Development of a solar tunnel dryer for plantation crops

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Abstract

Fresh coconut kernel containing 45 to 55% moisture content (M.C.) has to be dried to 5 to 6% moisture level in order to obtain good quality copra. The common practice of getting copra is by sun drying the fresh coconut kernel on cement floor or on sand floor for seven to nine days. Unlike other crops, while drying, the endosperm of coconut is exposed to dirt. Prolonged drying also results in microbial infection. Drying using solar dryers and indirect dryers produce good quality copra in a shorter time. So a solar tunnel dryer of a semi cylindrical shape with a capacity of 1500 coconuts / batch or 200 kg of pepper was developed. The temperature inside the dryer was 20-25° C higher than the ambient and the R.H. value was 20 - 22% lower than the ambient. Since the drying was done continuously much above the ambient air temperature and at lower R.H. level, the copra was 3 - 4 times less infested by fungi and bacteria than that produced by open sun drying. Drying time for copra was 32 sunshine hours. The cost of the dryer is Rs 13650/ and the cost of drying one kg of copra is Rs. 1.15 and for pepper Rs.1. The dryer can also be used to dry other plantation crop / produces.

Key words: Solar tunnel dryer, plantation crops

Introduction

Drying is an important post-harvest operation in the processing of coconut for extraction of coconut oil. Fresh coconut kernel containing 45 to 55 percent moisture content has to be dried to 5 to 6 percent moisture level in order to obtain good quality copra. Drying must be carried out within four hours of splitting since coconut kernel deteriorates very rapidly due to growth of mould and bacteria (Patil, 1991). Within four hours, microbial activity in the form of slime formed due to bacterial growth is seen if temperature is less than 30 °C and relative humidity more than 80 percent. The surface slime continues to develop within 4-8 hours. Microbial activity is reportedly more if the moisture content of the kernel is above 20 per cent (Nair, 1984). Fungi is also reported to cause deterioration of copra followed by bacteria. Oil content levels of 40.2, 35.1, 20.1, and 0.6 percent have been reported in white, brown, black and green copra respectively. Nathaneil (1965) found that the loss due to microbial infection varies with moisture content of dried copra. Subrahmanyan (1968) recorded the occurrence of *Staphylococcus aureus*, *Bacillus* sp. and yeast at 20-50 percent moisture content of copra. Thomas *et al.*, (1987) stated that deterioration of copra started during drying and storage. Bacterial action is initiated during processing and the severity of subsequent mould infection and insect attack depended on the extent to which the cell structure has been broken down by the bacteria.

The common practice of producing copra is by sun drying the fresh coconut kernel on cement or sand floor for seven to nine days. Unlike other crops, while drying, the endosperm of coconut is exposed and so is susceptible to contamination with dirt. Prolonged drying also results in microbial infection. The microbial contamination can be reduced if drying is done more quickly in suitable dryers. However precaution has to be taken because rapid drying causes case hardening. (Grimwood, 1975). Drying using solar dryers and indirect dryers produce good quality copra.

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 consequentially 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.

Materials and Methods

THEORETICAL CALCULATIONS

Basic data:

Mean insolation (I)	=	50 Langley/h
	=	500 kcal/m²/h
No. of sunshine hours/day (average of 8 months) (S)	=	8.5
Area of the solar collector	=	14.1 m²
Effective area of the solar collector (A)	=	9.4 m²
Duration of drying (D)	=	4 days
Initial moisture content of kernel	=	45 %
Final moisture content of copra	=	6 %
Rise in temperature	=	20 °C
Mean copra weight/ nut	=	165 g

ENERGY BALANCE:

Energy input:

Quantity of heat received by the collector	=	I x S x A x D)/ 1000 Mega Cal.
Quantity of heat received by the collector	=	(500 x 8.5 x 9.4 x 4)/1000
	=	159.8 Mega Cal

Energy utilized:

Quantity of heat utilized for drying copra (H)

