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Design of indirect heating copra dryer

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SUMMARY : Coconut plantation is abundant in konkan region of Maharashtra (India). Small landholders can improve their income through value added activities in downstream processing of coconut. One such activity would be to dry copra for preservation and subsequent oil extraction. Copra drying in konkan region is practiced largely through sun drying and chula drying. In both these drying methods, copra quality deteriorates significantly due to either open fire smoke, dust and mould growth in sun drying. There is need to have a natural convection indirect heating small mechanical copra dryer suited to the requirements of konkan farmers. This paper present design features of a natural convection indirect heating batch type small mechanical copra dryer. The dryer was fabricated from the materials such as M. S. sheet, M. S. angle, G. I. sheet, aluminum pipe, glass wool and asbestos rope etc. Components of dryer were drying chamber housing with two trays inside, heating chamber, burning cum heat exchanging unit *i.e.* furnace and chimney. The total area required for housing the dryer is 0.81 m^2. The capacity of the dryer is 50 kg coconuts per batch (to hold coconut halves 50 per cent (w.b.) moisture content) The cost of the dryer was worked out to be Rs.10,000/-. This is suitable dryer for drying of coconuts in rainy season.

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The world production of coconut is about 55 million tons. In India, coconut is cultivated in about 19, 10,000 ha mainly in southern states of Kerala, Karnataka, Tamilnadu, Andhra Pradesh and Maharashtra (Thampan 1998). Maharashtra occupied eleventh place in area and seventh place in coconut production. The total area under coconut cultivation in the Konkan region is about 16789 ha with production of 244.4 million nuts (Indian coconut journal, 2003).In the year 2006-07 India is highest coconut producing country in the world, it is about 15840 million nut annually (Anonymous,2008).

Dried copra is one of the major agricultural exports of konkan region practiced largely through sun drying and chula drying. The sun drying requires the drying cycle for a batch of copra is of 5 to 7 days, depending on the availability of the sun. As the drying cycle is long, this causes problem of dirt and dust accommodation on the surface of copra which deteriorate quality of copra. The konkan region of Maharashtra has more than 100 rainy days of the year and receives average rainfall 3000-4000mm (40-140mm/hr). Sun drying is impossible during rainy season. In Chula drying, as direct contact of smoke copra quality gets deteriorates.

To get the mould free copra during rainy season natural convection indirect heating small mechanical batch type copra dryer was demanded for konkan region of Maharashtra. By keeping all these points in view, natural convection indirect heating small mechanical batch type copra dryer was design at Agricultural Process Engineering Department of Dr. Balasaheb Sawant Konkan Krishi Vidypeeth Dapoli, Ratnagiri (M.S.).

EXPERIMENTAL METHODS

A dryer working on indirect heating natural convection principle. The dryer was designed in following components:

– Drying chamber
– Heating chamber
– Furnace
– Chimney

The various dryer parameters like size of drying chamber, heating chamber furnace, air flow rate, fuel requirement and height of chimney etc. were worked out based on psychrometric and heat transfer principles. The

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width of the dryer in relation with the diameter of the furnace has been standardized and it was found that the dryer width, furnace diameter ratio should be of the ratio 3:1 for better performance (Annamalai *et al.,* 2002). Assumptions required for design of the dryer are given in Table A. Coconut husk used as fuel.

Table A : Assumptions for design of copra dryer

Sr. No.	Parameter	Assumptions
1.	Initial moisture content of coconut (w.b.)	55 per cent
2.	Final moisture content of coconut (w.b.)	6 per cent
3.	Drying period of coconut, θ	25 hour
4.	Drying temperature of air, t_2	75 ºC
5.	Temperature in drying	65 ºC
6.	Temperature of exhaust, t_1	40 ºC
7.	Initial temperature of coconut, t_{ci}	27 ºC
8.	Final temperature of coconut, t_{cf}	65 ºC
9.	Specific heat of water, C_{pw}	1 kcal/kgºC
10.	Specific heat of coconut, C_{pc}	0.7 kcal/kgºC
11.	Latent heat of vaporization of water.	600 kcal/kg
12.	Calorific value of coconut husk, C_n	4500 kcal/kg.
13.	Weight of 100 coconuts halves, W	50 kg
14.	Thermal efficiency	25 per cent
15.	Heat exchanger efficiency, η_{ex}	35 per cent
16.	Combustion efficiency, η	65 per cent
17.	Density of coconut ρ_c	450 kg/m^3

Design parameter :

On the basis of assumptions the following considerations were put in the design of the dryer and drying system.

