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Design and development of an indirect heating type shell fired copra dryer

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Abstract

A shell fired copra dryer was designed and developed to dry coconut in 24 h which works on indirect heating and natural convection principles using coconut shell as fuel. The capacity of the dryer developed was 1000 nuts per batch. The drying air temperature in the drying chamber was 80°C. The unique burner designed generated heat for 5 hours without tending and the heat is retained for one more hour. No electrical energy is used in this dryer making it farmer friendly. Once the fuel is charged it produces heat for 6 hours thereby allowing the farmer to do other works as compared to other dryers where in fuel is loaded once in 15-20 minutes. Smoke does not come into contact with the copra; hence the copra produced is of good quality. About 100 grams of shell charcoal is also produced during the final phase of heating.

Key words: Copra, shell, coconut oil

Introduction

In India, coconut is broken transversely into two cups and is then generally sun-dried. About seven days are needed to reduce the moisture content to 5-6 %, (w.b) from the initial 45 - 55%, (w.b). During rainy season, when conventional practice of sun drying is not possible, drying by artificial method is the only possible solution for processing the produce. The existing direct type kiln dryers are not desirable as the product becomes inferior in quality due to smoking and improper drying (Grimwood, 1975). Copra which has been smoke dried using coconut husk or wood is often contaminated with poly cyclic aromatic hydrocarbon.The common quality defects are high Free Fatty Acid (FFA) content, extensive fungal contamination, notably by *Aspergillus spp.* which may produce carcinogenic aflatoxins, high Poly cyclic Aromatic Hydrocarbon (PAH) content particularly (Drew *et al.,* 1993). Smoke contamination can be avoided by using heat exchangers to heat the drying air indirectly (Arseculeratne, *et al.,* 1976). Coconut oil and copra cake thus produced can contain unacceptably high levels of aflatoxin (Conning and Landsdown, 1983; Samarajeewa and Arseculeratne, 1983). At present, the copra industry is beset with quality and technical problems that resulted to very low prices of copra-related products in the world market. Many of these difficulties stemmed from technical problems of inappropriate drying conditions and poor dryer design. Indirect type dryers are available but require frequent fuel loading or use electrical energy which is very costly. In the small holder's copra dryer developed by CPCRI (Patil, 1983) the drying air temperature is only 60 °C there by increasing the drying time. Fuel is also to be loaded every fifteen minutes forcing the user to remain near the dryer. Design of a dryer that does not require frequent fuel loading and also could reduce the drying time is reported here.

Materials and Methods

The dryer parameters like size of the drying chamber, size of burner, shape of heat exchanger, ventilation holes etc. have been designed taking into consideration, various factors like bulk density, psychrometric and heat transfer principles. This dryer uses only coconut shell, as fuel and no other fuel can be used. The dryer is designed to hold 1000 coconuts. The

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factor of safety is greater than two which indicates that during de-shelling operation one person can sit inside the dryer and separate the shell from kernel.

The dryer consists of a drying chamber, a unique burning chamber, a heat exchanger and ventilation holes. This dryer was fabricated using locally available materials such as bamboo sheet, Galvanized iron sheet, Mild Steel angle and fire resistant plywood. The contact area (sides) with copra is provided with heat resistant plywood. The design drawing of dryer and burning chamber is shown in Fig. 1 and 2.

Description of the dryer

The overall dimensions of the dismantling type rectangular frame were 2.25 m (L) x 1.5 m (B) and 1.5 m (H) using 40 × 40 × 3 mm equal angle iron and 20 x 5 mm mild steel flat as supporting frame. The rectangular structural frame was divided into four parts namely (i) Air inlet chamber (20 cm from the ground level), (ii) heating chamber (60 cm height from the ground level), (iii) plenum chamber (30 cm above the heating chamber) and (iv) drying chamber (30 cm above the plenum chamber) and it requires a housing shed of 3 m^2 size. The dryer as well as the burning chamber have rectangular cross section.