= {[((M1 – M2)/(100 – M2)) x Q x W x f] + [Q x W x T X Cp]}/1000

Where, H = Heat energy required for drying, K Cal

M1 = Initial moisture content of the product, percent in wet basis

M2 = Final moisture content of the product, percent in wet basis

Q = Number of nuts to be dried per batch

W = Mean weight of product per nut, kg

f = Latent heat of vaporization of water, assumed as 600 K Cal/Kg

Cp = Specific heat of material to be dried in K Cal/Kg, assumed as 1 K Cal/Kg

= {[((45 – 6)/(100 – 6)) x 1500 x 0.165 x 600] + [1500 x 0.165 x 20 x 1]}/1000

= 66.56 Mega Cal

Drying efficiency

= (66.56 /159.8)/100

= 41.6 %

The dryer was designed to dry 1500 coconuts per batch. The dryer consisted of a semi cylindrical shape tunnel structure, having a transparent cover made from UV stabilized polyethylene film of 200-micron thickness. The floor area of the dryer is 3.5 x 3 square meter and the radius of the tunnel is 1.5 meter. The solar collector is of black polyethylene film of 250-micron thickness spread on the ground inside the dryer for better absorption of solar heat. A gradient of 10° to 12° was provided along the length of the tunnel to induce natural convection airflow. Thermocol insulation -10 cm thick - was provided below the black sheet to prevent heat loss through the floor. Inlets for fresh air had been provided along the periphery of the tunnel near the ground level. Two chimneys of 20 cm diameter and 75 cm height were provided on top of the curved surface to allow exhaust of hot moist air. In order to prevent condensation of moist air during night hours and for better heat distribution an exhaust fan of 0.2 m³/s capacity was fixed. The solar dryer was fixed with its curved surface facing north-south direction for maximum insolation. Two trolleys of 3.4 meter length and 1.2 meter width at the bottom and 90 cm width at the top containing trays which can be drawn out to keep the coconut or other produce for drying are provided. The design drawing and the photograph of the dryer is given separately below.

Results and Discussion

The solar collector and the products kept inside absorb the sunlight entering inside the tunnel dryer which in turn emit long wave thermal radiation and the polyethylene sheet prevents it from passing through. As a result, the solar energy is trapped for raising the temperature inside and used for drying the kernel kept inside. The testing of the tunnel dryer was carried out with coconut. 1500 nuts were loaded in the trolley and pushed inside the drying chamber. After 12 hours of solar drying, the kernel was shrunk and shell was partially detached from the kernel. At this stage the shell is removed manually and the kernel is further dried. It took another 20 sunshine hours for the kernel to be dried completely. The variation in temperature and relative humidity of ambient air and air inside the drying chamber are shown in *Fig.1* for first day, Fig.2 for second day and Fig. 3 for third and fourth days of drying. The variation in moisture content of copra with respect to the drying time is shown in Fig.4 for coconut and Fig 5 for green pepper. When the ambient air temperature varied from 26 to 33.5 °C the drying air temperature increased to 45 to 55°C and RH inside the drying chamber was reduced by 20%.

The copra dried in the solar tunnel dryer and the control trial were analysed for its quality and the results are shown in Table 1. It can be seen that there is significant reduction in the population of fungi, bacteria and lipolytic micro-organisms in the copra samples dried with solar tunnel dryer compared to that of sun drying. The optimum moisture level recommended for safe storage of copra is 6% (w.b) and when moisture content is high, copra will be infected with bacteria, and fungi. Paul (1969), and Susamma and Menon, 1981 isolated a number of fungi and bacteria from deteriorated copra. The fungi isolated were *R. stolonifer, R. oryzae, Mucor hiemalis, P. citrinum, Culvularia senegalensis* etc. Since the drying was done continuously much above the ambient air temperature and at lower R.H. level, the copra was free from fungi and bacteria.

Drying trials were conducted with pepper also. Capacity of the dryer is 200 kg wet beans and the time taken for drying was 20 hr. Moisture condensation during night hours is a serious problem in this type of closed structure dryers. So the exhaust fan should run continuously day and night during drying period.

Economic analysis of the dryer

The construction cost of the dryer was estimated to be Rs. 7650/ - and with the trolley it was Rs. 13650/= and the expected life of the dryer is 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 2. The cost of drying was calculated as Rs.0.90 / Kg of copra and for drying pepper the cost was Rs.1.10.

