Proceedings of Placrosym XV (2002): 690-696

DEVELOPMENT OF A FORCED CONVECTION SOLAR CUM ELECTRICAL DRYER

K. Madhavan & S. J. D. Bosco

Central Plantation Crops Research Institute, Kasaragod

ABSTRACT

Solar drying relies on the sun as the source of energy. It generates higher air temperature and consequential lower relative humidity, which are both conducive to, improved drying rate.

But during the drying process if the sky becomes cloudy or it starts raining, the temperature comes down and the product gets spoiled. Unlike other crops, coconut endosperm is exposed while drying and so is more likely to get infected with fungus and bacteria if the drying air temperature is less than 50°C. In order to control the spoilage and to have faster drying a forced convection solar cum electrical dryer has been designed with solar energy as the main source of energy and electricity as the alternate source of energy. It consists of a semi circular parallel plate solar collector, electric heaters, blower motor and the drying chamber. Hot air is drawn from the solar collector and blown in to the drying chamber. When the temperature in the drying chamber goes below the preset value (55°C for coconut), electric heaters get switched on and the temperature is retained between 55°C and 70°C thus drying at a uniform temperature and producing quality copra. The capacity of the dryer is 2000 coconuts per batch and the drying time taken is 24 hrs. The cost of the dryer is Rs.40000/- and the drying cost per Kg of copra is Rs.1.05.

INTRODUCTION

Solar drying relies on the sun as the source of energy. It differs from sun drying in that a structure is used to enhance the effect of insolation. Compared with sun drying solar dryers can generate higher air temperature and consequential lower relative humidity, which are both conducive to, improved drying rate and lower final moisture content of the dried crop. As a result the risk of spoilage is reduced both during the actual process and subsequent storage. The higher temperatures attainable are also a deterrent to insect and microbial infestation. Additionally protection against dust, insects and pests is enhanced by drying in an enclosed structure.

But during the drying process if the sky becomes cloudy or it starts raining, the temperature comes down and the product gets spoiled. Unlike other crops, coconut endosperm is exposed while drying and so is more likely to get infected with fungus and bacteria if the drying air temperature is less than 50°C. Moreover fresh coconut will have moisture content of 45% to 50% and once the endosperm is open, drying should be commenced immediately so that the moisture content is brought down to 30% or less within four hours to prevent bacterial attack (Grimwood, 1975, Ward *et al*, 1932). Otherwise preservation of fresh kernel is essential and (Patil, 1980) has reported a chemical treatment of dipping fresh kernel in 1000 ppm propionic acid by which fresh kernel could be preserved up to 49 days without spoilage. In order to control the spoilage and to have faster drying a solar cum electrical dryer has been designed with solar energy as the main source of energy and electricity as the alternate source of energy. It consists of a semi circular double pass flat plate collector, drying chamber fixed below the collector to avoid the extra insulation normally necessitated in the conventional solar cabinet dryers. A blower of 2HP rating and six numbers of 1000W heaters are also provided. Hot air is drawn from the solar collector and blown in to the drying chamber. When the temperature in the drying chamber goes below 55°C or any other preset values, electric heaters get switched on and the temperature is retained between 55°C and 70°C thus drying at a uniform temperature and producing quality copra.

MATERIALS AND METHODS

Development details

It consists of a semi circular double pass flat plate collector having the transparent cover made from UV film of 0.2 millimetre size, the absorber plate made from agrifilm of 0.25 millimetre size and the bottom casing made of 0.46 millimetre. The dimension of holes used for air entry was fixed so that the heat supplied by solar heated air would be optimum for the drying operation of 2000 coconuts per batch. Similar type of an all-plastic dryer on bamboo framework was tried in Korea to dry red pepper. (Trim and Ko, 1982).

The dryer is provided with facility for an electrical back up controlled by electronic switching circuits. It was designed in such a way that the electric heaters of 2 KW capacity each (6 nos.) will be switched on only when the temperature inside the drying chamber is less than 55°C and switched off when the temperature exceeds 70°C. This is done by monitoring the temperature inside the drying chamber and operating the switching thermistor circuits. A separate control circuit is also incorporated to switch off the hot air blowers once the drying is complete by monitoring the exhaust temperature using thermistor sensors.

