Design and Development of Solar Copla Dryers

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Abstract

Dried coconut meat is known as copra. Wet meat (45 to 50% moisture content, wet basis) has to be dried to 6% moisture content for storage and for oil extraction. Drying of copra is commonly practised in open on mud or cement floor requiring about 9 days. A low cost solar dryer using black painted palmyra mat as drying floor and double layered polythelene sheet as transparent cover was found to reduce drying time to 5.5 to 6 days. The solar cabinet dryer with drying surface inclined at an angle equal to latitude, provided with reflectors from 3 sides of the dryer and also having a provision for manual suntracking was developed. The drying time required was 3.5 to 4 days at double the spreading density compared to open sundrying.

Introduction

Copra is the dried meat obtained from the coconut (*Cocos nucifera.* Lin.). Fresh coconut meat contains about 45 to 50% moisture content (wet basis) and it has to be dried to 6% moisture content for safe storage and for oil extraction. Annual production of the coconut in India is about 5 800 million nuts from 1.1 million ha area (1). Forty percent of the total production is converted into copra upon drying (2). The coconuts are harvested every month except during monsoon when the trunk becomes slippery. About 68% of the total production has been harvested and processed during October to May (**Table 1**) (3).

India, a tropical country, is blessed with plentiful supply of bright sunshine. On the west coast the average intensity of solar radiation is in the order of 440 cal/cm^2/day. The average sunshine hours are about 8.5 during October to May (4). The availability of this free energy for copra drying during this period is most economical.

The average land holding of coconut growers in India is only 0.2 ha and about 90% of total land holdings are below 1 ha (5). These small farmers dry their copra on the mud floor in the yard of the house. Copra is a high moisture and slow drying product. Unlike other agricultural products, the endosperm is exposed for drying which makes it more vulnerable to deterioration due to dirt, dust and microorganisms. The substitution of drying floor with black painted palmyra mat reduces drying time by 21% (6).

Two types of small capacity solar copra dryers have been developed with the following objectives: 1) To improve the copra quality by avoiding a direct atmospheric exposure during the process of drying and 2) To conserve and effectively utilise the convective heating of the air due to solar energy received by the black surface.

Table 1 Annual Coconut Production Pattern

Month	Production
October	5.6
November	6.5
December	6.0
January	6.4
February	7.7
March	9.8
April	14.1
May	11.7
June	9.8
July	8.2
August	7.7
September	6.5
Total	100.0

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Description of Dryer

Low-Cost Poly-Solar Dryer

The drying surface was a black painted palmyra mat. The frame was made up of 10 mm diameter MS bars. The transparent cover was of double layered 200 gauge polythelene sheet. The frame was such that the top cover was inclined at 27°, that was angle of latitude + average angle of solar declination over the rain free days in order to get maximum penetration of solar radiation. For air circulation at inlet and exhaust, 0.75 cm diameter

Fig. 1 Low cost poly solar dryer.

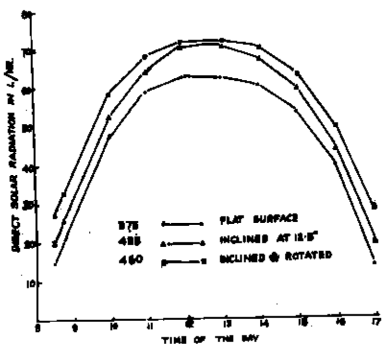

Fig. 2 Variation of solar radiation in a day.

Table 2 Materials for Low Cost Poly-Solar Dryer

Material	Quantity
MS bar, 10 mm dia	8.0 m
GI wire	20.0 m
Polythelen sheet (200 gauge)	8.0 m
Black painted palmyra mat	one

holes were provided at front and rear top of the poly dryer. The bottom of the poly cover was tied to the frame by wire rings. The position of the structure was kept stationary facing south. The area of the drying surface was about 1.17 m (**Fig. 1**). The transparency of the new double layered polythelene sheet was 80%. The bills of materials is given in **Table 2**.

The direct solar radiation at Kasaragod (12.5°N, 75°E and 10.7 MSL) on the flat surface in the month of January was 374 langleys/day (0830 to 1700). The solar radiation on the inclined surface (12.5°) facing south was 425 langleys/day and the inclined surface at 12.5° continuously facing sun received 460 langleys/day (**Fig. 2**).

