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Comparative efficiency of solar energy based dryers in relation to copra drying

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Abstract

Three types of solar energy based dryers viz. solar cum electrical dryer, solar cum biomass dryer and solar tunnel dryer developed by Central Plantation Crops Research Institute were compared with reference to their Specific Fuel Consumption (SFC), Solar Collector Efficiency and cost of drying of coconut. These three dryers were selected because the shape and size of the drying chamber of all dryers were the same and capacity is 1500 coconuts (225 kg. copra) per batch. It was seen that SFC was better in the case of solar cum electrical dryer followed by solar tunnel dryer but efficiency of the solar collection was found to be the least in the case of solar tunnel dryer. Cost of drying was minimum for solar tunnel dryer and maximum for solar cum electrical dryer.

Key words : Solar cum electrical dryer, solar cum biomass dryer, solar tunnel dryer, specific fuel consumption, solar collection efficiency

Introduction

Drying is an important post-harvest operation in the processing of coconut for extraction of coconut oil. Fresh coconut meat which contains 45 to 55% moisture content (M.C.) has to be dried to 5 to 6% moisture level in order to obtain good quality copra. Drying must be carried out within four hours of splitting since coconut meat 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%. The surface slime continues to develop and within 48 hours, penetrating mould also makes its appearance. The common practice of getting copra is by sun drying the fresh coconut meat on cement floor or on sand floor for seven to nine days. Unlike other crops, while drying, the endosperm of coconut is exposed and so is susceptible for contamination due to dirt. Prolonged drying also results in microbial infection. However, precaution has to be taken because rapid drying causes case hardening. (Grimwood, 1975). Compared with sun drying, all types of 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. 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. So dryers are the best solution for proper drying of copra. CPCRI has developed dryers with different sources of energy such as solar energy, electrical energy, energy from biomass and the combination of them. In this paper the efficiency of these dryers are compared with reference to the specific fuel consumption, energy consumption and cost of drying.

Materials and Methods

Copra dryers developed by Central Plantation Crops Research Institute, namely, solar cum electrical dryer, solar cum biomass dryer and solar tunnel dryer were compared for their efficiency and cost. These three solar dryers were selected because the shape and size of the

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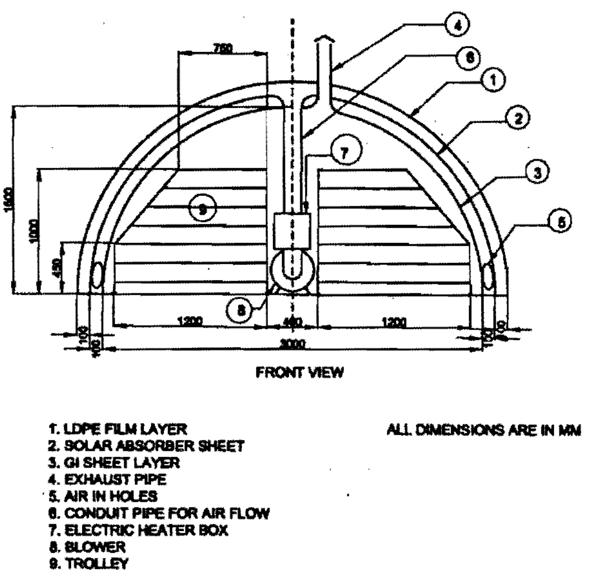
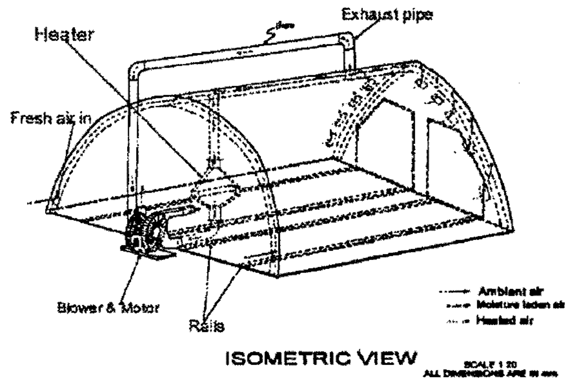
drying chamber for these dryers were semicircular in shape and of 3m x 3m x 1.5m size and capacity is 1500 coconuts (225 kg. copra) per batch. Two trolleys of 3.2 m length and 1.2 m width at the bottom and 0.9 m at the top having trays to keep the coconut for drying were provided in each dryer. This can be drawn out to load the coconuts and pushed inside for drying .

