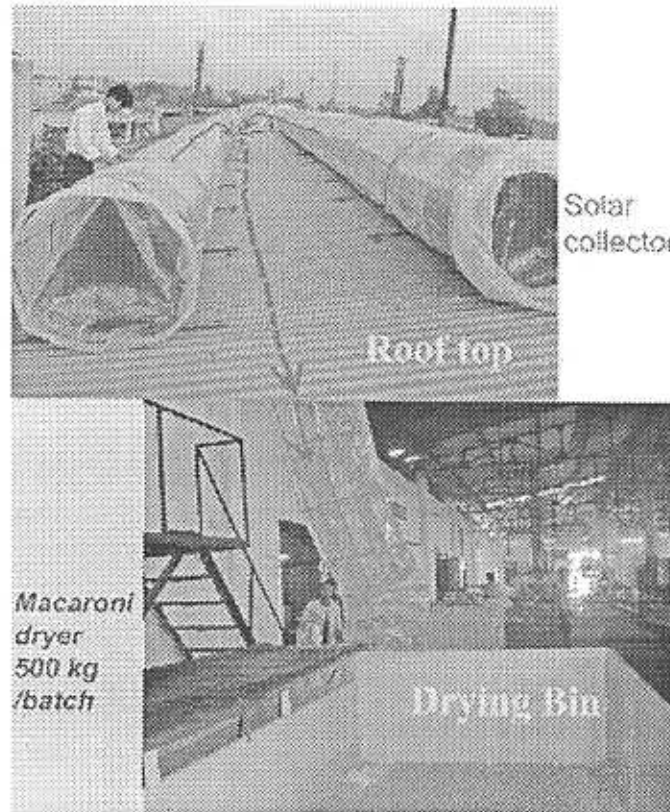


Figure 3: The macaroni dryer

## RESULTS AND DISCUSSION

### *The laboratory dryer*

Figure 4 shows the heat power of the 3-m<sup>2</sup> solar collector, which ranged from 300 to 1200 W, corresponding to an temperature increase between 6 to 22 kelvin, and the drying temperature reached 36- 50 °C. This is the basic data used in up-scaling the collector with the same configuration.

The lab dryer was tested with different available materials to confirm the above heat power. For example, 4.1 kg of fish with an initial MC of 69.6 % was dried down to 19.7 %MC in 21 hours (two sunny days).

