Banana Fruit Drying

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ABSTRACT

A comparative study of various methods of banana drying: solar natural convection drying (SNCD), LPG natural convection drying (LPGD) and solar forced convection drying with supplemental heat from LPG (SFCD+LPG), was performed. Experimental results showed that SNCD took 6-7 days (57 h) for completing one batch of bananas. Specific primary energy consumption and drying efficiency were 19.2 MJ/kg of water evaporated and 12.5 % respectively. LPGD took 5 days (45 h) for completing one batch of bananas. Specific primary energy consumption and drying efficiency were 8.4 MJ/kg of water evaporated and 30 % respectively. The last method, SFCD+LPG took 5 days (44 h) for completing one batch of bananas. Specific primary energy consumption and drying efficiency were 16.1 MJ/kg water evaporated and 15.8 % respectively.

Economic analysis showed that SNCD has a discount pay-back period of 3.6 years and a benefit to cost ratio of 1.2. LPGD has shorter discount pay-back period and higher benefit to cost ratio, i.e., 2 years and 2.9 respectively. The last method, SFCD+LPG was not very attractive because of longer discount pay-back period, i.e., 10 years and a benefit to cost ratio lower than 1, i.e., 0.6.

1. INTRODUCTION

The region of Phitsanulok and surrounding districts have a considerable amount of "nam-wa" bananas produced, which are commonly dried by open-sun drying, thus exposed to dust, insects, mold and micro-organisms, causing further product quality problems. These problems could be reduced by using an effective solar dryer. At present, there are 3 drying methods used in this area; solar natural convection drying, LPG natural convection drying and solar forced convection drying with supplemental heat from LPG. Comparative study of these methods of drying would be appropriate.

Drying rate of damp cloth using solar natural convection cabinet dryer was found to be 4.2 kg/m^2-day[1]. The ratio of the area of air exit to the surface area of solar collector of 0.11 delivered the optimum drying efficiency with drying rate of 3.2 kg/m^2-day[2]. Wibulswas and Thaina[3] dried damp cloth with a hybrid solar natural convection dryer and found that drying rate was 5 kg/m^2-day. Furthermore, some research was conducted to develop a model dryer that employed forced convection, e.g. tobacco barn- drying using solar energy[4], modification of the drying barn to dry various fruits[5] and solar banana drying[6]. Additional information is available in the literature[7,8]. In addition to these findings, research results and developments concerning solar dryer from various Asian countries were reported[9]. Rakwichien et al.[10] studied a hybrid solar forced convection dryer for "nam-wa" bananas and found that thermal efficiency was 30%. Schirmer et al.[11] studied banana drying in solar tunnel dryer powered by a 53 W solar cell module. The results showed that bananas could be dried within 3-5 days compared to 5-7 days needed for natural sun drying. Through the observation of various projects within Thailand, it could be concluded that the use of solar natural convection dryer for bananas is economically feasible[12], and solar forced convection dryer is also realized as feasible technology[6,13].

With various types of fruit dryer available, the objective of this research is therefore to compare the performance and economics of various types of the banana dryer, i.e., solar natural convection drying, LPG natural convection drying and solar forced convection drying with supplemental heat from LPG.

2. MATERIALS AND METHODS

2.1 Details of dryers

The details of three banana dryers tested in this research are as follows:

a) Solar natural convection dryer

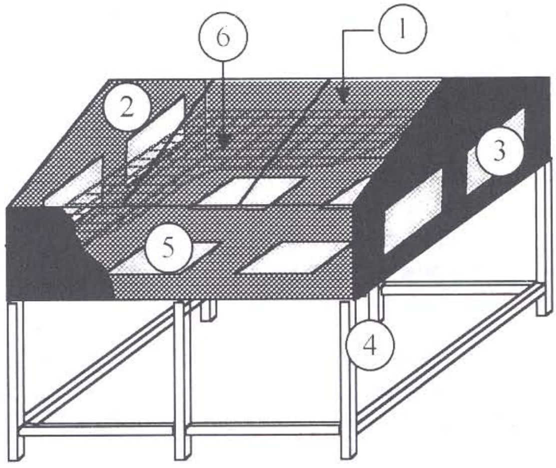
As shown in Fig.1, this block-shape dryer, designed by Department of Energy, Ministry of Sciences, Technology and Environments, is made of plywood coated with black color and its cover is made of transparent plastics. Inside the dryer, there is a bamboo tray. Its collector area is 2.64 m^2 and its capacity is 25 kg of fresh banana with 9 kg of dried banana outputs.

