Journal of Scientific & Industrial Research
Vol. 69, August 2010, pp 635-638

Experimental investigation on a solar tunnel drier for copra drying

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Received 04 March 2010; revised 18 May 2010; accepted 02 June 2010

A natural convection solar tunnel drier (STD) was developed for copra drying under meteorological conditions of Pollachi, India. STD reduced moisture content from 52.2% to 8% in 57 h under full load and 52 h under half load conditions. Drying rate in bottom tray was lower (2%) than that of top tray. Average efficiency of STD was estimated as 20%. Quality of copra obtained was good (84.66% Milling copra Grade 1) as compared to open sun drying (53%).

Keywords: Copra, Drier efficiency, Moisture content, Solar tunnel drier

Introduction

India ranks third largest coconut producing country (area, 15.5%; coconut production, 21%) in the world. It annually produces 14.81 billion nuts from an area of 1.93 million ha[1]. Copra is richest source of oil (70%). Moisture content (52%, wet basis) in fresh coconuts is required to be reduced to 7% by drying to concentrate oil content. In India, traditional methods (kiln and sun drying) used for processing copra produce poor quality. In kiln drying, smoke will be in direct contact with coconut cups. Hence, high quality copra could not be produced due to formation of high acid content and polycyclic aromatic hydrocarbons[2].

In open sun drying (OSD), rate of drying depends on intensity of solar radiation, ambient temperature, wind velocity, relative humidity (RH), initial moisture content, type of crops, crop absorptivity and mass of product per unit exposed area. OSD has many disadvantages (degradation by wind-blown debris, rain, insect infestation, human and animal interference) resulting in product contamination. Speed of drying and product quality reduce due to over or under drying, intermittent sunshine, wetting by rain etc[3]. Mohanraj & Chandrasekar[4,5] tested performance of a forced convection solar drier integrated with heat storage materials for processing copra. Various types of solar driers are reported[6]. Sarsavadia[7] studied performance of recirculation type forced convection solar drier for dehydration of onions. Hossain & Bala[8] reported performance of solar tunnel drier (STD) for drying chillies. Garg & Kumar[9] studied performance of semi-cylindrical STD. Condori *et al*[10] studied performance of tunnel green house drier for sweet pepper and garlic drying.

This study presents drying characteristics and quality of copra produced in a natural circulation STD for high quality copra production.

Experimental Section

Experiments were carried out under meteorological conditions of Pollachi (latitude, 10.39°N; longitude, 77.03°E) in India during summer months of 2009. On the basis of measurement, sunshine duration at this location was measured to be about 11 h per day. However, potential sunshine duration is only 8 h per day (9.00 am - 5.00 pm) based on higher solar intensity.

Solar Tunnel Drier (STD)

An STD (Fig. 1) as a community model solar greenhouse drier [4 m(W) × 10 m(L) × 3 m(H) at centre] was designed and constructed (capacity to dry 5000 coconuts per batch) at Negamam village using locally available materials. Semicircular portion of drier was covered with UV (200 μ) stabilized polyethylene film.

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Fig.1—Drying of copra inside solar tunnel drier

No post was used inside greenhouse, allowing a better use of inside space. Two exhaust fans (diam, 30 cm) one at front and another at rear end, were fixed. Three exhaust vents with adjustable butterfly valves were provided at roof top. Inside drier, cement flooring was coated with black paint to improve its performance. STD is provided with metallic racks for keeping coconuts in layers for drying.

Instrumentation

Calibrated thermocouples (8 numbers, PT 100, uncertainty ± 0.5°C) were fixed at different locations inside drier to measure air temperature. Humidity sensors (4 numbers, uncertainty ± 1%) were placed at different locations inside drier for measuring air humidity. Ambient humidity was calculated based on measured values of wet and dry bulb temperatures, using two calibrated thermometers, one covered with wet cloth. A solar intensity meter (Delta Ohm, Italy; uncertainty, ±10%) was used to measure instantaneous solar radiation. All temperature sensors, humidity sensors and solar intensity meter were connected to a computer through a data logger (Simex, Italy). Air velocity at drier exit was measured by using a vane type thermo-anemometer (Equinox, Germany; uncertainty, ± 0.5%). A digital electronic balance (Precision scientific company, India; capacity, 1 kg; uncertainty, ± 0.1%) was used for weighing samples.