Air inlet chamber

The dryer was fabricated with 20 cm ground clearance. This was fabricated using 20 x 5 mm M.S flat and 16 gauge G.I. sheets on all the sides for the fresh air to enter with the help of movable doors hinged on the main frame using 75 mm M.S. hinges. Hinges were provided for regulating the supply of fresh air.

Heating cum heat exchanging chamber

Above the air inlet opening, the heating chamber was provided to burn the coconut shells. The heating chamber was divided into two separate compartments of 1.40 m (L) x 0.90 m (B) x 0.60 m (H) and was fabricated by using 16 gauge. G.I sheet. Two trolley type fuel holding trays made of 20 x 25 x 5 mm M.S angle and 16 gauge G.I sheet were provided to load the fuel (coconut shell). The heating cum heat exchanging chamber was placed at a vertical inclination of 4 degree for smooth flow of flue gases to the chimney. Two separate chimneys have been provided for proper escape of flue gas and smoke. The height of the chimney was 1.5 m for better draft. Butterfly valves were provided in the exhaust pipes. A separate smoke chamber was fabricated so that smoke does not accumulate in the burning chamber and for better natural draft.

Plenum chamber

The empty space provided above the heating chamber is known as plenum chamber. A door has been provided which was made of 20 x 5 mm M.S. flat. The door is hinged to the main frame by using 3 nos. of 75 mm M.S. hinges.

Drying chamber

The top portion of the dryer is known as drying chamber. The weld mesh for stacking copra is made of 10 gauge, 25 ×25 mm weld mesh. Wire mesh was also provided to avoid the falling of small copra pieces and coconut pith on the heating chamber and for even distribution of hot air in the drying bin. On one side of the drying chamber a door has been provided for easy loading

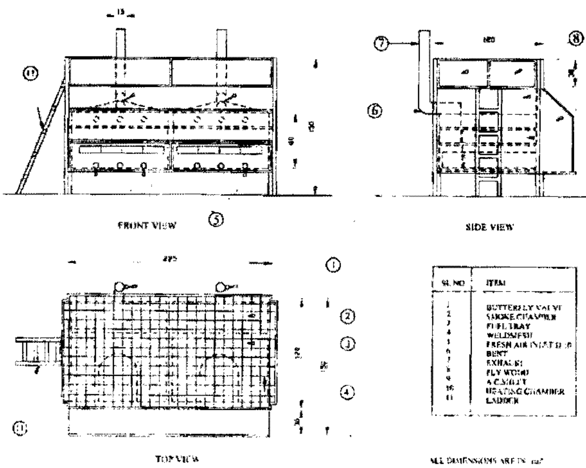

Fig. 1. Design drawing of shell fired copra dryer

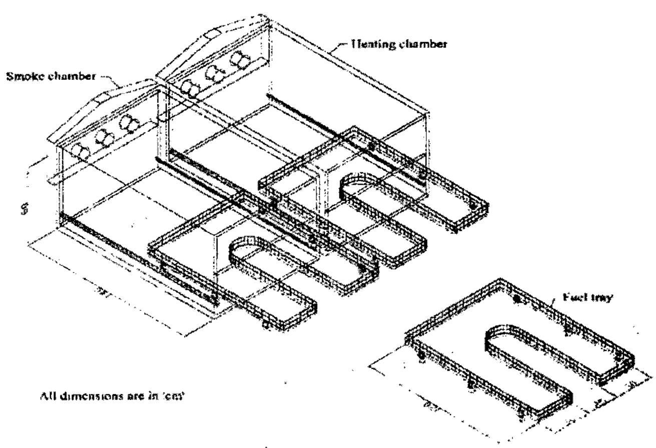

Fig. 2. Design drawing of burning chamber of shell fired copra dryer

and unloading of coconuts. The sides of the heating chamber are covered by 6 mm thick bamboo plywood sheet.