b) LPG natural convection dryer

This dryer, as shown in Fig.2, designed by Agricultural Machinery Center, Phitsanulok, uses LPG for heating air. There are two trolleys with eleven 1.1x1.5 m^2 bamboo trays each in the drying chamber. The side and back walls of the dryer are made of brick coated with cement while the door and roof are insulated by rice husk, 2.4 cm thick, covered with zinc sheet. The dryer capacity is 192 kg of fresh banana with 73 kg of dried banana outputs.

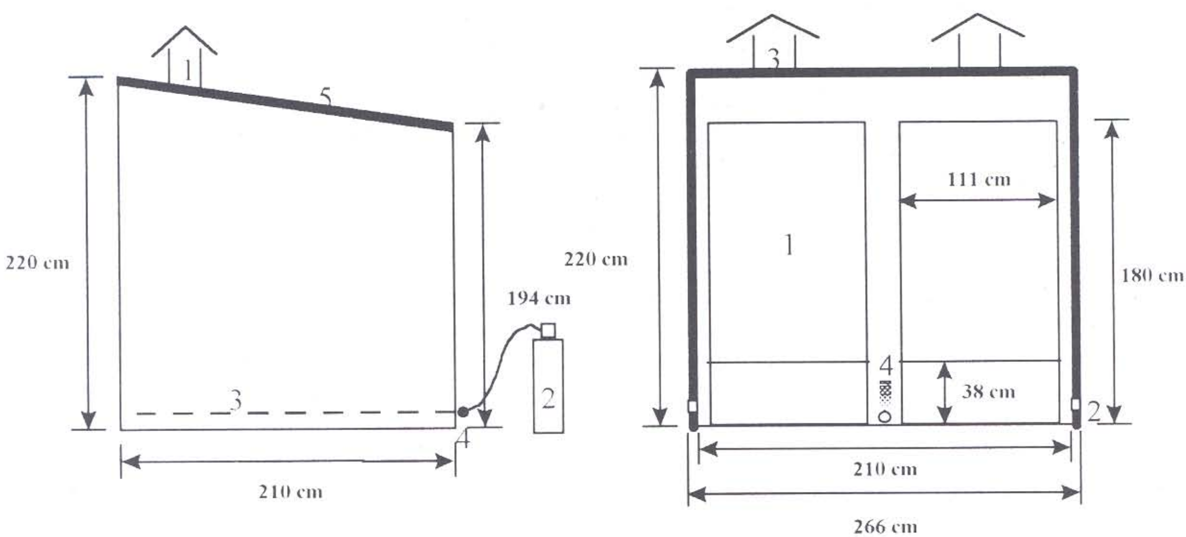
c) Solar forced convection dryer

This dryer[14], designed by Asean-Canada Project at Naraesuan University, has solar collector units that are separated from drying chambers (Fig.3). Heat transfers from the collectors to the forced air in flow-channel which later exits at collector outlet. In case of insufficient temperature, LPG will be a stand-by auxiliary that directly heats ambient air in a junction burner located near the exhaust fan. One drying system comprises of 23.1 m^2 of solar collector area and a drying chamber of 1.73m x 2m x 6m long that accommodates three trolleys, five shelves and sixty trays. In operation, the air passes through the solar collector and directly enters the drying chamber through four perforated ducts located on the chamber floor. After that it further moves vertically past the drying bananas before exiting at the chamber roof through six outlets.