Experimental Procedure

Experiments were conducted during January - March 2009 under meteorological conditions of Pollachi, India. Matured and good quality nuts were split into two halves crosswise to remove coconut water. Initial moisture content was calculated by taking 10 different samples from different locations. Broken coconuts along with shell were loaded over trays (porosity 90%) of drier unit. Then, exhaust fan was switched on to exhaust initial high humid air. Solar intensity, ambient wet and dry bulb temperatures were measured every 1 h interval till end of drying. After attaining 40% moisture content, copra kernels were scooped from shells and dried further to reach final moisture content of 8%. Finally, copra was graded according to BIS: 6220 - 1971.

Data Analysis

Determination of Moisture Content

Samples (10 g) were chopped from randomly selected 5 cups and kept in a convective electrical oven, maintained at 105 ± 1°C for 5 h. Initial (m_i) and final mass (m_f) at time t of samples were recorded using electronic balance and repeated every 1 h interval till end of drying. Moisture content on wet basis (M_{wb}) is defined as

$$M_{wb} = (m_i - m_f)/m_i \quad \ldots(1)$$

where, m_i and m_f are initial and final weight of samples respectively.

Table 1—Grading of copra

S. No.	Characteristics	Requirements MC Grade 1	MC Grade 2	MC Grade 3
1	Impurities, % by wt, *Max*	0.5	1	2
2	Mouldy cups, % by count, *Max*	4	8	10
3	Black cups, % by count, *Max*	5	10	15
4	Wrinkled cups, % by count	5	10	15
5	Chips, % by wt, *Max*	5	10	15
6	Moisture content % by wt, Max	6	6	6
7	Oil content (on moisture free basis), % by wt, *Min*	70	68	66
8	Acid value of extracted oil, *Max*	2	4	10