Evaluation of the dryer

The dryer was tested for production of copra from January 2003 to January 2004. Hourly observations of various parameters like drying air temperature at the corners and at the centre were recorded using a thermometer. Moisture content was recorded on hourly basis using the moisture meter developed by Madhavan K (1985). The relative humidity was measured using Barigos hygrometer. For making copra, the coconuts were broken into two halves and kept inverted for 4 - 5 minutes in order to drain the water. After the coconut water was completely drained, the cups were stacked in the drying chamber, layer by layer in such a way that in the first two layers, the kernels faced upwards and in the subsequent layers, the kernels faced downwards. The cups in adjacent layers were stacked in a brick-laying-fashion, one overlapping the other. Drying was carried out continuously for 24 h by firing the burner four times at intervals of approximately 6 h. The quantity of fuel consumed was 640 half shells in case of full load. For the initial trial shell has to be procured. For the subsequent drying the shell which is removed from copra can be used. Hence, no additional charges towards fuel is incurred. The main advantage of this type of dryer is that once the fuel is charged the farmer can do other unit operations for 6 hours. The total drying time is 24 h. Since smoke does not come into contact with the copra the quality of copra obtained is very good. The thermal efficiency of the drying was calculated using the formula as stated below (Singh *et al.,* 1999).

$\eta =$

Where,

η = Thermal efficiency of the dryer, %

M_o = Initial moisture content (%, w.b.)

M_f = Final moisture content (%, w.b.)

φ = Quantity of the final dried product at *Mf* moisture content kg.

= Latent heat of vaporization in kcal/kg.

= Quantity of fuel used in kg.

= Calorific value of fuel used in kcal/kg.

The latent heat of vaporization is assumed to be 540 kcal / kg and the calorific value of shell is assumed as 3500 kcal/kg. The dryer performance data is presented in Table -1.

Results and Discussion

In assessing the performance of the dryer, (i) Air temperature, (ii) Kernel drying rate, (iii) Product quality, and (iv) Drying cost were evaluated.

The dryer developed requires eighty half shells in each tray to make one row. The coconut shells were interlocked and laid on the tray. The hollow end of the row of shells was ignited (a little kerosene being added to help initial burning). When the shells begin to burn well and without smoke, the tray was pushed inside the heating chamber. The shells burn uniformly by the incoming air for which ventilation holes is provided on the door. The number of holes required was standardized based on tests conducted. Additional ventilation door was provided with provision to open and close in case of necessity and to retain the heat once the shells were burnt completely.

Firing the dryer

Each fuel tray produced heat for 6 h with a temperature of about 80 - 82 °C. Generally after about 6 h, when the temperature drops below 60 °C, the fuel trays were removed from the dryer, cleaned and reloaded with fuel, refired and replaced in to the respective burning chambers. This higher temperature ensures faster

Table 1. Copra dryer performance data

Sl.No	Produce	No. of nuts	Average ambientair temperature°C	Drying air temperature °C	Exh®aust air temperature °C	Average initial moisture content% d.b.	Average final moisture content, % d.b.	Total drying time, h	Fuel used	Quantity of fuel used, kg	Quantity of final product, kg	Thermal efficiency, %
Test-1	Copra	1000	33.4	72.4	65.1	90.146	6.20	22	Shell	63	175	26.48
Test-2	Copra	1000	32.2	73.2	66.2	88.342	6.15	21	Shell	60	168	26.06
Test-3	Copra	1000	31.6	71.6	64.1	92.126	6.25	26	Shell	64	166	25.31
Test-4	Copra	1000	32.7	74.5	66.4	86.234	6.2	25	Shell	62	172	25.25
Test-5	Copra	750	31.3	75.6	68.4	87.243	6.2	28	shell	74	128	16.08
Test-6	Copra	500	32.1	81.4	74.5	89.142	6.25	32	shell	86	92	9.41

removal of moisture. About 4 loads of fuel were required to dry the copra to about 6.25 % d.b. The heat generated by burning of the fuel heated the heating chamber. The air above heating chambers got heated up and moved upwards through the layers of fresh coconut kernel and the hot air laden with moisture escaped from the top of the drying chamber in to the atmosphere, and fresh air entered through the ventilation door provided at the bottom. This phenomenon was carried out with the help of natural convection.