Installation & fabrication:

The drawing of the solar dryer is given in Fig.4 & 5. and the materials required is given in Table 1. (Refer other figures also). In order to have maximum insulation the solar dryer is fixed in such a way that its curved surface is facing north south direction. Cement sealing is required at the floor level to prevent the entry of ambient air. Two trolleys of 3.2 meter length and 1.2 meter width having drying trays are provided. This can be drawn out to load the coconuts and pushed inside the drying chamber for drying. The air temperature inside the drying chamber is displayed on the control panel. There are two potentiometers provided on the control panel to set the lower and upper level temperature.

Installation details of Solar-cum-electrical dryer: (Fig. 5)

1. There are three layers of sheets for the parallel plate solar collector.

a. The top layer is provided with transparent LDPE film of 0.2 mm thickness.

b. The middle layer is provided with agrifilm (black LDPE film) of 0.25 mm thickness.

c. The bottom layer is provided with GI sheet of 0.56/0.46 mm thickness

2. To support these layers, frames should be made of

a. Bottom frame-angle iron of 0.2 meter at the interval of 0.75 meter

b. Middle frame & top frame-MS flat of 24x4 mm size at the interval of 0.75 meter

3. All the three layers should be fixed with the respective frames by means of riveting to make airtight between the two annular spaces.

4. The conduit pipe (6) and the exhaust pipe (4), both diameter 150 mm are made of GI sheet of 24/26 G thickness.

5. Electric heater box (7) is made of GI sheet of 18/20 G thickness to accommodate 2000 W industrial electrical flat heaters. This box should be connected in between the conduit pipe (6) and the blower (8).

6. The blower is made of GI sheet of 24/26 G thickness fitted with the 2 hp three phase – 1440-rpm electric motor.

7. All other details and dimensions of the Solar-cum-electrical dryer are given in the diagram.

8. Backside should be closed with LDPE film of 0.25 mm thickness fixed on the MS flat (25x6 mm) frame.

9. Front side is provided with the doors made of LDPE film of 0.25mm thickness fixed on the MS flat (25x6 mm) frame. The doors should be provided in such a way that it should be opened completely so as to move the trolley in and out of the dryer.

10. Two trolleys of 3.2 meter length having 1.2 meter width at the bottom and 90 cm at the top and of the shape to accommodate inside the drying chamber is used to load the coconut for drying.

RESULTS AND DISCUSSION

Procedure of operation

1. Switch on the blower motor.

2. Load the coconut cups facing up or down in the trays. Push the trays inside the drying chamber. Close the chamber door.

After 8 to 10 hours of drying, switch off the blower, open the door and pull out the trolley outside and inspect the coconut cups. It must be ready for removing the shell.

