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Drying Characteristics of Coconut in Solar Tunnel Dryer

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Coconut (*Cocos nucifera*) is a traditional food ingredient processed in agro-industries in many parts of Tamilnadu. Drying of coconut kernels at industrial level is currently done in open sun drying, which has problems of hygiene. While drying, the endosperm of coconut is exposed and it is susceptible for contamination due to dirt. The coconut kernel having initial moisture content of 50-55 per cent is reduced to 6 per cent during drying operation for safe storage and to maintain food quality. In order to solve the problem of hygiene and to effect faster drying rate, the MPUAT design solar tunnel dryer was installed at M/s Supa Farms, Chinniyampalayam, Coimbatore, Tamilnadu. Solar tunnel dryer is semi-cylindrical tunnel shaped structure covered with UV stabilized polyethylene sheet. The floor area (18.0 x 3.75 m) of the tunnel dryer is black coated to attain the maximum drying efficiency. The results showed that the temperature inside the solar tunnel dryer gets boosted up by 15-20^{o}C more than the ambient. The results also revealed that the coconut kernels being dried in the solar tunnel dryer was completely protected from rain, insects and dust and the dried coconut kernels were high quality compared to open sun dried product.

Key words: Solar Tunnel Drier, UV stabilized polyethylene, moisture content, and drying time

Coconut is a commercial crop in India. Kerala, Tamil Nadu, Andhra Pradesh and Karnataka are the major coconut producing states in India. In tropical countries, the uses of solar energy technologies have large scope compared to other countries. The introduction of solar drying system seems to be the most promising alternative option in reducing post harvest losses (Muhlbauer *et al.,* 1993). Open sun drying is the most commonly used method for drying coconut kernels in most of the developing countries. Drying under hostile climate conditions usually leads to severe losses in the quantity and quality of the product. On the other hand, mechanical drying is an energy consuming operation. Solar dryers are now being increasingly used since they are better and more energy efficient option. Sun shines in India over an average 3000-3200 h/yr delivering about 2000 kWh/m^2/yr of solar radiation on horizontal surface (Mani, 1980). This abundantly available solar energy can be used for drying of coconut kernels. Mainly coconut kernels contain moisture content in the range of 50 to 55 per cent.

Reduction of moisture content to the desired level is the essential function of solar drying operation. The moisture removal involves two operations like low temperature heating and exhaust of moist hot air. Both the operations will be easily carried out by solar tunnel structure.

Solar tunnel dryer has ample potential for drying products which required hot air less than 60^{o}C. The solar dried products have much better quality as compared to open sun dried products. Studies on multi-purpose solar tunnel dryer were carried out at the Institute of Agricultural Engineering, University of Hohenheim (Bala *et al.,* 2003). Fuller (1995) also reported the experimental study on tunnel dryer and a comparison of its performance with conventional dryer. The Maharana Prathap University of Agriculture and Technology (MPUAT), Udaipur has developed a solar tunnel dryer for drying 1.5 tonnes of capacity (Rathore, 2004). The study of MPUAT solar tunnel dryer is the part of

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ongoing research work at Department of BioEnergy, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Tamil Nadu under local conditions.

Materials and Methods

The solar radiations are transmitted through UV stabilized PVC sheet of the tunnel dryer. The plastic cover has the property of transferring short-wave radiations. These solar radiations are converted into long wave thermal radiations inside the solar tunnel dryer. As the plastic sheet is opaque to long wave radiations, these radiations are trapped inside the dryer and raising inside tunnel temperature. It is expected that a temperature increase of about 15-20^{0}C above ambient temperature inside the solar tunnel dryer. This increase of temperature is suitable to reduce the initial moisture content of coconut kernels from 50 -55 per cent to fixed moisture content of 6 per cent. Hence it is proposed to integrate small poly cover in tunnel shape structure for drying the coconut kernels.

The solar tunnel dryer has a transparent cover material and a chamber-cum- drying tunnel. The air is passed through natural convection at one end and moist air is exhausted by exhaust fan at other end of the tunnel. As stated by Garg and Kumar (1998) solar irradiance on the absorbed plate and cover was estimated for the positioning of semi-cylindrical solar tunnel dryer and it was observed that East-West orientation of solar tunnel dryer is more appropriate than any other orientation.

The main structural components of solar tunnel dryer are hoops, foundation, drying floor and UV stabilized polythene film. The fabrication detail of each component as follows; Solar air collector cum drying chamber of solar tunnel dryer consists of 18 m length and 3.75 m width for drying 5000 coconuts per batch. It is semi cylindrical shaped tunnel metallic frame structure covered with UV stabilized semi transparent polythene of 200 micron. A single layer polythene film for the cover of solar tunnel dryer is preferred due to material economy and easy handling. This polythene has been purchased from IPCL, Bangalore.

