

CHILI AND GARLIC DRYING BY USING WASTE HEAT RECOVERY FROM A GEOTHERMAL POWER PLANT

J. Hirunlabh, S. Thiebrat and J. Khedari
School of Energy and Materials
King Mongkut's University of Technology, Thonburi
Bangkok, Thailand

INTRODUCTION

In Thailand, natural sun drying is one of the most common ways to preserve agricultural products. Many agricultural products are spread on the ground to be dried by sun and wind. During the drying, these products are neither protected against dust and rain, nor against rodents, birds and insects. This results in poor quality products due to contamination and high loss caused by uneven or incomplete dehydration. In order to meet the food requirements of the growing population and moreover to provide high quality products, Thailand is developing dryers that respond to such demand. In addition, to overcome the dependence on solar energy which is the most common energy source for drying, different sources of energy are envisaged. Geothermal is one with relatively high potential at industrial scale. In fact, Thailand has more than forty medium-enthalpy geothermal resources scattered throughout the country, particularly in the north. In Fang district, Chiang-Mai province, the Electricity Generating Authority of Thailand (EGAT) (EGAT, 1995) has installed a geothermal power plant. It is a binary cycle system with a total generating capacity of 300kW_e. The rejected temperature of hot water is about 80°C. Hence, the idea of using this waste heat for drying of chili and garlic.

Chili and garlic are important products for Thailand's economy. They are popular for Thai people in both forms: fresh and dry. Chili and garlic drying by using hot water from geothermal power plant is a new undertaking which has better performance for drying the product and does not cause any pollution. The purpose of the investigations in the paper are, first to design an industrial dryer and second, to find out the appropriate drying conditions using hot water from the geothermal power plant. The evaluation of the economic feasibility and cost analysis of the drying system is also conducted.

METHODOLOGY

Chili (Pairintra, et al., 1996) and garlic (Asasujarit, et al., 1996) drying in this study is similar to the general method of drying but differs in the source of energy, which comes from hot water from the geothermal power plant. Figure 1 shows the experimental design dryer (Thiebrat, 1997). The cabinet dryer of 2.1 m width, 2.4 m length and 2.1 m height has 36 trays placed in two compartments. A motor of 2 hp (1420 rpm) is used for driving the fan producing an air

flow at constant rate of 1 kg/s. Likewise, controlling the temperature of drying air is made by varying the flow rate of the incoming geothermal hot water into the water-to-air heat exchanger installed at the inlet of dryer cabinet. A valve installed on the air duct between the outlet of the dryer chamber and the inlet of ambient air allows control of the rates of incoming and recycled air. At this geothermal power plant, only one dryer could be placed due to space limitation.

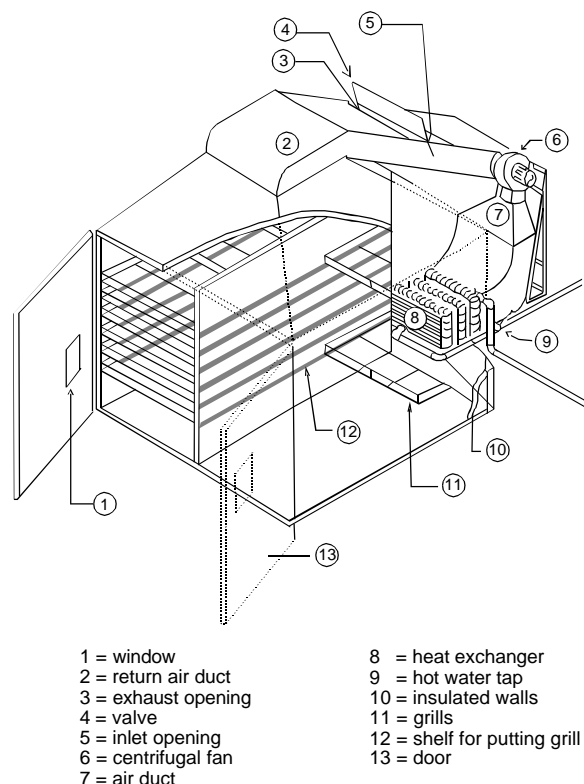


Figure 1. Schematic view of the dryer with air/geothermal hot water exchanger.

RESULTS

Due to budget limitations, only two tests per product were made which might not be sufficient to draw final conclusions. However, general and subjective conclusions were formulated concerning the use of heat recovered from waste hot water from geothermal power plant.

Table 1. Experimental Results for Chili and Garlic Drying

Description of Drying	Type of Product			
	Chili		Garlic	
	Test 1	Test 2*	Test 1	Test 2
Condition of Drying				
- Air Flow Rate (kg/s)	1.00	1.00	1.00	1.00
- Hot Water Flow Rate (kg/s)	1.00	1.00	0.09	0.04
- Average Air Temperature in the Cabinet (°C)	50.4	44.9	40.6	34.8
Average Ambient Air				
- Temperature (°C)	30.0	28.3	27.0	25.4
- Relative Humidity (%)	73.3	76.7	64.4	65.9
Conditions				
- Initial Moisture Content (%) (db/wb)	281/73	326/76	274/73	340/77
- Final Moisture Content (%) (db/wb)	16/13	10/9	127/55	132/56
- Initial Weight (kg)	467	570	245	213
- Final Weight (kg)	141	148	149	112
Energy Consumption (MJ/kf H ₂ O evap.)				
- Hot Water	39.52	103.10	15.36	5.97
- Electricity	1.42	2.06	8.15	9.74
- Total Energy Consumption	40.94	105.16	23.51	15.71
Drying Time (h)	46	90	76	94

* During this test, electricity was cut off for a few hours.