The solar cum electrical dryer consists of a semi circular double pass flat plate solar collector having a transparent cover made from UV film of 200-micron size, an absorber plate made from black polyethylene film (agrifilm) of 250-micron size and a bottom casing made of 0.46 mm G.I.sheet. (Fig.1&2). The space below the solar collector is the drying chamber semicircular in shape with 1.5 m radius. Similar type of an all-plastic dryer on bamboo framework was tried in Korea to dry red pepper. (Trim and Ko, 1982). In order to have maximum insolation the solar dryer is fixed in such a way that its curved surface is facing north- south direction. Heater assembly having 6 heaters of 1000 Watt each, a blower to draw hot air from solar collector and heaters to the drying chamber and an electronic control system were also provided. The electronic control system is provided with temperature sensors and it maintains the temperature in the drying chamber within set limits. The blower motor is fixed outside the dryer but heater assembly is kept inside the drying chamber thereby avoiding the extra insulation normally necessitated in the conventional solar cabinet dryers. (Madhavan *et al.*, 2003)

The biomass dryer is similar to solar cum electrical dryer in terms of solar collector solar collector, except

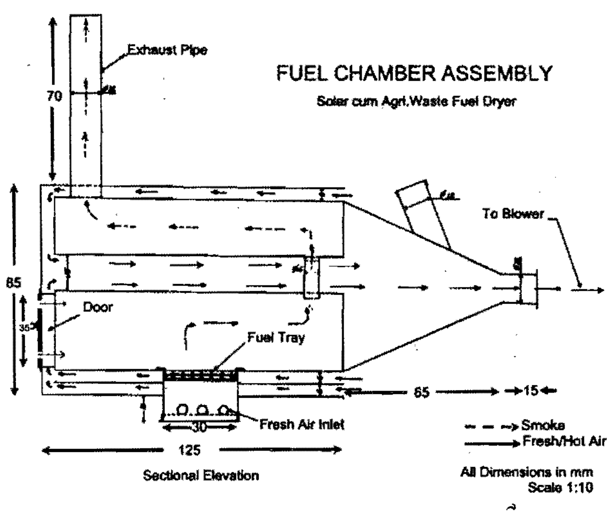
SOLAR CUM ELECTRICAL DRYER





for the heating chamber where biomass such as husk and shell was used as fuel (Fig.3). The heating chamber consists of mainly three compartments, the fuel chamber, air-preheating chamber and air-heating chamber. The pre-heated air will enter the middle compartment where the air is heated to about 110°C. A chute with butterfly valve for entry of fresh air is provided in the conical section of the heating unit to control the temperature at the outlet manually. The fuel capacity was 4 kg. of coconut husk. Loading of fuel is necessary after every one hour during drying. The electronic temperature control system is designed in such a way as to retain the temperature in the drying chamber within set limits. (Anonymous, 2003)

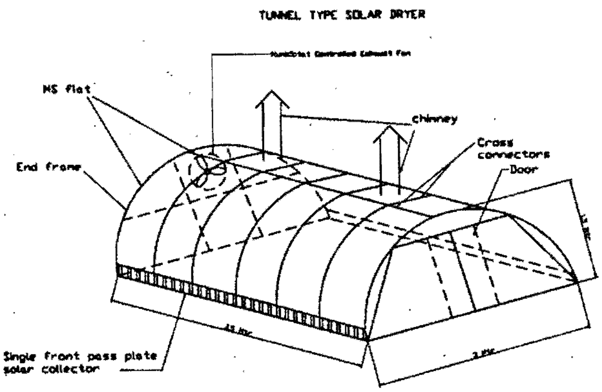
The solar tunnel dryer consists of a semi cylindrical shape tunnel structure having a transparent cover made from UV stabilized polyethylene film of 250 micron thickness. The floor area of the dryer is 3.5 x 3 m^2 and the radius of the tunnel is 1.5 m (Fig.4). The solar collector is the black polyethylene film of 250-micron thickness spread on the ground inside the dryer for better absorption of solar radiation. A gradient of 10° to 12° has been provided along the length of the tunnel to induce natural convection airflow. Thermocol insulation of 10 cm thickness is provided below the black sheet to prevent



heat loss through the floor. Inlets for fresh air have been provided along the periphery of the tunnel near the ground level. Two air exhausts 20 cm diameter and 75 cm height have been 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 200 W has been fixed. The solar dryer is fixed with its curved surface facing north - south direction to have maximum insolation (Brenndorfer *et al.*, 1985). Drying trials were conducted in these dryers in the months of December to February during 2003 and 2004.

Results and Discussion

Coconuts after dehusking and breaking into two halves were loaded in the trolley and pushed inside at 9 AM so that eight hours of solar drying was possible on



the first day. At 6 PM heaters were switched on to retain the temperature at 60°C and this was continued for the next 8 hrs by which time the shell was partially detached from the kernel and kernel was scooped out from the shell easily with a wooden wedge. After removing the shell, the coconuts were loaded in the trolley and pushed inside the drying chamber. Next day the drying was continued with solar energy and at 6 PM the heaters were switched on. Out of the total time taken for drying, the heaters were switched on for 10 hrs and the total drying time taken was 24 - 26 hrs in the solar cum electrical dryer.

