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Research Article

COPRA DRYING IN SOLAR AND BIOMASS INTEGRATED DRYER

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Abstract- Solar and biomass are the two sources of renewable energy highly suitable for drying application. Drying using solar energy is the traditional method but this method has a downside of interrupted during off-sunshine hours like rainy season, cloudy weather and night time. Hence, a combination of solar and biomass energy for drying is experimentally analyzed in this paper for copra drying. This article presents the experimental study on drying characteristics of copra drying in solar tunnel dryer integrated with biomass hot air generation system. It facilitates drying to continued under all weather condition and overcomes the limitations of conventional drying methods. The total drying time for drying copra from its initial moisture content of 108.3 per cent (d.b) to a final moisture content of around 5.26 per cent (d.b) was 48 hours. The drying characteristics curves were analyzed and the moisture reduction was uniform throughout the drying period and drying rate showed a peak during initial drying hours because of high moisture content in the fresh coconut and reduced gradually as the time passes. The moisture ratio decreases as the drying time increases. Hence, the solar and biomass integrated drying system reduced the drying time from 5 to 7 days in conventional open sun drying method to 2 days with improved quality of dried copra.

Keywords- Solar, Biomass, Copra, Coconut Husk, Integrated dryer.

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Introduction

Cocos nucifera (Coconut) is the most important commercial crop in various districts of Tamil Nadu. Copra is one of the major product processed from coconuts. Of the world production of coconut, more than 50 per cent is processed into copra. The dried kernel or copra is the richest source of edible oil and a by-product coconut oil cake, a source of vegetable protein used as an ingredient for livestock feed. The fresh coconut is converted to copra through various processes like husk removal, breaking into two, shell removal and drying. Drying is the oldest and most common post harvest technology in copra producing industries. Drying is basically a heat and mass transfer phenomena, which results in moisture reduction by evaporation under controlled condition [1]. It is achieved by means of supplying energy i.e., by passing hot air through the surface of the products thereby the product gets heated up and releases the moisture to attain the desired moisture content. Coconut has an initial moisture content of 55 per cent (w.b), which is to be reduced to 6 per cent (w.b) for obtaining good quality copra [2]. In order to get good quality copra for export or oil production, coconuts need to be dried to its final moisture content as fast as possible. Otherwise, the growth of microorganisms will take place as a result of the low ambient temperature and the high relative humidity and often leads to severe deterioration in quality.

There are two conventional methods widely used for drying copra. The first method is kiln drying, which has the problem of smoke deposits that may form polycyclic aromatic hydrocarbons in the copra. The coconut is dehusked, split in to half and kept in a kiln, where the coconut husk or any other fuel combusted to produce the heat required for drying coconut. This is the most common method involves the use of a kiln with direct heat and smoke generated from the combustion of fuel such as husks, shells and firewood. The second method is open sun drying, which has the major problem of slow and intermittent drying, no protection over rain, contamination by dust, birds, insects and microbial contamination, undesirable quality change and non uniformity of dried products [3]. The coconut is split in to half by drained of water and the halved nuts left with the meat facing the sky for drying. After two days the meat can be removed from the shell easily and again kept for drying process, which is completed after five to seven days [4, 5].

Solar energy is one of the most promising renewable energy sources. In order to overcome the problems of open sun drying, the solar dryer was first developed by Everitt and Stanley in 1976 [6]. Drying using solar dryers is the method of controlled sun drying to enhance the quality of dried products. But solar dryers too takes more time as the solar energy availability is seasonal. Therefore, solar dryers alone is not a solution for the above problems in copra production. Solar dryers combined with biomass hot air generation system for drying during off-sunshine hours reduces the drying time and improves the quality of the dried copra.

The main objective of this present work is to experimentally study the drying characteristics of copra in solar and biomass integrated drying system, which is an integrated system of solar tunnel dryer (STD) and biomass hot air generation system (BHAGS).