Solar tunnel dryer consists of metallic frame having circumference of 11.75 m., developed through 13 hoops of G.I pipes bent to 3.75 m diameter, these hoops are having horizontal spacing as 1.5 meter, over which UV stabilized polythene sheet in wrapped. One end of the frame consists of an iron gate of 1.6 m x 0.80 m size for loading and unloading the material inside the dryer. The tunnel has a tilt of 10-15^0 with horizontal to generate natural convection flow in the dryer. Equi-spaced six inch diameter hole covered with cowl to protect against rains and natural disorders was provided for natural convection. Periodically the exhaust fan will run to maintain the humidity. Exhaust fan is connected with automatic humidity controller.

The design of the system is modular and therefore, length of the collector and the dryer and the radius of the cover are fixed as per the flow rate and temperature requirements about 15-20^{0}C above the ambient temperature. An exhaust fan of 1700-1900 m^3/hour air flow rate capacity of 0.9 kW rating for removing moisture air was also provided near door of the dryer. For running this exhaust fan, 220 V, A.C. 50 Hz supply is required. On an average 1-2 electrical units (kWh) were consumed in operation of the exhaust fan for drying one batch. The temperature inside the solar tunnel dryer comes out to 15-20^{0}C higher than ambient temperature. Foundation pipes are used to provide a firm support to the hoops in the structure G.I. pipes of 25 mm diameter and 100 cm length. Floor of solar tunnel dryer was made of Cement Concrete of 1:2:4 ratio and painted black for better absorption of solar radiation. The black coated floor act as heat absorber in solar tunnel dryer.

Location of the dryer

The solar tunnel dryer was installed at Supa Farms, Chinniyampalayam, Coimbatore, Tamil Nadu, which is undertaking the processing of high quality coconut products. The farm is located at about two kilometers from the Avinashi main road and situated at 11^o 02' N latitude and 77^o 03' E longitude. The altitude of the location is 399 m above mean sea level. It lies under

Table 1. Moisture reduction in the drying of coconut

Time Hr:min	Moisture content reduction, % (w.b)							
	Open sun drying					Solar Tunnel Dryer		
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 1	Day 2	Day 3
10:00	55.0	44.1	34.1	23.9	15.5	55.0	35.2	21.0
11:00	53.0	42.5	32.9	21.6	13.8	52.0	33.6	18.4
12:00	51.5	40.9	30.8	19.8	11.4	48.4	31.8	16.3
13:00	49.6	39.6	28.6	18.1	10.1	44.2	28.4	14.9
14:00	47.3	38.2	26.9	16.9	9.2	41.7	25.1	11.5
15:00	45.1	36.7	25.1	15.3	8.0	38.5	23.6	8.9
16:00	44.2	35.1	24.6	14.9	6.9	36.1	22.5	7.5
17:00	43.4	33.3	23.2	14.1	6.3	34.1	20.1	6.4

Western Agro-climatic zone and receives solar radiation throughout the year. The location is in the agricultural belt where the farmers are cultivating coconut as one of their main crops.

Conventional drying of coconut

In conventional drying, equally splited nuts were spread over in open yard of concrete drying floor to make drying operation by open sun drying for 24 hours. Initially the shells were removed manually after a drying period of 1-2 days and the kernels further dried. Drying was continued another 16 hours till the moisture content of the copra comes to around 6 to 7 per cent. Thus coconut contains 50 to 55 per cent (w.b) moisture initially and it is to be brought down to 5-6 per cent (w.b) by drying. Unlike other crops, while drying, the endosperm of coconut is exposed so, it is susceptible for contamination due to dirt in open sun drying.

Testing of solar tunnel dryer without coconut kernels

The experiments were conducted without product to find out the temperature profile at different locations in solar tunnel dryer. Under this condition the useful heat extracted by the tunnel drier was evaluated. For floor temperature measurements, thermometers were placed at every 4.5 m interval from 0 m (front end of the dryer) to 18.0 m (back end of the dryer) along the length of solar tunnel dryer location with North, Center and South positions of every interval points. Similarly, the air temperature and relative humidity inside the solar tunnel dryer were recorded by placing the thermometers and digital relative humidity meter at different heights i.e., 0m, 0.5m, 1.0 m and 1.5 m from the floor level at 0 m to 18.0 m along the East-West orientation of the solar tunnel dryer.