1 = transparent plastic cover, 2 = plywood drying chamber, 3 = air outlet
4 = dryer legs made of wood, 5 = air inlet, 6 = bamboo tray

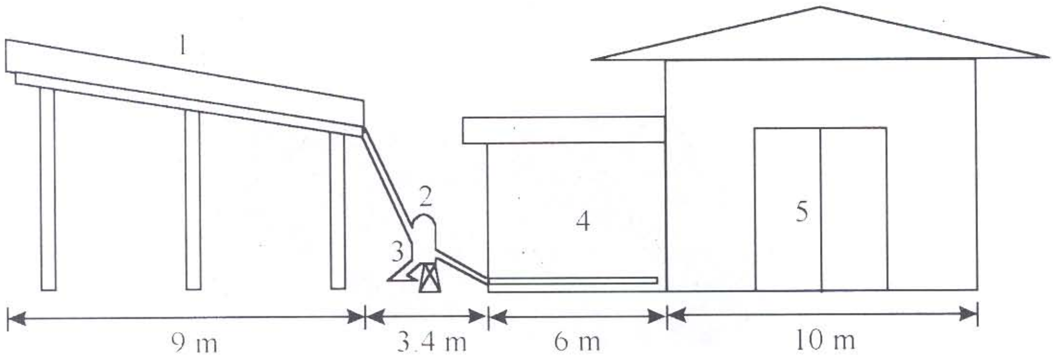
Fig. 1. Solar natural convection dryer.



1 = air outlet, 2 = LPG container
3 = burner, 4 = LPG valve
5 = dryer roof

1 = trolleys, 2 = air inlet, 3 = air outlet
4 = the flame from LPG burning

Fig. 2. LPG natural convection dryer.



1 = collector, 2 = blower (1.5 kW), 3 = LPG burner
4 = cabinet dryer, 5 = facilitating room
Fig. 3. Solar forced convection dryer with LPG as stand-by auxiliary.

2.2 Experiments

The experiments for each type of dryer are as follows:

a) Solar natural convection dryer

Peeled ripe bananas of 25 kg were spread on the dryer tray and dried during daytime. At the end of the first and second days of drying, they were collected, put in plastic bags and kept all night to start on sweetening before spreading them on the tray again the next day. During night time of the third, fourth and fifth day of drying, they were piled in the middle of the tray to prevent case hardening. After the fifth day of drying, all bananas were flattened and further dried for another two days to complete the process. Seven dryers were used in this experiment to obtain continuous output of dried banana every day.

b) LPG natural convection dryer

Peeled ripe bananas of 192 kg were dried during daytime every day. At the end of the first, third and fourth day of drying, all bananas were piled in the middle of the tray and left all night to prevent case hardening while at the end of the second day they were collected and kept in plastic bags all night to start on sweetening. In the middle of the fourth day, the bananas were flattened before being further dried for one day, completing the process. The drying temperature was approximately 55°C.

c) Solar forced convection dryer

The experiment was conducted with 360 kg of peeled ripe bananas. The experimental process was the same as the LPG natural convection dryer.

The three experiments mentioned above collected the following data:

- Air flow rates were determined by the average air-flow velocity of the exhaust air at the cross-section of the air product, with a fan anemometer.
- Temperature, entering and exiting solar collector, was measured by a type K thermocouple

connected with data logger with an accuracy of +/- 1 °C and recorded at one hour intervals.

- Total solar radiation received on the solar collector surface, was measured by a solar indicator with an accuracy of+/- 5%.
- LPG consumption was determined by recording LPG weight displaced.
- Electrical consumption of the centrifugal fan was measured with a meter (Yokogawa), with an accuracy of +/- 1%
- Moisture content of the product, by the random selection of two banana samples, was weighed by accurate scales, 0.01 g, then cut into small pieces and dried in an oven at 103 °C for 72 hours.
- Water evaporation was measured by large scales (Max.cap. 60 kg), with an accuracy of +/- 0.1 kg, and recording weight changes before and after each drying period.

3. RESULTS AND DISCUSSION

3.1 Results of Banana Drying

The results of banana drying testing of various methods are depicted in Table 1. From all tests, it was determined that initial moisture content of the fresh banana was between 230 %-300 % dry basis, and average final moisture content upon SNCD, LPGD and SFCD+LPG of 50, 47 and 47.3 % dry basis respectively. As reported on the table, the specific energy consumption of the LPGD is the lowest. This is caused by the fact that the efficiency of solar collectors are much lower than that of LPG combustion.