In the solar cum biomass fuel dryer, electric energy was replaced with biomass fuel and the drying time taken was 26-28 hrs and the duration for which biomass fuel used was 12 hrs. In both the cases the temperature was maintained between 55°C and 65°C by the electronic temperature control system. In the case of solar tunnel dryer, the drying time taken was 4 days (32 sun shine hours).

Efficiency of dryers was compared in terms of Specific Fuel Consumption (SFC). The energy utilised to dry same quantity of coconut to bring down the MC from 50% to 6% (d.b) was calculated for each dryer.

A. Energy utilized for solar cum electric dryer

$E_1 = S + P \times W$

Where S is the solar energy, P the process time in hours and W the power consumed in watts

Intensity of solar radiation = 3400 langlay/day = 142.12 MJ/m^2/day

Effective area of the solar collector = (5.4/8) x 3.2 = 2.16 m^2

Quantity of heat received by the collector = 306.98 MJ/ day

Quantity of heat received by the collector in 2 days S = 613.96 MJ

1 KWh = 3.6 MJ

So E_2 = 613.96+10 h x 6 KW x 3.6 = 829.96 MJ

SFC of the dryer = E1 / Q_1 where Q_1 is the quantity of final product made

= 829.96 MJ/ 225 kg. = 3.689 MJ/kg

B. Energy utilized for solar cum biomass dryer E_2 = S + Energy of total biomass

Energy of 1 kg of biomass (with 30% moisture) = 15 MJ (Brenndorfer *et al.*, 1985) (2). The biomass used in the dryer was coconut husk. 4 kg of the husk was loaded at a time in the fuel tray and burned. The fuel is to be loaded at every one hour to retain the temperature inside the drying chamber between 55°C and 65°C .

Energy utilized for solar cum biomass dryer E_2 = (613.96 MJ+ 15 x 12 x 4 MJ) = 1333.96 MJ

SFC for the batch = E_2 / Q_1 = 1333.96 / 225 = 5.929 MJ / Kg of copra

C. Energy utilized for solar tunnel dryer = Quantity of heat received by the collector in 4 days = 306.98 x 4 = 1227.92 MJ

SFC for the batch = 1227.92 / 225 kg. copra = 5.457 MJ / kg of copra

SFC was better in the case of solar cum electrical dryer because the heater assembly was fixed inside the drying chamber and so no heat is lost. But in the case of biomass dryer the fuel attachment was fixed outside the drying chamber and so some amount of heat was lost. The solar tunnel dryer uses only solar energy and so its SFC was found to be lower than that of solar cum electrical dryer.

The efficiency of the dryers was compared by comparing the efficiency of the solar collector also. For the solar cum electrical and the solar cum biomass dryers, the temperature elevation was about 25°C because of the double pass parallel plate solar collector whereas the solar tunnel dryer was designed using a single front pass plate solar collector and so the temperature elevation was about 18°C only.

$$\text{Efficiency of the solar collectors} = \frac{V p \ddot{A} T\ Sp \times 100}{Ic\ Ac}$$

Where V = Volumetric flow rate of air, ÄT = temperature difference inside drying chamber and ambient in Kelvin, p=density of air, Sp=specific heat of air, Ic=Insolation and Ac=effective solar collector area (Thanaraj *et al.*, 2004).

Based on the above formula, efficiency of different types of dryers was compared (Table 1). Since the electric and biomass dryers are of forced convection type, volumetric air flow rate v was higher in these dryers. Similarly the drying air temperature was also higher compared to solar tunnel dryer. So the efficiency of the solar collector of solar electric dryer and solar biomass dryer was found to be better than that of solar tunnel dryer. Comparison of cost is also provided in Table 1.

Table 1. Comparison of solar collector efficiency

Dryer type	V	ÄT in Kelvin	Ac (m^2)	Efficiency	SFC (M J /kg copra)	Dryer cost Rs.	Drying time / batch	Cost of drying Rs./ kg. copra
Solar cum Electrical dryer	0.2083	298	2.16	26.01	3.689	40000	24 – 26 hrs	2.95
Solar cum Biomass dryer	0.2083	298	2.16	26.01	5.829	48000	26 – 28 hrs	2.75
Solar tunnel dryer	0.096	291	2.16	11.71	5.457	13600	32 sun shine hrs (4 days)	2.15

Quality of copra from these dryers was analysed. The population of fungai and bacteria are much less than that of sun drying as reported earlier. (Madhavan and Bosco 2002, 2004).

Advantages of solar cum electrical dryer and solar cum biomass dryer are that they need not wholly depend on the solar energy. Whenever temperature in the drying chamber falls below the set level due to poor solar radiation from the collecters, heaters will be switched on automatically in the solar cum electrical dryer. In the case of solar cum biomass dryer an audible alarm will be given to alert the attendant to feed fuel once the temperature comes down the set level. SFC was better in solar cum electrical dryer but cost of drying was higher than that of other dryers. Solar tunnel dryer was found to be cheapest among the three and cost of drying was also minimum.

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