Materials and Methods

As the performance trials were carried out at Renewable Energy Park, Department of Bioenergy, Tamil Nadu Agricultural University, Coimbatore, Coconuts were procured from industry in nearby village of Coimbatore district. The industry is a coconut oil producing industry with daily processing capacity of 20,000 coconuts.

Solar and biomass integrated drying system

The solar and biomass integrated drying system for drying copra consists of solar tunnel dryer (STD) and biomass hot air generation system (BHAGS) and is shown in [Fig-1].

The solar tunnel dryer of 18.0 m x 3.75 m x 2.0 m consists of a semi cylindrical pipe structure covered with ultra violet stabilized Polyethylene sheet and oriented towards east - west direction, as maximum exposure to sunlight is possible. The solar radiation is transmitted through the UV sheet, which has the property of transferring short-wave radiations and opaque for long-wave radiations. Therefore, the radiation is trapped inside the dryer and increases the temperature of the dryer during sunshine hours.

The biomass hot air generation system consists of combustion chamber for burning biomass or agro residues and gas to air heat exchanger for exchanging heat between hot flue and fresh air. The heat from hot flue gas transferred to the fresh air and the hot air obtained from biomass hot air generation system is forced to the solar tunnel dryer to facilitate night time continuous drying of copra. The blower of 3 HP was installed to force the hot air from BHAGS to STD.

Fig-1 Solar tunnel dryer integrated with biomass hot air generation system installed at Department of Bioenergy, Tamil Nadu Agricultural University, Coimbatore

Instrumentation

The temperature and relative humidity inside STD was measured at 24 points by diving the total length of solar tunnel dryer into 4 zones with each zone having 6 temperature points. it was measured using temperature and relative humidity transmitter having this film sensor for temperature with accuracy 0.3°C and thin film polymer capacitor for relative humidity with accuracy ± 2 per cent. The temperature of flue gas and hot air in BHAGS was measure using k-type thermocouple. Power input to the blower was measured with an 3 phase power analyzer. The air velocity inside the dryer was measured using electronic hot wire anemometer. The weather parameters such as ambient temperature and ambient relative humidity, wind velocity, wind direction, solar radiation and rainfall details were measured using an automatic weather station installed at the project location.

Experimental Procedure

The coconuts with initial moisture content of 108.3 per cent (d.b) were loaded in the tray system inside STD and the experiments were conducted using solar energy (STD) from 8:00 am to 5:00 pm and biomass energy (BHAGS) from 5.00 pm onwards. At the time of using BHAGS, the STD acts as a drying chamber, which received the required heat from BHAGS. The temperature of the samples in the solar dryer, biomass hot air generator, distribution duct and the ambient temperatures were measured at every 15 minutes interval. After the moisture content was reduced to 40 per cent, the copra kernels were scooped from the shells and dried further without shells. During night time, biomass energy was used simultaneously for performing continuous drying. Drying experiments were continued till the moisture content was reduced to the required level.

Drying characteristics

The plots of moisture content versus drying time, moisture ratio versus drying time and drying rate versus drying time are otherwise known as drying characteristics curves [7]. The parameters for plotting the drying characteristic curves were calculated as given below.

Dry basis moisture content

The moisture content of coconuts in dry basis was determined as follows:

$$M_{db} = \frac{W_m}{W_d} \times 100 \qquad \text{------------- [1]}$$

where M_{db} is the moisture content, per cent (d.b), W_m is the mass of moisture of the sample, kg and W_d is the bone dry mass of the material, kg.

Drying rate

The drying rate for coconuts was determined as follows

$$R = \frac{Q_{rem}}{t \times W_d} \qquad \text{----------------- [2]}$$

where R is the drying rate, g of moisture removed per hour per 100 g of bone dry matter, Q_{rem} is the quantity of moisture removed, g, t is the drying time, h and W_d is the weight of dry matter present in the sample, g.