Solar Cabinet Dryer

To achieve maximum reception of solar radiation, a solar cabinet dryer as shown in **Fig. 3** was developed. The frame of the dryer was made of locally available jackwood. The drying surface 1.06 m^2 area was of 22 gauge corrugated GI sheet to get absorber area of 1.19 m^2. The drying surface was inclined at an angle of 12.5° and fitted on 3 cm thick jackwood plank board with 2 g coir fibre insulation in between. The drying chamber was made of 3 mm window glass on sides and 3 mm acrylic plastic sheet on the top to avoid the risk of breakage during handling. The height of the drying chamber was kept at 40 cm uniformly from inlet to exhaust end. Inlet and exhaust of 0.35 m^2 area covered with wiremesh were provided for air circulation. Commercial grade aluminium foil mounted on the hard board was used for the reflectors on the three sides. The reflectivity of such reflectors has been 74 to 85% (7). The total area of the reflectors was 1.5 m^2. The inlet opening was covered by black painted GI sheet hood inclined at 45°. The area of the hood was 0.36 m^2 and was provided to have pre-heating of the incoming air and to avoid the effect of direct air drought. Caster wheels were provided for changing the direction and movement to short distances. The GI rod on the top cover guided the position of the dryer which was changed at 1100 and 1400. The bill of material is given in **Table 3**.

Fig. 3 Solar cabinet dryer.

Materials and Method

The tests of drying were conducted in a body dryer and in solar cabinet dryer in comparison to the open drying on the black painted palmyra mat. The spreading densities were 40 nuts/m^2, 60 nuts/m^2 and 80 nuts/m^2 on outside in poly dryer and in the cabinet dryer, respectively. The initial moisture content and the moisture content at the end of every day were determined for a composite sample by oven drying method (105°±1°C for 8 h). The temperature inside the dryer and outside were measured by mercury thermometers. The relative humidity of the air inside the cabinet and outside was measured by Assman's psychrometer. The solar radiation on the flat and inclined surface was measured by direct solar radiation meter (Surya Mapi) in langleys per h. The air velocity in the cabinet was measured with the vane anemometer. The drying of copra was conducted up to 6% moisture content, wet basis.

Table 3 Materials for Solar Cabinet Dryer

Material	Quantity
Jack wood	0.075 m^3
Coir fibre (insulation)	2.0 kg
Corrugated GI sheet (22 gauge)	1.25 m^2
GI sheet (22 gauge)	0.35 m^2
3 mm window glass	1.40 m^2
3 mm acrylic plastic sheet	1.25 m^2
Aluminium foil (24 gauge)	1.65 m^2
Hard board	1.65 m^2
Wooden reapers	11.00 m
Caster wheels	4 pcs.

Results and Discussion

The initial moisture content of copra was 46±2%, wet basis. The average drying conditions in the day during the experimentation were 60% relative humidity, 30.4°C temperature and 49% (r.h.), 46.1°C temperature on the outside and in the cabinet dryer, respectively. The difference in the air temperature in the dryer and outside was minimum at 7°C and maximum at 20°C. The average solar radiation on the inclined surface and flat surface was 67 and 55 langleys per h, respectively (**Fig. 4**). The average temperature of the air in the poly dryer was 36.2°C compared to 30.4°C of the ambient air (**Fig. 5**). The average solar energy per hour and variation in the air temperature in the cabinet in comparison to outside over total drying period showed that (**Fig. 6**) even at constant variation of solar radiation the temperature difference was less on the first day compared to the other three days. This may be mainly due to the higher moisture content of the copra on the first day. The average temperature differences over the period of drying between ambient and drying cabinet was 17°C. The average air velocity in the cabinet measured during drying was 5m/min. The variation in the moisture content of copra with respect to drying time in days for open, poly dryer and cabinet dryer was plotted on the ordinary graph (**Fig. 7**). The drying time required was 7 days, 5.5 to 6 days and 4 days in case of open, poly dryer and cabinet dryer, respectively. The drying test results as presented in **Table 4** showed that the drying capacities were 0.91 $g/m^2/day$, 1.74 $g/m^2/day$ and 3.6 $g/m^2/day$ in