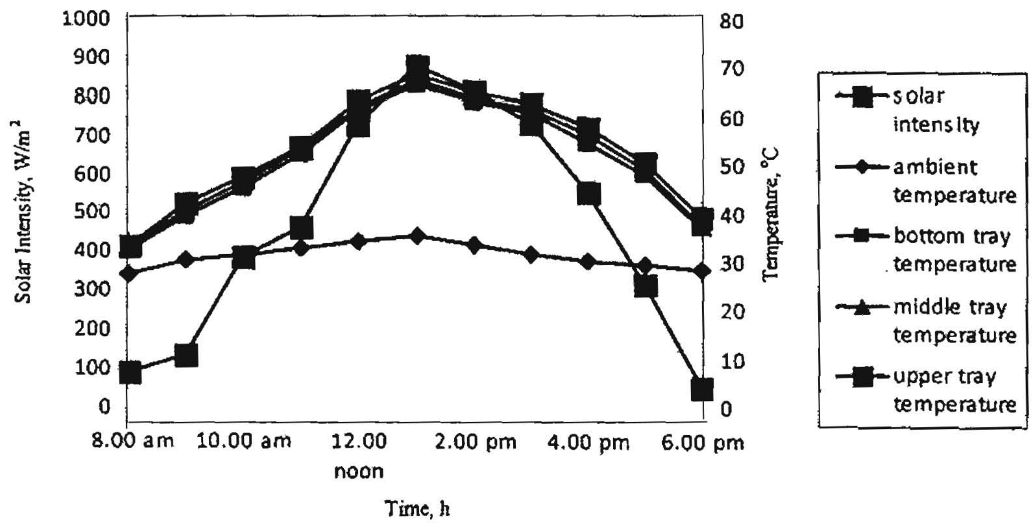

Fig.2—Variation of solar intensity and temperature with time

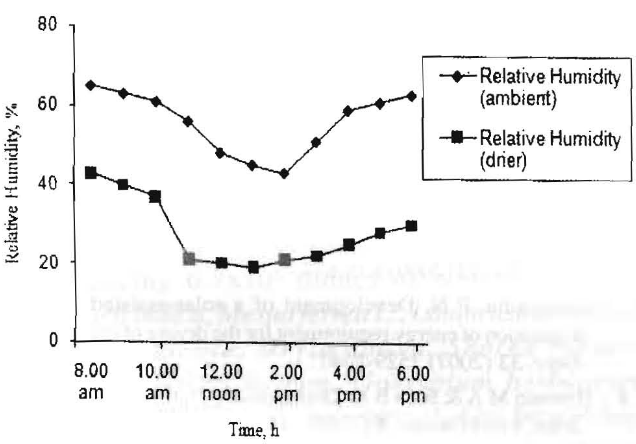

Fig.3—Variation of ambient and drier relative humidity

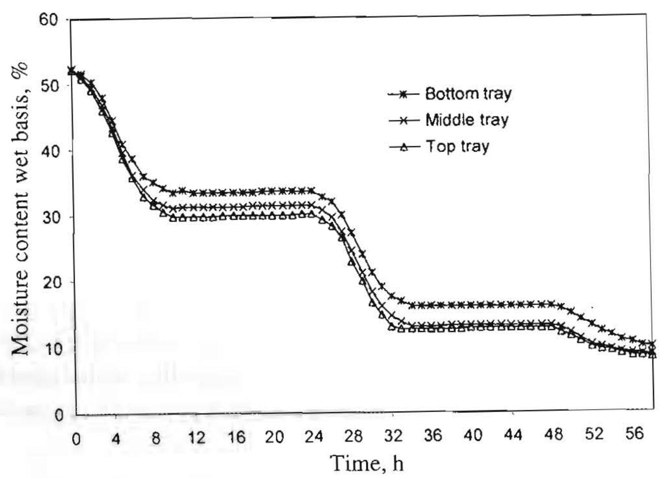

Fig.4—Variation of moisture content with time

Determination of Drier Thermal Efficiency

Thermal efficiency of STD was estimated as

$$\eta_{th} = \frac{m_w h_{fg}}{A * I} \times 100 \qquad \ldots(2)$$

where, η_{th}, drier thermal efficiency; m_w, mass of water evaporated in time t = $m_i - m_f$; h_{fg}, latent heat of vaporization of water (kJ/kg); A, area of STD in m^2; and I, solar intensity in W/m^2.

Grading of Copra

Grading of copra was done after drying according to BIS: 6220-1971 by randomly selecting 100 cups (Table 1). Chips in bulk sample were separated and weighed (% by wt). Wrinkled cups were separated and calculated their number as percentage of cups constituting bulk sample. Number of mouldy and black cups were counted and reported as percentage. Grading of copra under Milling Copra Grade 1 (MCG1) was found better in STD (84.66%; range, 83-86%) as compared to OSD (53.00%; range, 52-54%). Average thermal efficiency of STD was found to be 20%.

Results and Discussion

Maximum solar intensity recorded was 857 W/m^2 (Fig. 2). Maximum temperature recorded in upper tray

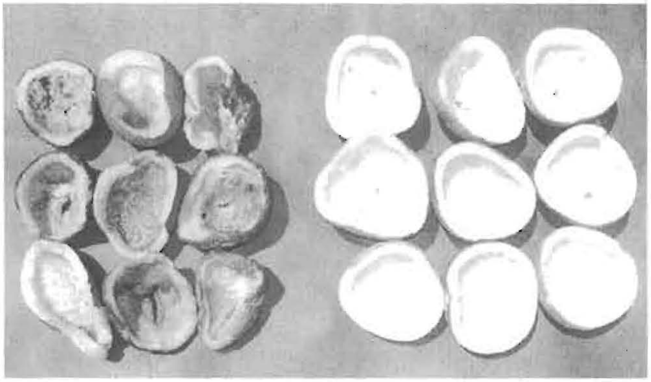

Fig. 5—Comparison of copra quality in: a) open sun drying; and b) solar tunnel drying

was 67°C during peak sunshine hours and temperature reduced to 35°C during off sunshine hours and nights. Average RH of air inside STD was 30% as compared to average RH of ambient air (60%), indicating that air inside STD had high drying potential as compared to ambient air (Fig. 3). Air velocity varies (0.3 - 1 m/s) during drying period under natural convection. Average moisture content (Fig. 4) of coconut was reduced from 52% to 8% after 52 h under half load and 57 h under full load in STD. Moisture removal rate from coconut was high during initial stage of drying. Reduction in moisture content of copra at the top tray was 2-3% higher than that of bottom tray. STD is found to produce high quality white copra as compared to OSD (Fig. 5), possibly due to less humid drying environment provided by STD in absence of microbial activity. High quality white copra produced in STD fetches more market prices for coconut farmers.

Conclusions

Developed natural convection solar tunnel dryer is capable of drying copra as well as most of agricultural products under climatic conditions of Pollachi. Moisture content was reduced from 52% to 8% in 52 h under half load and 57 h under full load conditions. Drier produced high quality copra (milling grade 1, 85%). Average thermal efficiency of solar tunnel drier was estimated 20% and pay back period of solar tunnel drier was only 5 months.

Acknowledgement

Financial support by DST, Govt of India, New Delhi for this study is gratefully acknowledged.

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