Moisture ratio

The moisture ratio was calculated as

$$MR = \frac{M - M_e}{M_o - M_e} \qquad \text{--------------- [3]}$$

where, MR is the moisture ratio, dimensionless value, M is the moisture content at time t, per cent (db), M_o is the initial moisture content, per cent (db) and M_e is the equilibrium moisture content, per cent (db).

For longer drying period, the equation can be reduces to:

$$MR = \frac{M_t}{M_o} \qquad \text{------------------ [4]}$$

Results and Discussion

The performance of solar tunnel dryer integrated with biomass hot air generation system was studied with coconuts. The coconuts were split in to two and dewatered before drying process. For the first 8 h, i.e., during day time the source of heat was solar energy only. In evening, starting at 5:00 PM, a measured quantity of coconut husk at the rate of 15 – 17 kg h^{-1} was burnt in biomass hot air generation system to supply heat during night hours to maintain the temperature inside solar tunnel dryer. During the STD trails, the air opening at the bottom of the solar tunnel dryer was opened manually to create natural draft and increase drying rate, whereas the openings were closed during the operation of BHAGS in order to avoid the entry of humid air from atmosphere, which reduces the hot air temperature thereby drying efficiency. The experiment was continued for the consecutive days.

The drying was continued till the required moisture content of the kernel was attained. The time required for drying till the optimum moisture was estimated to be 48 hours (excluding processing time for coconuts). It was reported that the drying time varies from 40 to 45 h for the solar and biomass combined mode [8]. This confirmed the results of present study. During experiment, the ambient temperature varied from 23.5 °C to a maximum of 30.8 °C. The ambient relative humidity varied from 84 per cent to 54 per cent during peak sunshine hours. The solar intensity varied from 2 W m^{-2} to 900 W m^{-2}. The wind speed was varied from a minimum of 0.4 m s^{-1} to maximum of 2.2 m s^{-1}.

Effect of temperature distribution during drying in integrated mode

[Fig-2] showed the temperature distribution outside and inside the drying chamber during STD and BHAGS integrated mode. The temperature distribution throughout the length of the tunnel dryer was measured at four zones. The overall maximum and minimum temperatures during the drying process was found to be 63 °C and 20 °C for zone 1, 58 °C and 23 °C for zone 2, 58 °C and 26 °C for zone 3 and 53°C and 24 °C for zone 4 respectively. The maximum and minimum temperature during operation of dryer under solar tunnel dryer mode only was 63 °C and 21 °C for zone 1, 58 °C and 25 °C for zone 2, 58 °C and 26 °C for zone 3 and 53°C and 24 °C for zone 4. Similarly, the maximum and minimum temperature during operation of dryer under biomass hot air generation system mode was 58 °C and 20 °C for zone 1, 54 °C and 23 °C for zone 2, 57 °C and 26 °C for zone 3 and 49°C and 24 °C for zone 4. It was cleared that the temperature distribution during solar tunnel dryer mode and biomass hot air generation system mode is having a minimum variation of 2 – 4 °C. There was not much variation in temperature between various zones. This confirmed that the design had very good air flow pattern and temperature distribution throughout the length of the solar tunnel dryer both during STD mode and BHAGS mode.

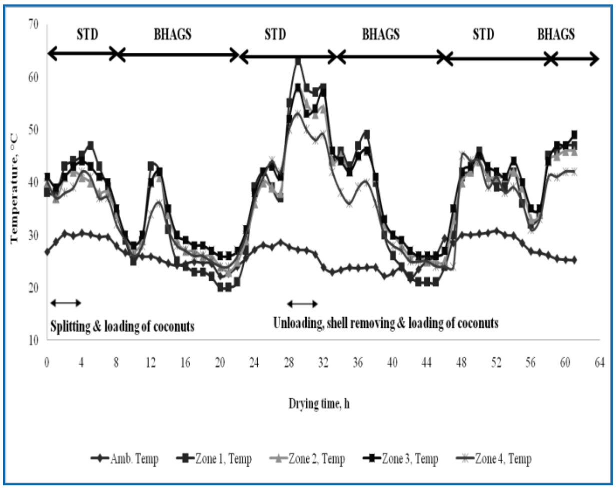

Fig-2 Variation of temperature in different zones of solar tunnel dryer integrated with biomass hot air generation system