Testing of solar tunnel dryer with coconut kernels

The tunnel dryer was evaluated for finding the performance in actual loaded condition with 5000 coconut kernels. Kernels with known moisture content were taken and loaded in the floor of the solar tunnel dryer. Temperature variation inside the dryer and ambient temperature was measured with the help of thermometers. Initial and final moisture content of the kernels was measured by oven drying method. Drying was continued till the moisture content of the kernel tended to a constant value. A known quantity (150 Kg) of kernel sample was kept in open air for the purpose of comparison between open sun drying and drying in solar tunnel dryer. The weight reduction was measured at every one-hour interval for knowing the quantity of moisture removed.

Results and Discussion

Performance of solar tunnel dryer

No Load Test

No load test was conducted to find out the temperature profile and relative humidity at different locations in solar tunnel dryer. Under this condition the useful heat gained by the solar tunnel dryer was evaluated. The observed temperature and relative humidity at different locations (0, 9 and 18 meters) under no load were recorded. In no load test an average maximum temperature and relative humidity inside the tunnel dryer was 55 ^{o} C at 14:00 hrs and around 60 per cent at 12 noon, respectively while the minimum temperature and relative humidity were 35.8 ^{o} C and 45 per cent at 14:00 hrs, respectively.

Full load testing

The solar tunnel dryer was evaluated for finding the performance in actual loaded condition with coconut kernels. The known quantity (5,000 coconut kernels) was taken for the drying test in the solar tunnel dryer. The temperature and relative humidity at different locations (0,9 and 18 meters) were measured under load condition on the first day of drying and the results were observed. In load test, the maximum temperature and relative humidity inside the tunnel dryer was 49 ^{o}C and 85 per cent at 12:00 noon, respectively, while the minimum temperature and relative humidity were 35^{o}C and 55 per cent at 16:00, hrs respectively. The kernel was shrunk and shell was partially detached from the kernel after 12 hours of drying in side the tunnel dryer. At this stage shell was removed manually and the kernel allowed for further drying (Fig 1). Drying was continued till the moisture content of the coconut kernels was reduced to 6 to 7 per cent.

Fig.1. View of solar tunnel dryer with coconut kernels

Reduction in moisture content

The moisture content observations of solar tunnel dryer were presented in Table 1 and results were plotted in Fig. 2. At the time of loading, the initial moisture content was 50 to 55 per cent on wet basis. Drying was continued till the coconut moisture content was reduced to 6 percent in both the solar tunnel dryer and in open air. Under full load condition drying takes only 24 hours in solar tunnel dryer and where as it was 40 hours for open sun drying. The gain of about 16 hours (40 per cent) is achieved in the tunnel dryer over conventional open sun drying.

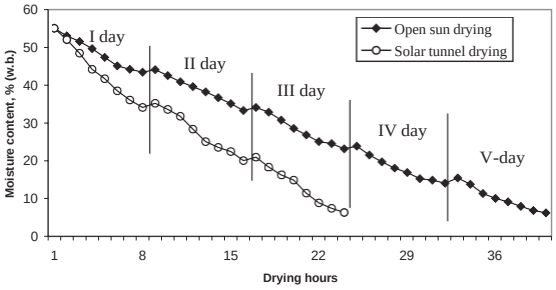

Fig 2. Variation of moisture content with time

The variation in the moisture content at different days of drying of copra is shown in Fig 2.. The ambient air temperature varied from 26^{o}C to 33.5^{o}C and the drying air temperature in the tunnel dryer increased from 45^{o}C to 55^{o}C. The same way relative humidity inside the dryer was reduced by 20 per cent. The copra dried in the solar tunnel dryer has the advantage of significant reduction in the population of fungi, bacteria and lipolytic micro organisms in the coconut kernels compared to open sun drying.

Cost economics

The economic feasibility of solar tunnel dryer was worked out for drying of one tonne of coconut in comparison with the conventional sun

drying system and the results indicated saving in cost of 42.2 per cent over solar tunnel dryer. (Table 2)

Conclusion

The solar tunnel dryer can be used for drying of agro industrial produces like coconut kernels, chilli and sago. The temperature gain upto 60°C can be effectively utilized for drying operation. The dried product has superior quality in color, texture and reduction in population of fungi, bacteria over conventional drying method. It reduces the cost of drying to 42 per cent and drying time to 40 per cent over conventional drying practice.

Table 2. Comparison of drying cost for a capacity of 1 ton/batch

Drying method	Cost of drying, Rs/ton	Savings by using solar tunnel dryer compare to open sun drying	
		Rs.	(%)
Solar tunnel dryer	520	380.00	42.20
Open sun drying	900		

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