Effect of drying air temperature on drying time and moisture content of coconut in copra dryer

The moisture content of coconuts reduced exponentially as the drying time increased (Fig. 3). The percentage moisture content available was more in the case of coconuts placed in the top layer as compared to bottom layer at the drying air temperature of 80 °C for the same drying time. It took 22, 21, 26 and 25 h to dry coconut from the average initial moisture content of 90.14, 88.34, 92.12 and 86.23 to 6.25 % (d.b.), respectively in the four drying tests conducted. The average mean relative humidity of ambient air was 74.12, 72.56, 86.45 and 84.12 %, respectively in the four tests. The average time taken to reduce the moisture content from 89.21 % (d.b.) to 6.25 % (d.b.) was 23.5 h where as in the small holders dryer, it took 36 to 40 h there by reducing the total drying time by 12.5 to 16.5 h. Thus almost two batches of copra could be dried in the time taken by small holders dryer. In case of sun drying it took 6-7 days where as in this dryer copra can be dried in one day. Thus there is a saving of 6 days off time for the farmer during which he can attend to other works. Also to dry 1000 nuts the total area required is only 3 m^2 where as in case of sun drying it required a minimum of 12 m^2 open drying yard which is hardly available with the farmers under Kerala conditions.

The time recorded with newly developed dryer for drying copra were different from those reported in literature. Palmer (1968) and Dumalaun and Lozada (1982) reported a drying time of 18 to 20 h at drying temperature of 60 °C. Sreenarayanan *et al.* (1989) reported a drying time of 20 h in a mechanical dryer to reduce the moisture content from 50 to 7 % (w.b.) at a drying temperature of 65 °C. Patil (1983) reported a drying time of 36 - 40 h in small holder's copra dryer. Annamalai *et al.* (1989) reported average drying time of 33 - 37 h in a 1000 nut capacity natural convection dryer at an average drying temperature of 60 - 70 °C. Anonymous (1984) reported a drying time of 25-30 h in case of coconut dried in the I.R.H.O hot air copra dryer.

Brenndorfer *et al.* (1985) reported that the temperature, moisture content and the physical dimensions of coconut meat were the most important factors affecting the rate of moisture removal. The internal structure and composition of the coconut meat were also of importance. The age of the coconuts also affects drying. Coconuts stored for 2-3 months after harvest drastically reduces the drying time due to weight loss mainly because of decrease in water content. Anonymous (1984) reported that the drying time depends on the thickness of the layer of copra, its density, free circulation of hot air and fuel used. Singh *et. al.* (1999) reported a drying time of 24 h at an average drying air temperature of 75 °C for drying coconut in a kiln type dryer. Sudaria *et al.* (1996) reported an average drying time of 8.67 h in case of coconuts dried in improved farmer's direct type dryer.

Effect of drying air temperature on drying time and drying rate of coconut dried in copra dryer

The drying rate of coconut was 11.74 % d.b / h in the first hour and 3.19 % d.b / h in the final stage of drying at 80 °C drying air temperature (Fig. 4). It was

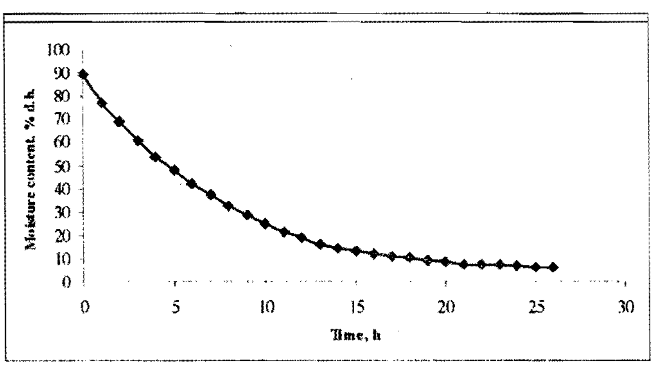

Fig. 3. Effect of drying air temperature on drying time and moisture content of coconut dried in shell fired copra dryer