Table-1 *Drying characteristics of solar and biomass integrated system*

Drying time, (h)	Moisture removed, (g)	Moisture (d.b) (%)	Drying rate (g/g h)	Moisture ratio
0	0	108.30		1.000
2	40	101.05	0.042	0.933
4	85	91.58	0.045	0.846
6	125	83.16	0.044	0.768
8	140	80.00	0.037	0.739
10	160	75.79	0.034	0.700
12	180	71.58	0.032	0.661
14	200	67.37	0.030	0.622
16	220	63.16	0.029	0.583
18	240	58.95	0.028	0.544
20	260	54.74	0.027	0.505
22	280	50.53	0.027	0.467
24	300	46.32	0.026	0.428
26	320	42.11	0.026	0.389
28	340	37.89	0.026	0.350
30	360	33.68	0.025	0.311
32	375	30.53	0.025	0.282
34	400	25.26	0.025	0.233
36	415	22.11	0.024	0.204
38	434	18.11	0.024	0.167
40	450	14.74	0.024	0.136
42	460	12.63	0.023	0.117
44	475	9.47	0.023	0.087
46	485	7.37	0.022	0.068
48	495	5.26	0.022	0.049

Drying characteristics of copra drying in integrated mode

The drying characteristic curves such as moisture reduction, drying rate and moisture ratio of coconut by solar and biomass integrated drying were presented in [Fig-3(a)], [Fig-3(b)] and [Fig-3(c)] respectively and the data were given in [Table-1]. The time required to dry coconuts from initial moisture content of 108.3 per cent (d.b) to a final moisture content of around 5.26 per cent (d.b) was 48 hours (excluding splitting, shell removing, loading and unloading time). The moisture content versus drying time for coconuts was presented in [Fig-3(a)], which showed that the moisture removal was uniform during drying process. This may be because of maintaining uninterrupted environment throughout the drying period. It showed that moisture removal was less during the beginning and end of everyday and it was rapid in the afternoon around 1:00 PM to 3:00 PM.

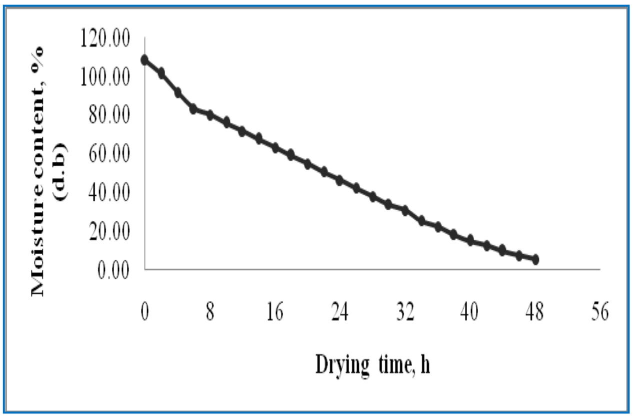

Fig-3(a) Moisture reduction curve in solar and biomass integrated drying of copra