3. Remove the shell of the copra and load in the trolley and push inside the drying chamber.

4. After 22 to 24 hours of drying the copra will be ready with 5 – 6 % moisture.

Table 1. Material required for fabrication of "SOLAR- CUM-ELECTRICAL DRYER

Sr. No.	Material	Sizes	Quantity
A	**Dryer**		
1.	M.S.Angle	30x03mm	25m/35kg
2.	M.S.Angle	30x06mm	13m/30kg
3.	M.S.Angle	25x03mm	15m/14kg
4.	M.S.Flat	25x03mm	125m/75kg
5.	M.S.Flat	25x06mm	10m/12kg
6.	M.S.Flat	30x03mm	2.5m/2kg
7.	G.I.Sheet	26Gx8x3ft	11sheets
8	G.I.Sheet	18Gx	2sheets
9	HDPE Black sheet	250 microns	$17M^2$ /4kg
10	HDPE White sheet	200 microns	$22M^2$ /4kg
11	MS Pipe	"ID	8.0m
12	GI Pipe "B"class	2" ID	13m
13	GI Fittings,likeT,"Elbow.etc.	2"	
14	MS Rod	6mm,dia	10m/3kg
15	MS Bolt nuts	6mm,10mm	3kg
16	GI screw bolts	6mm	100nos
17	Metal screws	15mm	100nos
B	**Trolley**		
1	MS Angle	40x40x6mm	30m/105kg
2	MS Angle	25x25x6mm	25m/45kg
3	MS Angle	25x25x3mm	72m/80kg
4	MS Flat	25x3mm	25m/15kg
5	MS Flat	30x6mm	8m/12kg
6	MS Rod	10mm	32m/20kg
7	Castor wheels	100mm,dia	16nos
8	Weld mesh	10Gx25x25mm	$600ft^2$
C	**Electrical Unit**		
1	Metal box with doors & locking facility	60x45x25mm	1no
2	Control panel	1	set
3	Motor	3Ph, 2Hp	1no
4	Wire connections	1	set
5	Main 3Ph contactor	2	units
6	Strip heaters 2 feet long	2000W	6nos

During drying if the temperature inside the drying chamber is less than 55°C the heaters will be switched on automatically and then the temperature inside the drying chamber will increase and if the temperature increases above 70°C the heaters will be switched off by the electronic switching system. Once the drying is complete as confirmed by monitoring the exhaust temperature using thermistor sensors, the blower and the heaters (if remains on at that time) will be switched off.

Drying trials were conducted with 2000 coconuts per batch and the drying time taken was 22-24 hours. The initial moisture content of the sample was found to be 48% on an average basis (wet basis). The moisture content of the samples at every four-hour interval was recorded using CPCRI Copra moisture meter. The electric energy consumed depends on the number of sunshine hours on a particular day. Whenever the temperature inside the drying chamber fell below 55°C the heaters were switched on by the electronic switching circuit and the temperature raised up to 70°C when electronic switching circuit cut electric supply to the heaters. But the blower continued to run drawing hot air from solar collector and electric heater or solar collector alone. At the end of drying when the exhaust air temperature and the inlet air temperature remains almost same a thermistor sensor located at the exhaust vent activates another switching circuit and cut off the electric supply to the blower terminating the drying operation. The variation in temperature and relative humidity of ambient air and air inside the drying chamber (Fig. 1 & Fig. 2) and the variation in moisture content of copra with drying time (Fig. 3) were shown. After 8 to 10 hours of drying, shell gets loosened from the kernel and was removed. The drying time taken was 24 hours when heaters were used but it took 36 hours (4 days) when solar energy alone was used. The copra dried in the solar cum electrical dryer and the control trial were analysed for its quality and the results were shown in Table 2. Trial 1 was done during August when there was intermittent rain and very often the sky used to be cloudy and the R.H was above 80%. Trial 2 was done during February when the R.H was about 70%. It can be seen that there is significant reduction in the population of fungi, bacteria and lipolytic micro-organisms in the copra samples dried in the solar cum electrical dryer even during unfavorable weather conditions. The optimum moisture level recommended for safe storage of copra is 6% (w.b.) and If the moisture content is high copra will be infected with bacteria, and fungi (Madhavan,1986). Paul (1969), and Susamma, Menon (1981) isolated a number of fungi and bacteria from deteriorated copra. Since the drying was done continuously much above the ambient air temperature at lower R.H. level the copra was free from fungi and bacteria.