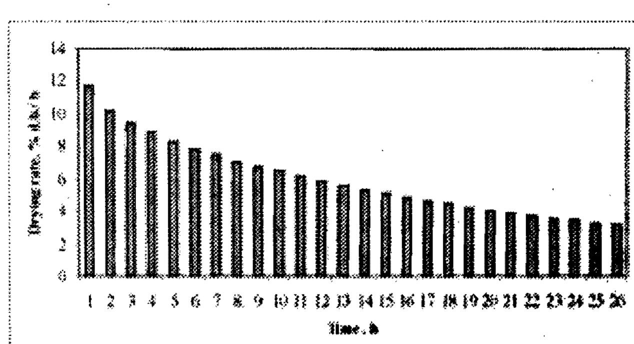

Fig. 4. Effect of drying air temperature on drying time and drying rate of coconut dried in shell fired copra dryer

due to the fact that the coconuts were having high moisture content in the order of 89.21 % (d.b.) at the beginning of drying and was only 6 to 6.25 % (d.b.) in the final stage of drying. From Fig. 4. it is clear that the constant rate period of drying was absent for the entire duration and the drying of coconut took place under the falling rate period at all the drying air temperatures. Rajashekaran *et al.* (1961) reported that at constant air velocity the drying of half coconuts in cup shape occurs entirely in the falling rate period.

The drying rate was more up to an average drying time of 11 h during which the drying rate ranged from 11.74 to 6.15 % (d.b.) / h for drying air temperature of 80 °C and after that the drying rate was 5.84 to 3.19 % (d.b.) / h. The reason may be that initially more moisture was lost in less time due to the availability of free moisture and at later stages the moisture available in coconut was less. Also, during drying, as moisture content decreased, the difference in vapour pressure between the inner surface of the kernel and out side drying air also decreases. Drying also causes shrinkage of outer cells. These two factors slow down the moisture diffusion. This may be the reason for decrease in drying rate during extended periods of drying. Moisture movement is known to be dependent on diffusion and capillary flow. From Fig. 4 it is clear that the constant rate period was totally absent during entire duration and the drying of copra took place under the falling rate period. Similar type of results was quoted by (Rachmat *et al.*, 1999) where the drying rate was 2 % (w.b.) / h at drying air temperature of 50 to 60 °C.

Performance of copra dryer

The performance data of the dryer is given in Table 1. From the Table 1 it can be seen that at full load the thermal efficiency was in the range of 25.25 to 26.4 % which indicates good performance of the dryer. Patil and Singh (1984) reported thermal efficiency of 42.65 % in case of electrically operated copra dryer. Annamalai *et al.* (1989) reported thermal efficiency of 18.7 to 23.4 % in a natural convection copra dryer. Singh *et al.* (1999) reported thermal efficiency of 31.25 % in case of copra dried in kiln type dryer. Rachmat *et al.* (1999) reported thermal efficiency of 10.72 % in case of pit type copra dryer. Thus in comparison, the thermal efficiency was found to be better as compared to other indirect type of dryers available. The thermal efficiency reduced to 9.41 % at 50 % capacity (Table 1) indicating that, the dryer should be used at full capacity only. The quantity of fuel consumed was 86 kg at 50 % load where as it was in the range of 60 to 64 kg in case of full load indicating that the hot air escaped into the atmosphere at a faster rate there by increasasing the quantity of fuel required.

Cost economics

The cost of the dryer was estimated to be Rs. 15,000.00. The cost involved to dry one kilogram of copra in the copra dryer was worked out and found to be Rs. 2.43. As the quality of copra dried in the copra dryer is found to be good, it would fetch higher price in the domestic as well as international market.

Conclusion

A shell fired copra dryer was developed to dry coconut in 24 h. The capacity of the dryer developed was 1000 nuts per batch. The drying air temperature in the drying chamber was 80 °C. The unique burner designed generated heat for 5 hours without tending and the heat could be retained for one more hour. No electrical energy is used in this dryer making it farmer friendly. Once the fuel is charged it produces heat for 6 hours thereby allowing the farmer to do other useful work as compared to other dryers where in fuel is loaded once in 15-20 minutes. Smoke does not come into contact with the copra; hence the copra produced is of good quality. About 100 grams of shell charcoal is also produced during the final phase of heating.

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