Table 1. Microbial analysis of copra

Micro-organism (Number of colonies per g of sample)	Sun drying n=26	Solar tunnel dryer n=26	t-Value
Fungi (x100)	6.67	2.10	30.82
Bacteria (x100)	15.15	4.43	17.67
Lypolytic micro-organisms (x100	3.93	1.2142	37.5

*** significant at 1% level*

Table.2 Economic analysis

Assumptions:	
1. Capacity of the dryer	: 1500 nuts / batch
2. Cost of the dryer	: Rs. 13650.00
3. Drying time	: 32 sunshine hours
4. No. of working days/year	: 240 days
5. Life of the dryer	: 10 years
7. No. of labourers required	: 2 man days
8. Cost of labour	: Rs.100/ day
9. Cost of electricity	: Rs 1/ unit
10. Quantity of copra from 1500 coconuts	: 247.5 kg
11. Quantity of pepper in 1 batch	: 200 Kg. wet
Fixed cost per year:	
Annual depreciation (10% of cost)	: Rs. 1365/-
Annual Interest on half the new cost @ of 15%	: Rs. 1024/-
Maintenance cost @ 10% of annual cost + cost of polythene sheet	: Rs. 1500/-
No of batches in a year	: 60 (40 for pepper)
Total fixed cost / year	: Rs. 3900.00
Fixed cost / batch	: Rs. 65.00 (98.00 for pepper)
Variable cost :	
Cost of labour	: Rs. 200.00 (100.00 for pepper)
Cost of electricity	: Rs. 20.00
Total variable cost	: Rs. 220.00 (Rs. 115.00 for pepper)
Cost of drying / batch	: Rs. 285.00 (Rs. 213 for pepper)
Cost of drying / kg. of copra	: Rs. 1.15
Cost of drying / kg. of wet beans of pepper	: Rs. 1.10

Conclusion

A solar tunnel dryer has been developed. Its semi cylindrical tunnel structure has a transparent cover made from UV stabilized polyethylene film of 200-micron thickness. The solar collector is the black polyethylene film of 250-micron thickness spread on the ground inside the dryer. The floor area of the dryer is 3.5 x 3 m^2 and the radius of the tunnel is 1.5 meter. The temperature inside the dryer is 20 to 25 °C higher than that of ambient and the R.H. value was 20 to 22% lower than the ambient. Since the drying was done continuously much above the ambient air temperature and at lower R.H. level, the copra was almost free from any microbial infection. Drying time taken to dry copra was 32 sunshine hours. The cost of the dryer is Rs 13650/-. The cost of drying of one kg of copra is Rs. 1.15 and for pepper is Re.1.10. This can be used by farmers of small and medium

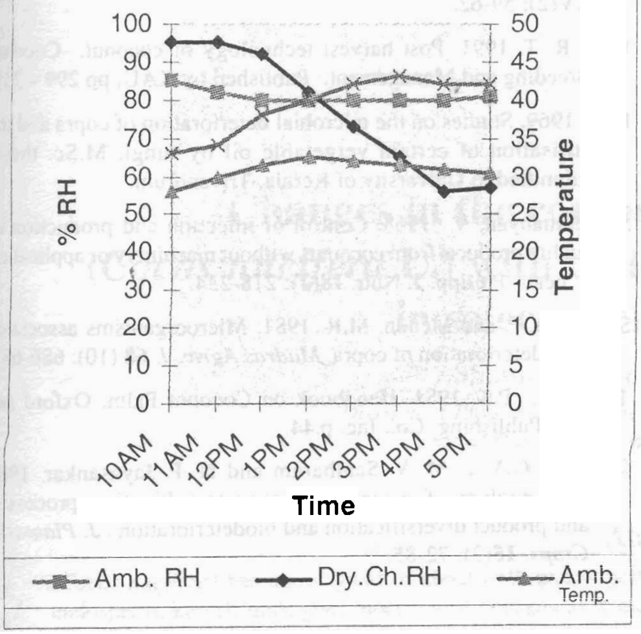

Fig. 1. Variation of RH & Temp. (I Day)

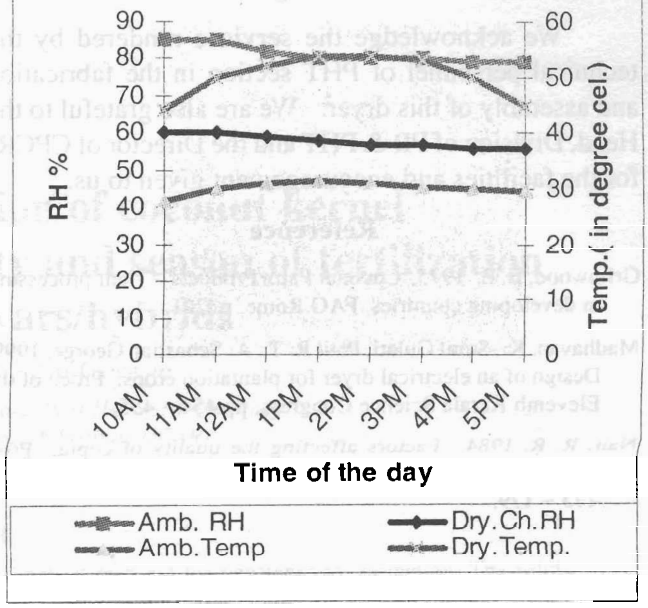

Fig. 2. Variation of RH & Temp. (II Day)