As indicated in Table 1, the energy consumed in the cabinet for drying is derived from two sources: electrical energy for the blower and thermal energy from geothermal hot water. Based on product quality and energy consumption, the optimum operating conditions are as follows; for chili, the flow rate of hot water is about 1 kg/s with 60% recycle of hot air leaving the dryer cabinet; whereas, for garlic, the hot water flow rate is about 0.04 kg/s without air recycle. In both cases, the air flow rate was 1 kg/s. The corresponding percentages were 3.5% and 96.5% for chili, and 62% and 38% for garlic.

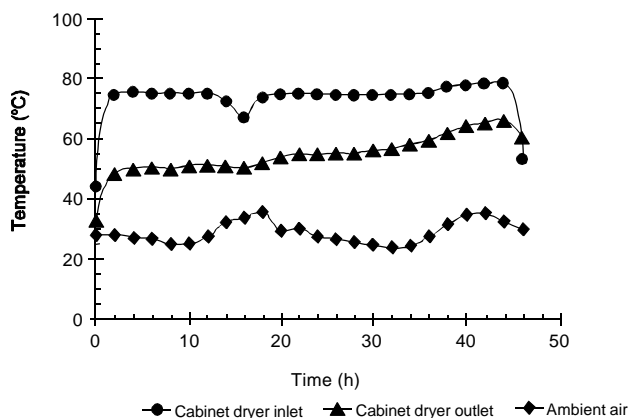


Figure 2. Evolution of air temperature for chili drying.

Figures 2 and 3 show the average temperature profile of air at inlet and outlet of the cabinet dryer and ambient for chili and garlic, respectively.

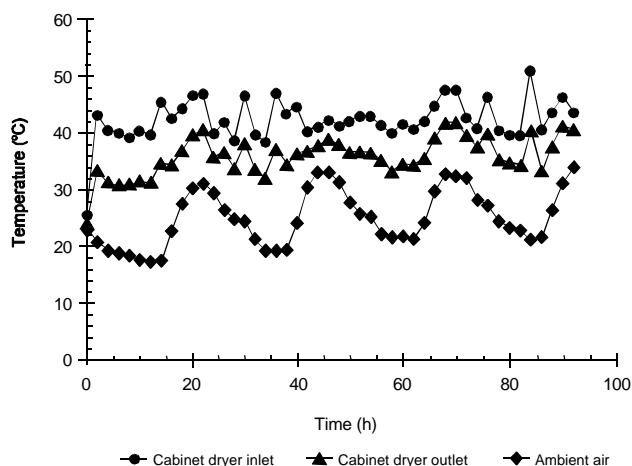


Figure 3. Evolution of air temperature for garlic drying.

To assess the economic feasibility of this drying system, a cost analysis was made under the following assumptions (Kiatsiriroat, 1994):

1. The capital cost of cabinet dryer was 40,000 Baht (\$1,080);
2. The annual rate of interest for the financial year was 14.25%;
3. The economic life of the cabinet dryer was 10 years;
4. The annual operating and maintenance cost were 10% of the cabinet dryer cost;
5. The operating time for cabinet dryer was 24 hours per day; 60 days for chili and 90 days for garlic; and
6. The system can dry chili at the rate of 13,500 kg/yr and garlic at the rate of 5,635 kg/yr.

The cost of energy for motor was 8,769.18 Baht/yr (\$237) and garlic at the rate of 5,635 kg/yr.

The annual cost for drying chili was 218,567 Baht (\$5,907) and 104,334 Baht (\$2,820) for garlic. The corresponding cost of evaporation of 1 kg of water was 23.25 Baht (\$0.63) for chili and 39.22 Baht (\$1.06) for garlic. The cost of drying process per kilogram of fresh product was 16.19 Baht (\$0.44) for chili and 18.52 Baht (\$0.50) for garlic. Finally, the cost of 1 kg of dried chili and garlic were 53.32 Baht (\$1.44) and 35.07 Baht (\$0.95), respectively.

SUMMARY

The objective of this research is to design a dryer that uses waste heat from a geothermal power plant. The dryer was built at the geothermal power plant in Fang district, Chiang-Mai province, Thailand. The geothermal hot water, about 80°C, circulates through a cross-flow heat exchanger of 100 mm width, 500 mm length and 300 mm height. A 2-hp (1420 rpm) motor is used for driving the dryer blower. The outgoing air from the heat exchanger with constant flow rate (1 kg/s) is introduced into the drying chamber of 10.5 m³ volume. The experiments were made for chili (450 kg) and garlic (220 kg).

For chili (75% wb to 13% wb), the required air temperature is about 70°C; whereas, for garlic (75% wb to 55% wb), 50°C is needed. The corresponding drying time and mass flow rate of hot water are about 46 hours/1 kg.s⁻¹ for chili and 94 hours /0.04 kg.s⁻¹ for garlic.

Thus, two sources of energy which are thermal energy from a geothermal power plant and electricity from a blower were used. The total energy consumed was 13.3 MJ or 40.94 MJ/kg H₂O evap. for chili 1.5 MJ or 15.71 MJ/kg H₂O evap. for garlic. The corresponding part of energy consumed from a waste heat geothermal plant is 96.5% for chili and 38.0% for garlic drying.

CONCLUSIONS

Drying agricultural product by using waste heat recovery from a geothermal power plant was investigated experimentally.

The air circulates through the drying installation at a constant rate. The control of temperature is made by varying the flow rate of hot water circulating through the water-to-air heat exchanger.

The design of the industrial scale dryer allows to recycle, partially or totally, the air leaving the drying cabinet. Investigation of performance of this dryer was made, basically, on product quality, drying time and energy consumption. Finally, an economic study showed that such dryer offers an interesting alternative for drying as the resulting costs are reasonable and the system operation is independent from weather conditions.

ACKNOWLEDGMENT

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