Design of drying chamber :

The drying chamber was designed based on the amount of coconut to be dried, density of coconut and the thickness of bed.

The floor area required for drying coconut was calculated as:

where,

A_d = Area of drying chamber, m^2

Mass of coconut = 50 kg

Thickness of bed = 0.15 m

Density of coconut = 450 kg/m^3

$$Ad = \frac{50}{450 \times 0.15} \qquad (1)$$

$$= 0.7407$$

$$\approx 0.75 m^2$$

The area of drying chamber = 0.75m^2

The thickness of bed for drying was considered by considering the geometric mean diameter thus the height of the cup was half of the geometric mean diameter. Thus, considering the height of cup was 9 cm and considering the free space for air distribution the total bed thickness for drying was considered as 15 cm. The two trays having dimensions 0.1m × 0.04 m was designed for drying chamber. The tray was made of perforated G.I. sheet having 0.02 m diameter. The overall dimensions of the drying chamber were 1.25 m (Length), 0.65 m (Breadth) and 0.60 m (height). Two doors having dimensions are 534mm (Length) and 530 (Height) were provided to the drying chamber for easy loading and unloading of the material. The drying chamber was connected with heating chamber through angle just above the heating chamber.

Airflow rate:

The rate of airflow required for drying can be calculated by making heat balance equation from the psychometric chart. Heat loss was assumed 30 per cent (Chakraverty, 2000).

$$Q_a = G x V_1 \qquad (2)$$

where,

Q_a = Airflow rate

V_1 = Humid volume in at air ambient air temperature (27ºC) and at 90 per cent R.H. from psychometric chart.

= 0.86 m^3/ kg.

G = Rate of air supply in kg/min

$$\frac{W_1[(X_{id} - X_{fd})\lambda + C_{pc}(t_{ci} - t_{cf}) + C_{pw}(t_{ci} - t_{cf})X_{id}}{(0.24 + 0.45H)(t_2 - t_1)\theta x 0.70}$$

where,

W_1 = Bone dry coconut in kg. = 47kg

X_{id} = Initial moisture content of coconut, (d.b.) in fraction. = 1.22

X_{fd} =Final moisture content of coconut, (d.b.) in fraction. = 0.063

λ = Latent heat of water vapour in kcal/kg. = 600 kcal/kg

C_{pc}= Specific heat of coconut in kcal/kgºC. = 0.7 kcal/kg ºC

C_{pw}= Specific heat of water in kcal/kgºC.= 1.0 kcal/kg ºC

$$= W_1[(X_{id}-X_{fd})\lambda + C_{pc}(t_{ci}-t_{cf}) + C_{pw}(t_{ci}-t_{cf})X_{id} x \frac{1}{0.70} = 1715 \text{ kcal/hr.}$$

t_{ci} = Initial temp. of coconut in ºC. =27 ºC

t_{cf} = Final temp. of coconut in ºC. = 65 ºC

H = Humidity at ambient air in kg/kg. = 0.02 kg/kg

t_2 = Drying temp. of air in ºC = 75 ºC

t_1 = Temperature of exhaust air in ºC = 40 ºC

θ = Drying period of coconut in hrs. = 30hr

Air requirement for drying, Q_a = 3 m^3/min

Fuel requirement :

The rate of fuel consumption can be calculated as follows: (Chakraverty, 2000).

$$F = \frac{qa}{\eta \times \eta_{ex} \times C_n} \qquad (3)$$

where,

F = Fuel rate, kg/hr.

q_a = Total heat required to heat the drying air, kcal/hr.

C_n = Calorific value of fuel, kcal/kg. = 4500 kcal/kg

= Combustion efficiency. = 0.65

= Heat exchanger efficiency = 0.35

Fuel rate = 1.67 kg/hr

From the quantity of fuel required the dimensions of the heating chamber were calculated. Considering free space the heating chamber was design. The overall dimensions of heating chamber were 1.00m (length), 0.65m (height) and 0.50m (width).The overall dimensions of furnace were 0.75m (length), 0.35m (height) and 0.35m (width). Opening of heating chamber was circular having diameter 0.23m. Heating chamber was placed just below the drying chamber.