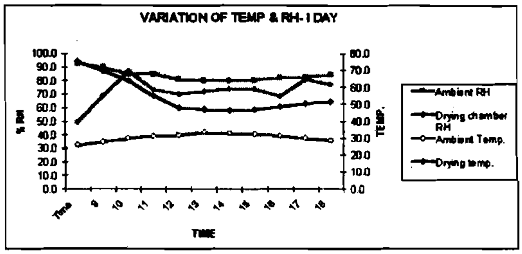

Fig.1

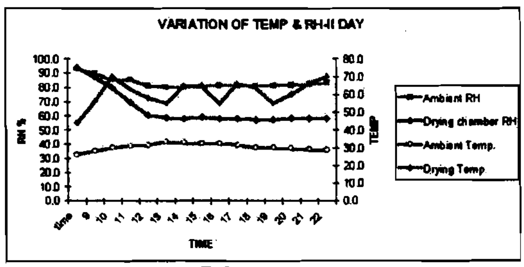

Fig.2

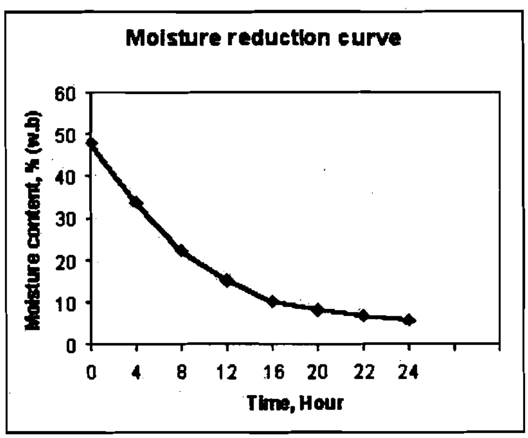

Fig.3

Economic analysis of the dryer

The construction cost of the dryer was estimated to be Rs. 40000/= and expected life of the dryer was 10 years. The straight line method of depreciation was adopted to calculate annual depreciation. The interest rate was assumed at 15% per annum for the half initial cost as capital every year. With these assumptions and considerations cost analysis was done as given in Table 3. The cost of drying was calculated as Rs.1.05 / Kg of copra when heaters are used and 88 paise / Kg of copra when only solar energy is used.