The color of dried banana skin from SNCD, measured by R.H.S. Color Chart, was Greyed-Yellow 162 group B while those from the LPGD and SFCD+LPG were darker, Greyed-Orange 163 group A. This is caused by higher temperature in drying chamber, 43 °C compared to 55 °C and 53 °C respectively, which leads to nonenzymatic browning reaction.

3.2 Economic Analysis

According to details in Table 2 and using the method of discounted pay-back period (DPBP) with 12% discount rate, it was determined that DPBP of SNCD, LPGD and SFCD+LPG were 3.6, 2 and more than 10 years respectively. The net benefit of SNCD, LPGD and SFCD+LPG were 12,000, 97,404 and 163,535 baht per year respectively. For benefit cost ratio (B/C ratio) with interest rate of 12 %, it was found that B/C ratio of SNCD, LPGD and SFCD+LPG were 1.2, 2.9 and 0.6 respectively. The DPBP of SFCD+LPG was dramatically higher and B/C ratio was significantly lower due to high investments.

4. CONCLUSION

The average efficiency of LPG natural convection drying is higher than those of solar dryers, 30.0% compared with 12.5% in solar natural convection dryer and 16.1% in solar forced convection dryer with LPG as stand-by auxiliary. The color of peeled bananas of LPG natural convection drying and solar forced convection dryer with LPG as stand-by auxiliary is darker than that of solar natural convection dryer.

Table 1. The results of banana drying testing of various methods.

	SNCD[A]	LPGD[B]	SFCD+LPG[C]
Initial weight of bananas (kg)	25	192	360.0
Final weight of bananas (kg)	9	73	141.1
Water evaporation loss (kg)	16	119	218.9
Total solar radiation at collector surface (MJ)	292.3	-	1814.9
Total energy consumption of LPG (MJ)	-	971.2	1060.4
Total electrical consumption of fan (MJ)	-	-	393.8
Total energy consumption (MJ)	292.3	971.2	3269.1
Latent heat of evaporation (MJ/kg)	2.4	2.4	2.4
Drying efficiency (%)	13.1	29.4	16.1
Specific energy consumption (MJ/kg of water evaporated)	18.3	8.2	14.9
Average drying efficiency (%)	12.5[D]	30.0[E]	16.1

Remark:
SNCD = Solar natural convection dryer
LPGD = LPG natural convection dryer
SFCD + LPG = Solar forced convection dryer with LPG as auxiliary
A = test results during April 1995.
B = test results during December 1995.
C = test results during May 1995.
D = average drying efficiency of all experiments during April-July 1995.
E = average drying efficiency of all experiments during July-December 1995.
LPG low heating value = 46 693 kJ/kg

5. ACKNOWLEDGEMENT

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Table 2. Details of economic analysis.

	SNCD	LPGD	SFCD+LPG
Project life, year	5	10	10
Fixed cost			
• Land rent , baht/year (Increase 20% every 5 years)	250	250	1,000
• Number of dryers	7	5	1
• Dryer cost, baht	28,000	125,000	1,350,000
Variable cost			
• Labor cost, baht/year (increase 10% every year)	18,000	84,000	84,000
• Operating cost, baht/year	4,836	25,916	75,430
• Banana cost, baht/year (3.2 baht/kg, increase 0.5 baht/kg every 2years)	27,900	196,416	571,680
• LPG cost, baht/year (12 baht/kg, increase 10% every year)	-	87,978	101,085.30
• Electricity cost, baht/year (2.5 baht/unit)	-		42,262.20
• Maintenance cost, baht/year	515	500	6,000
- Others, baht/year	500	500	20,000
Incomes			
• Amount of dried bananas per year	3,348	24,893	56,012
• Dried banana cost, baht/year (19 baht/kg, increase 10% ever 2 years)	63,612	472,967	1,064,228
Remark: 1 US$ = 25 baht			

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