Table 4 Drying of Copra by Different Methods

Drying method	Drying time (days)	Spreading density (nuts/m^2)	Copra production (kg/m^2/day)
Open drying on black painted palmyra mat	7.0	40	0.91
Poly solar dryer	5.5	60	1.74
Solar cabinet dryer	4.0	80	3.60

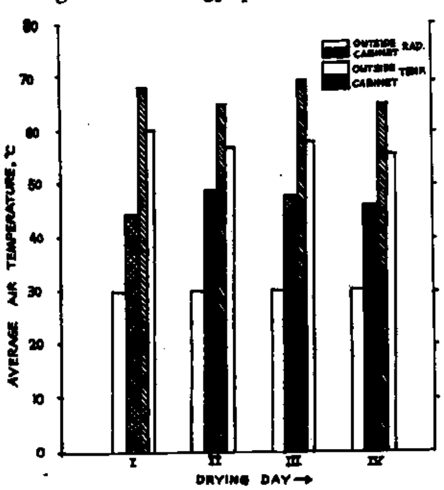

Fig. 4 Average drying conditions during experimentation.

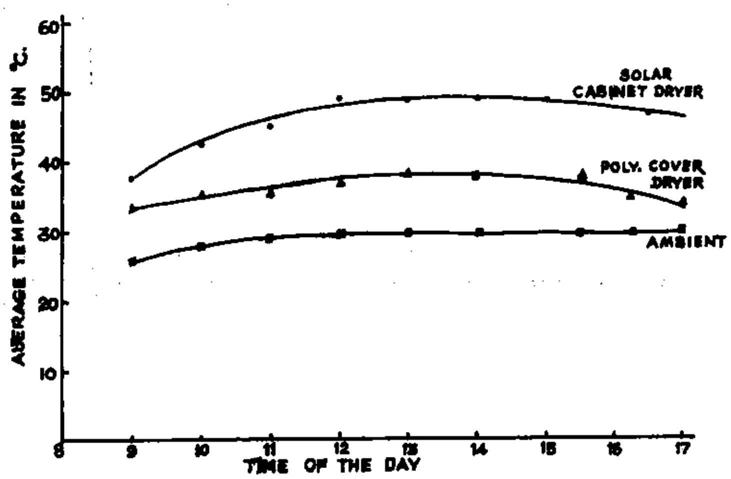

Fig. 5 Variation of temperature during the day.

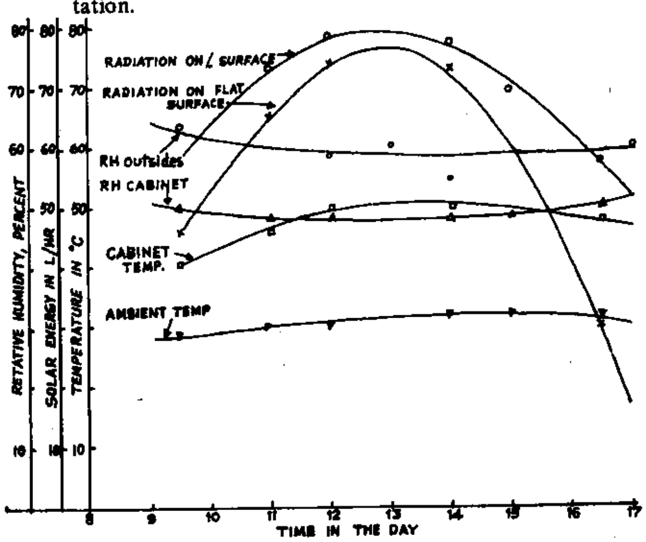

Fig. 6 Average drying conditions during experimentation.

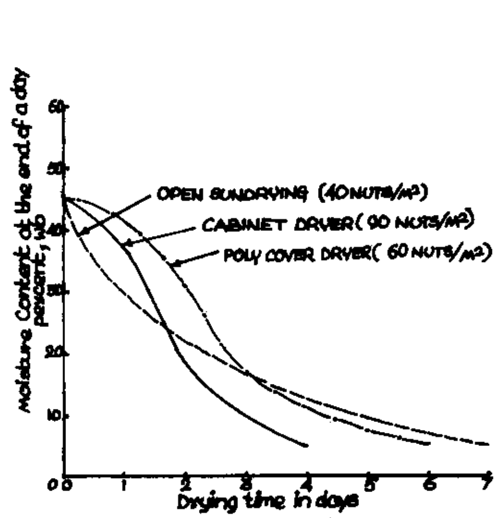

Fig. 7 Moisture content and drying time.