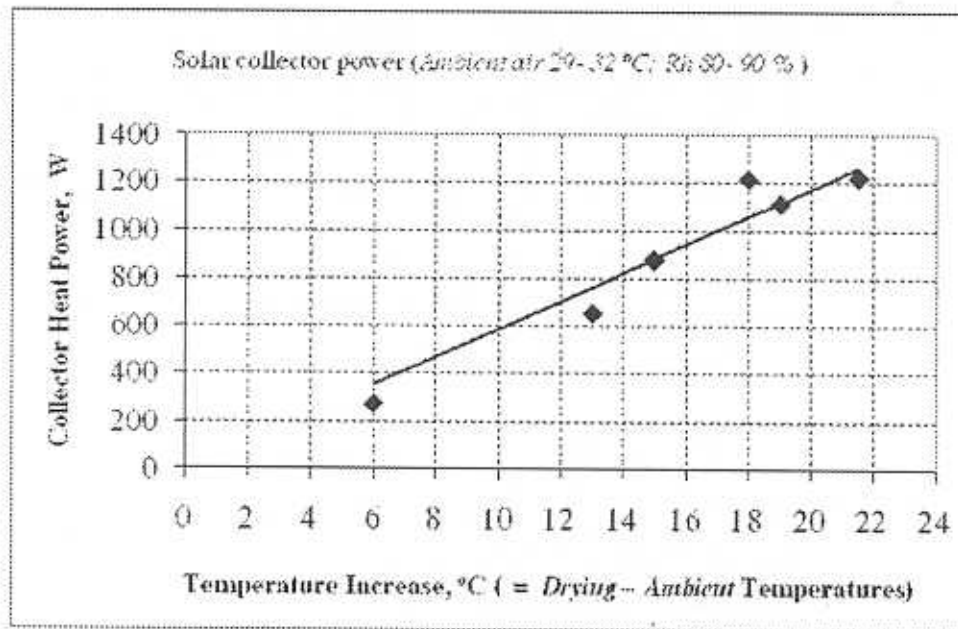


Figure 4: Collector heat power as a function of the temperature increase

### The macaroni 500-kg dryer

Drying tests in March 2006 with solar insolation ranging from 500 to 900 W/m<sup>2</sup> (average 680 W/m<sup>2</sup>) showed that the drying temperature reached 37- 52° C, averaging 14 kelvin above ambient temperature, over 5-hour drying time (Fig.5). The moisture content reduction of a typical drying batch is shown in Figure 6.

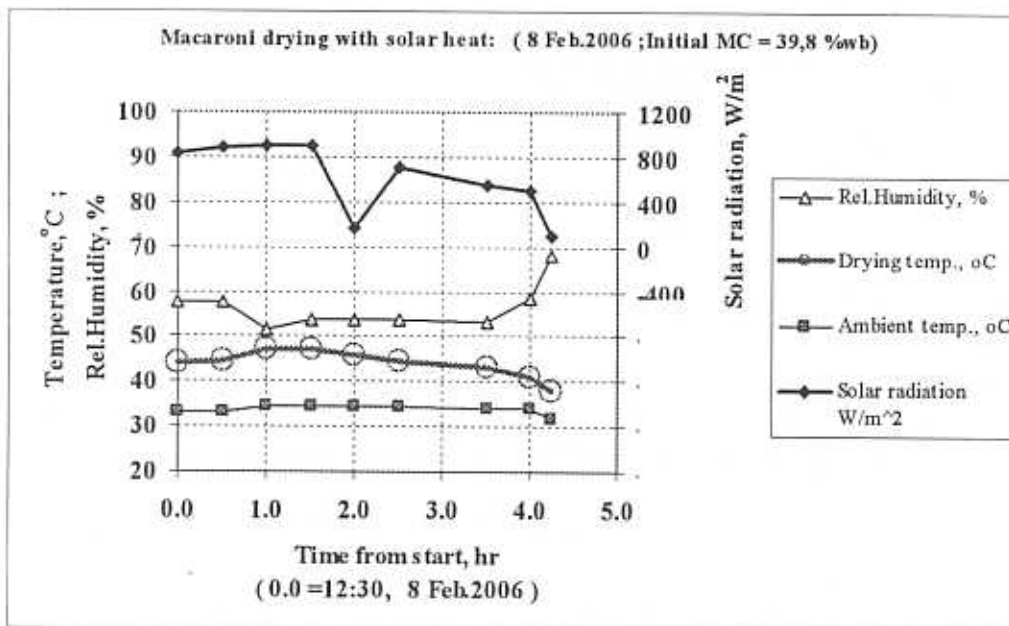


Figure 5: Ambient conditions and drying temperature for the drying batch in 8 Feb.2006

The collector power was estimated from the drying temperature, the airflow, the coal consumption of a batch under similar conditions. It was about 44 kW, and the collector efficiency was 40 %.

In the rainy days of April-June 2006, drying from solar energy alone was confirmed, although the drying time stretched out to 6 - 8 hours.