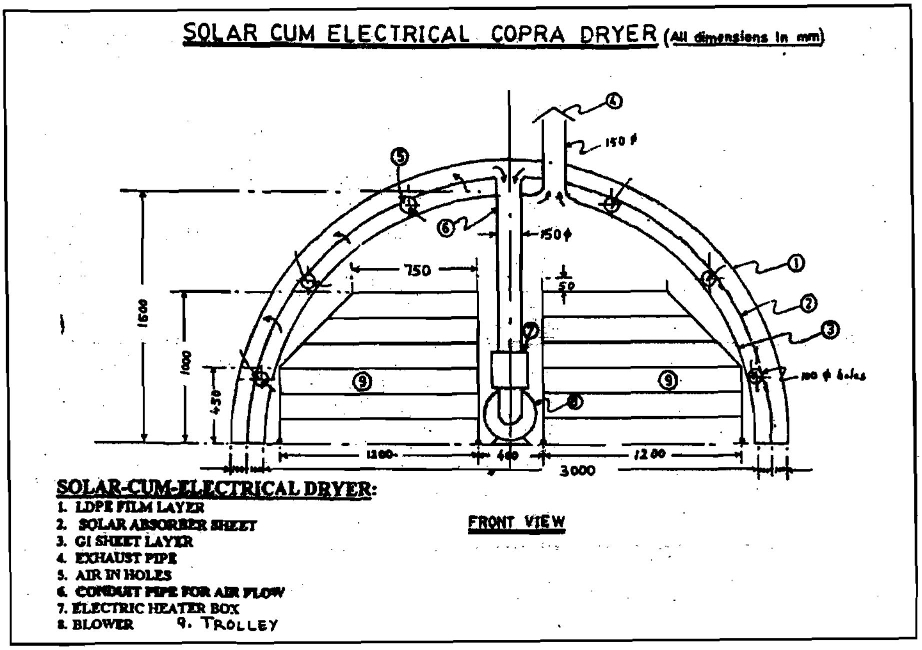

Fig. 4

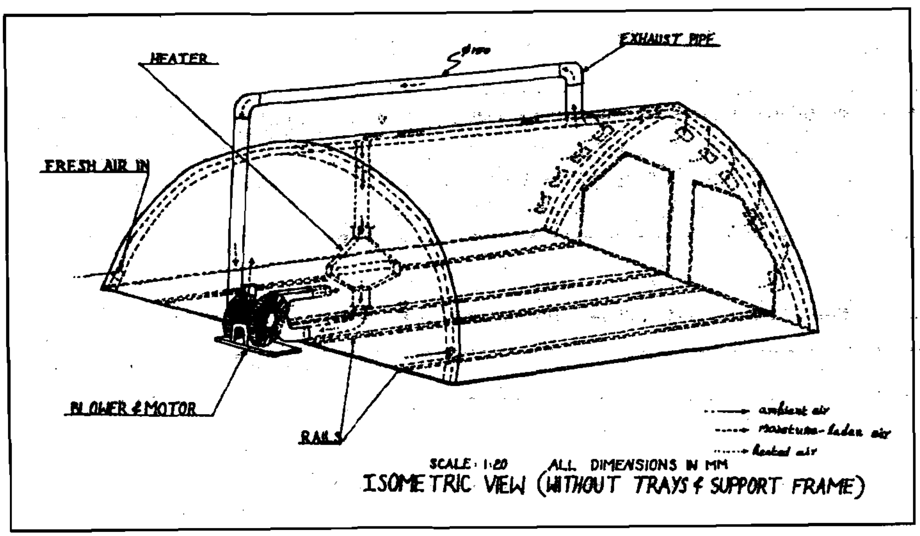

Fig. 5

Table 2. Microbial Analysis

Trial 1	Sun drying n=26	Solar cum electrical dryer n=26	t-Value
Fungi(x100)	6.6653	2.663	32.82**
Bacteria(x100)	15.1481	4.65	17.67**
Lypolitic microorganisms(x100	3.9300	1.77	37.5**

** significant at 1% level

Trial 2	Sun drying n=10	Solar cum electrical dryer n=10	t-Value
Fungi(x100)	2.9670	2.095	3.05*
Bacteria(x100)	5.22	4.429	3.19*
Lypolitic microorganisms(x100	2.221	1.214	9.37**

* significant at 5% level
** significant at 1% level

Table 3. Economic analysis

Assumptions:

1. Capacity of the dryer	:	2000 nuts / batch
2. Cost of the dryer	:	Rs. 40000/-
3. Drying time	:	2days with heaters & 3 days with out heaters
4. No. of working days/year	:	300
5. Life of the dryer	:	10 years
6. No. of labourers required	:	2 man days
7. Cost of labour	:	Rs. 100/ day
8. Cost of electricity	:	Rs 1/unit
9. Quantity of copra from 2000 coconuts	:	330 kg
Fixed cost per year:		
Annual depreciation (10% of cost)	:	Rs. 4000/-
Annual Interest on half the new cost @ of 15%	:	Rs. 3000/-
Maintenance cost @ 10% of annual cost+ cost of polythene sheet:	:	Rs. 1300/-

Particulars	With heaters	With out heaters
No of batches in a year	150	100
Total fixed cost/year (Rs.)	8300.00	8300.00
Fixed cost/ batch (Rs.)	55.00	83.00

Variable cost per batch:

Particulars	With heaters	With out heaters
Cost of labour	200.00	200.00
Cost of electricity	94.00	10.00
Total variable cost	294.00	210.00
Total cost/ batch	349.00	293.00
Cost of drying / Kg. Of copra	1.05	88 paise

Special Features of the Dryer

1. This has got solar energy as the main source of energy and electricity as alternate source of energy.

2. During the drying process if the sky becomes cloudy or it starts raining, the temperature comes down and the coconut gets spoiled. But this problem is eliminated here as the electric heaters will be switched on automatically and the temperature will be retained with in the set limits.

3. Once the drying is completed the blower will be automatically switched off and so over drying and under drying is avoided.

4. It can be used to dry other crops also.

Acknowledgement

The authors are grateful to the Director, CPCRI for providing the necessary help and encouragement. This project work was done with the financial support of Dept. of Electronics, Ministry of Information and Technology and we thank them. Thanks are also due to Mr. K. Vijay Kumar, Sr. Scientist for the statistical analysis, Mr. G.S.Hareesh, Instrumentation Mechanic for assisting to develop the electronic circuits and Miss Ranjitha, Sr.Research Fellow for the microbial analysis.

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