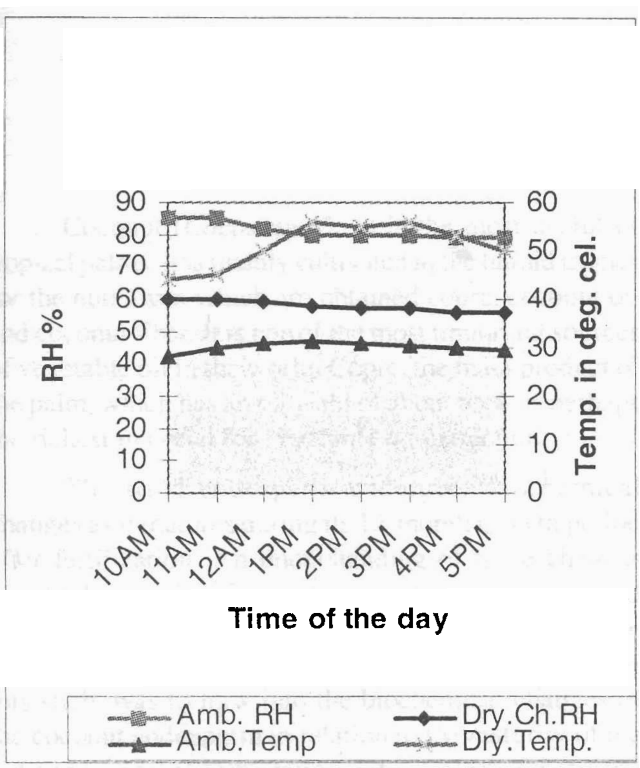

Fig. 3. Variation of RH & Temp. (III & IV day)

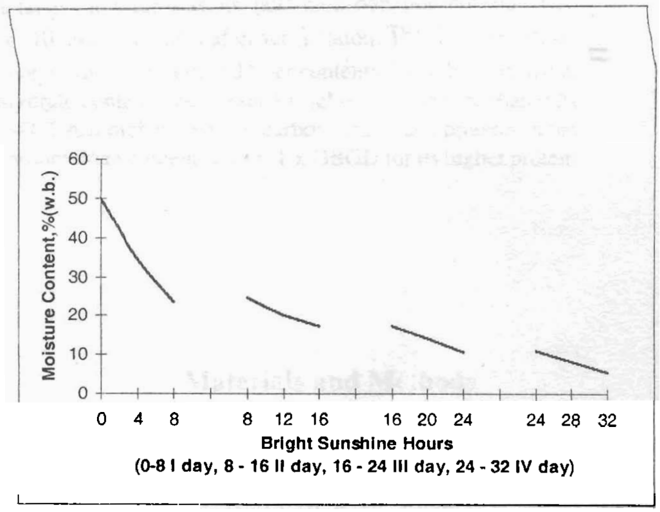

Fig. 4 Moisture Reduction Curve for Coconut

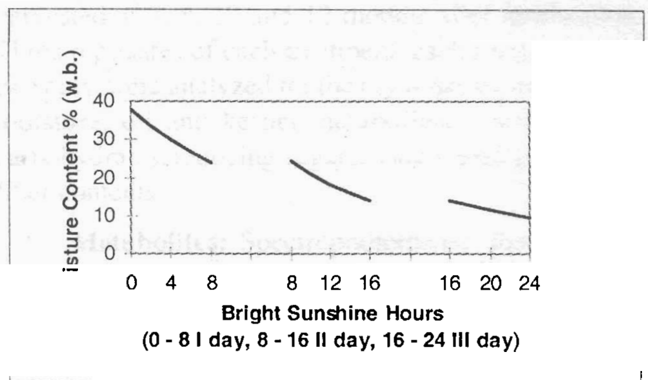

Fig. 5. Moisture Reduction Curve for Pepper

holdings to dry coconuts. The dryer can also be used to dry produce of other plantation crops.

Acknowledgement

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