Table 5 Copra Drying Rate and Drying Time

Method of drying	Rate of drying in kg of water /m²/h on the day														
	0.5h	1h	1.5h	2h	2.5h	3h	3.5h	4h	4.5h	5h	5.5h	6h	6.5h	7h	Average
Open	.44	.17	.107	.073	.071	.048	.051	.036	.027	.025	.017	.014	.016	.007	.078
Poly dryer	.148	.15	.258	.269	.343	.197	.117	.055	.038	.037	.036	.011	–	–	.138
Solar cabinet dryer	.356	.424	.448	.506	.198	.107	.08	.047	–	–	–	–	–	–	.270

open, poly dryer and cabinet dryer, respectively. The saving of time in comparison to open in the order of 21.4% and 42.8% was found by poly dryer and cabinet dryer, whereas per day capacity of drying/m^2 could be increased by 91% and 296% by the use of poly dryer and cabinet dryer, respectively. The less drying time required in the poly dryer might be the effect of conservation of heat energy produced by black painted palmyra mat due to the absorption of solar energy, which resulted in increasing in drying air temperature by 6°C. The quicker drying in the cabinet even at double the spreading density may be the combined effect of inclined surface, more surface area of the absorber, manual sun tracking, reflectors, pre-heating of inlet air and effective air circulation which resulted in average increase of cabinet air temperature by 17°C at 5 m/min air velocity compared to open sun drying.

From the drying curves as shown in **Fig. 7**, drying rates were calculated with the following formula at every 0.5 h, **(Table 5)**.

$$R = \frac{(M_0 - M_1)(100 - M_f)\,Q}{(100 - M_0)(100 - M_1)(t_0 - t_1)\,100}$$

where,

R = drying rate in kg of water/m^2/h; M_0 = moisture content (%), wet basis, at t_0 h; M_1 = moisture content (%), wet basis at t_1 hrs. t_0 and t_1 were drying time in h; M_f = final moisture content percent, wet basis = 6%; Q = final weight of the material/m^2

It was noticed that up to first half-day drying when surface (adhering) moisture content was evaporated, drying was faster in open compared to both dryers, i e, 0.44 kg/m^2/h, 0.358 kg/m^2/h and 0.148 kg/m^2/h in open, cabinet and poly dryer, respectively. This may be due to the fact that ample air movement was an important factor during this stage of drying as reported in earlier experiments (6). In the later stages drying in both dryers was faster compared to open drying which may be the effect of higher temperature due to effective utilization of incident solar radiation. Drying in the open, occured mostly at falling rate period except for first half-day. But drying at increasing rate up to first 2 and 2.5 days followed by falling rate was observed for cabinet and poly solar dryer, respectively. Drying at increasing rate in both dryers may be due to higher temperature of air and material which helped in bringing the moisture to the surface of the cups and its evaporation more easily. The nature of the drying changed to falling rate may be due to the less quantity available for drying. The average rates of drying over the total period were 0.078, 0.138 and 0.27 kg/m^2/h for open, poly dryer and cabinet, respectively. The efficient conversion of solar energy into heat energy and its effective utilization for copra drying was achieved due to the use of solar dryers. The drying rates were 77% and 246% more in poly dryer and solar dryer compared to open drying.

Conclusion

The quality of copra was observed to deteriorate due to adhering dirt and dust during open sun drying. Hence the solar dryers as described were very much suitable for copra drying. The cost of operation was very low as no external source of energy was required. The drying time required could be considerably reduced due to effective utilization of solar radiation even at higher spreading densities thereby avoiding microbial infestation as has been reported while prolonged open-sun drying. The cost of the dryers were Rs.50 and Rs.900 for poly dryer and cabinet dryer, respectively. These dryers could also suitably be used for drying pepper, cocoa, etc which are grown as intercrops with coconuts. The labour requirement in avoiding birds' menace during copra drying was also eliminated. The quality of copra obtained from the dryers was good, white in colour, compared to discoloured open-dried copra.

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