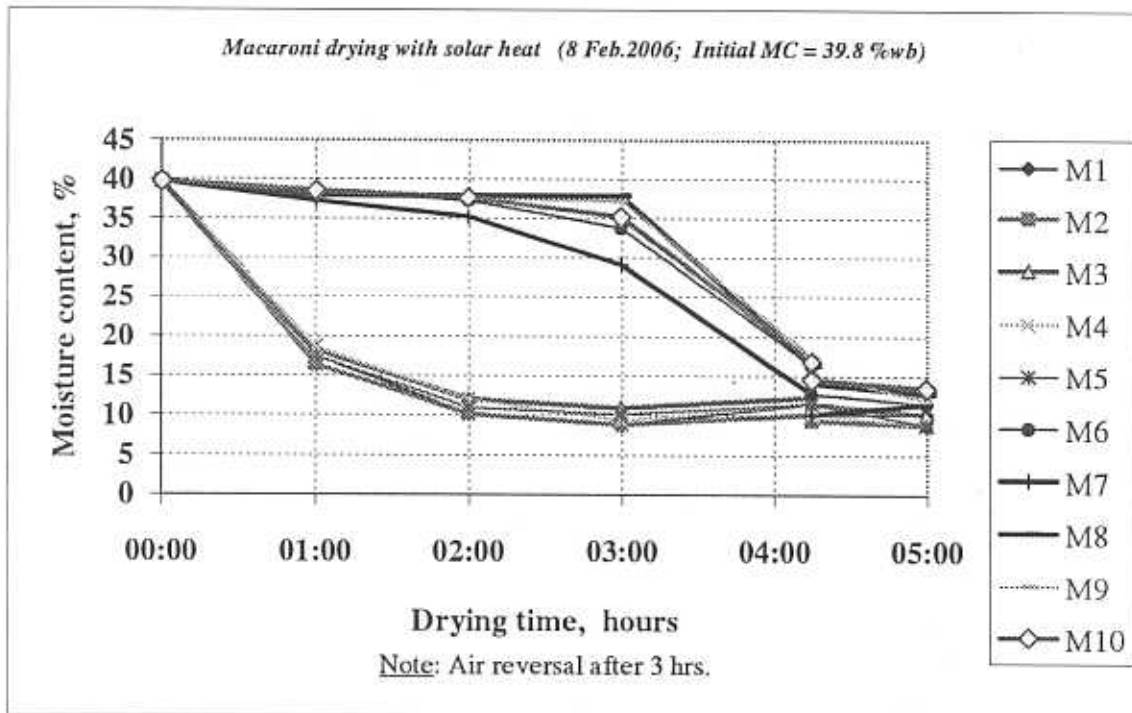


Figure 6: Moisture content reduction of the drying batch in 8 Feb.2006 (M1...M5= samples at Bottom layer; M6..M10= samples at Top layer)

### *Economic return*

The macaroni dryer was used in actual production since February 2006. By substituting coal with solar energy, the collector has saved US\$120/month; compared to its initial cost of US\$900 and the US\$50 replacement cost for PE tube after every 7 months; the pay-back period is less than one year. Use of clean solar energy meets the hygienic requirements for food drying.

### *Further research on the solar collector*

From the success in applying the cylindrical solar collector, the thought was to further reduce its investment cost. Using cheap materials such as bamboo slats and plastic wires, and installing the collector on the open ground instead on the rooftop, investment cost reductions for the collector down to 20 % is possible compared to the current steel-frame collector (Fig.7).

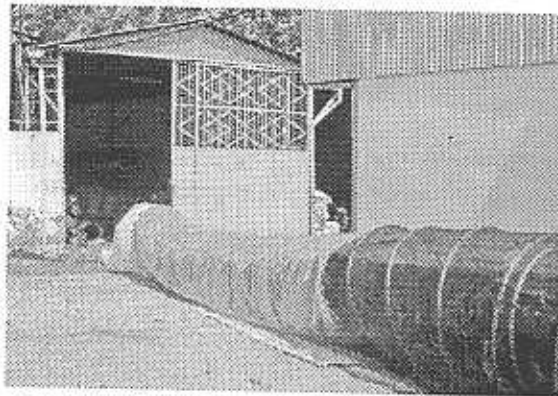


Figure 7: The solar collector using low-cost materials (Nguyen H.N. Bich. 2006).

## CONCLUSIONS

A 500-kg macaroni dryer using solar energy as the heat source has been designed, tested at Nong-Lam University, Ho Chi Minh City, and proved to be economical over more than one year of application at production scale. Basic data and configuration for the cylindrical solar collector has been gathered from tests. There are indications that greater investment cost reductions for the collector are possible, with promising prospects for application in drying other agricultural products.

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