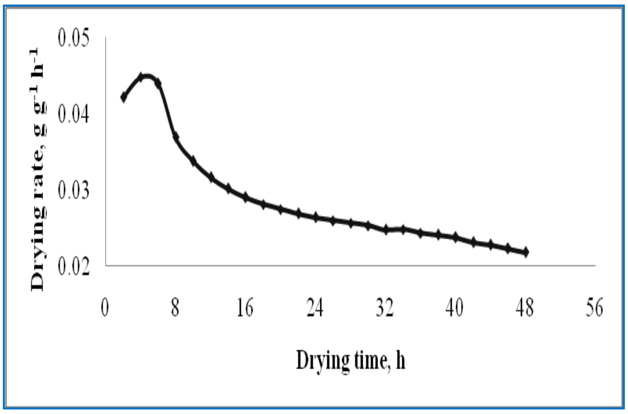

Fig-3(b) Drying rate curve in solar and biomass integrated drying of copra

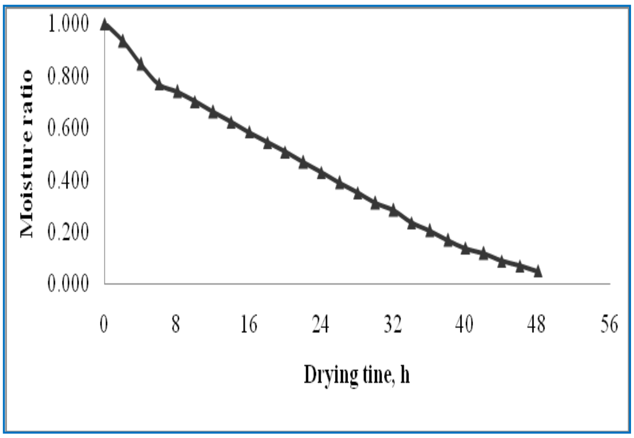

Fig-3(c) Moisture ratio with drying time in solar and biomass integrated drying of copra

The curve for drying rate versus drying time recorded only one peak level of drying during the total drying period of 48 hours. The maximum drying rate of 0.045 g of moisture per g of dry matter per hour recorded during first day of drying process and minimum drying rate was reached at the end of drying period as 0.022 g of moisture per g of dry matter per hour. At the beginning of drying process, when the moisture content was high, drying rate was also very high and as the moisture content approached the equilibrium moisture content, drying rate also reduced. As it would be expected, during the initial stages of drying there was a rapid moisture removal from the product (slope of moisture curve in [Fig-3(b)] was much higher in the beginning of drying process) which later decreased with increase in drying time. The moisture ratio versus drying time for drying of coconuts was presented in [Fig-3(c)], which showed that the moisture ratio of coconuts reduced as the drying time increased.

Conclusions

The analysis of drying characteristics from the experiment indicated that the biomass hot air generation system was found to be a successful solution for drying copra in continuous drying mode without interruption. The solar and biomass integrated drying system thus reduced the drying time from five to seven days in conventional open sun drying method to two days (around 70 per cent) with improved quality of dried copra. The drying characteristics such as moisture reduction was found to be uniform throughout the drying period, which showed that the constant environment is maintained inside the drying chamber throughout the drying period. Similarly, drying rate showed a peak during initial drying hours because of high moisture content in the fresh coconut and reduced gradually as the time passes and stabilized at the end of drying period. The moisture ratio also found to be decreased as the drying time increases. Hence it can be concluded that this type of solar and biomass integrated drying system is more suitable for copra producing industries to avoid the limitations of slow and intermittent drying with good quality copra.

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Abbreviations

d.b - dry bulb
w.b - wet bulb
HP - Horse Power
STD - Solar Tunnel Dryer
BHAGS- Biomass Hot Air Generation System
°C - degree Celsius
kg - kilogram
g - gram
h - hour
s - second
W - Watt
m - metre

Author Contributions

1. Corresponding Author [G SARAVANAPRIYA[1]*, R Mahendiran[2]] designed, developed and installed the system and carried out the experimental trials and data analysis. Draft the manuscript and revised critically and approved the research paper for publication.
2. Authors [S Kamaraj[3]] supervised and provided guidance and substantial contributions to design the work, interpretation of data and approved the draft for publication.
3. Author [C Karthik[4]] managed literature survey, assisted in data analysis and drafting of manuscript and approved for publication.

All the authors contributed equally to this work.

Conflict of Interest: None declared

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