Chimney :

Since airflow rate in the dryer takes place due to the draft caused by the pressure difference between outside cold air and inside hot air. (Basunia and Abe, 2001)

$$P = 0.000308 \times g \times (t_i - t_f) \times H \qquad (4) \quad (3.13)$$

where,

P= Pressure difference between outside cold air and inside hot air, Pa.

g = acceleration due to gravity 9.81 m/s^2.

H= height of the chimney, m.

Actual draft will be assumed to be 80 per cent of this draft (P).

Actual draft (P_1) =0.8 x P.

Velocity of exit air (c) = (2 x P1/ $ñ_e$)$^{0.5}$

Volume of exit air (v_e) = quantity of air in kg / $ñ_e$.

Rate of exit air (q_e) = v_e / drying time

Cross sectional area of chimney (a_c)= q_e/ c

For the design of chimney the pressure draft was calculated by considering the inside temp of gases in chimney and outside temperature of flue gases. From the psychometric chart the pressure draft was calculated as,

P= 1.45 pa.

From the pressure draft the height of chimney was calculated,

The height of chimney was calculated by using the equation 4.

H= 1m

The actual draft was calculated as 80 per cent of the calcutalated pressure draft.

P_1 = 0.80 x1.45

P_1 = 1.160 pa.

The velocity of exit air,

P_1 = 1C = 1.4 m/s

Volume of exit air,

V_e = 0.0425m^3

Rate of exit air,

q_e = 1.77´10^{-3} m^3/hr.

Cross sectional area of chimney

a_c = 1.26´10^{-3} m^2

Insulation:

The thickness of insulation was determined by considering heat loss from the heating chamber and drying chamber. Therefore, to avoid heat loss from the heating chamber and drying chamber, the insulation was necessary. Considering the heat loss the thickness of the insulation was decided. Considering the thermal conductivity of the glass wool was used as an insulating material. The thermal conductivity of glass wool 0.044 W/m^{0}k. The temperature inside the heating chamber was found to be 450^{0}C and out side temperature was 150^{0}C. The heat loss was 1500W. The temperature inside the drying chamber was found to be 100^{0}C and out side temperature was 80^{0}C. The heat loss was 500W.

Therefore, the thickness of insulation was,

$$Q_a = \frac{KxA(T_1 - T_2)}{x} \qquad (5)$$

where,

Q = Heat loss, Watt

K = Thermal conductivity of material, W/m^{o}K

T_i= Inside temperature of heating chamber or drying chamber, ^{o}K

T_o= Outside temperature of heating chamber or drying chamber, ^{o}K

x = Thickness of material, m

A =Area of heating chamber or drying chamber, m^2

Therefore,

The 0.33cm thick and 0.22cm thick glass wool material was used as insulation for drying chamber and heating chamber, respectively.

The materials required for fabrication of dryer are given in Table B.

Table B : Material used for the fabrication of copra dryer

Sr.No.	Material	Specifications	Quantity
1.	M.S.angle	3mm 1”×1”	6nos.
2.	M.S.angle	5mm 1”×1”	1nos.
3.	M.S sheet	22 gauge 4’× 8’	3 nos.
4.	M.S sheet	16 gauge 4’× 8’	2 nos.
5.	Aluminum pipe	43”	3 nos.
6.	Nut-bolt	¼”×1”	250gm
7.	Knifing paste filler	-	1kg
8.	Wheel castor	50mm P.T. Fibron	4 nos.
9.	Hinges	3”	4 nos.
10.	Glass wool	-	6 kg
11.	Asbestos rope	2500 mm × 2mm	1
12.	G.I. perforated sheet	16 gauge 4’× 8’	2nos.
13.	M.S. sheet	18 gauge 4’× 8’	1 nos.

EXPERIMENTAL FINDINGS AND ANALYSIS

The overall view of copra dryer and isometric view of copra dryer shown in Fig. 1, 2, 3 and 4. By design it was decided the area of drying chamber 0.75m^2. Drying chamber consisted two of trays having dimensions 0.1m×0.04m.The overall dimensions of drying chamber were 1.25 m× 0.65 m×0.60 m. Two doors having dimensions of 534mm (length) and 530 (height) were provided to the drying chamber for easy loading and unloading of the material.

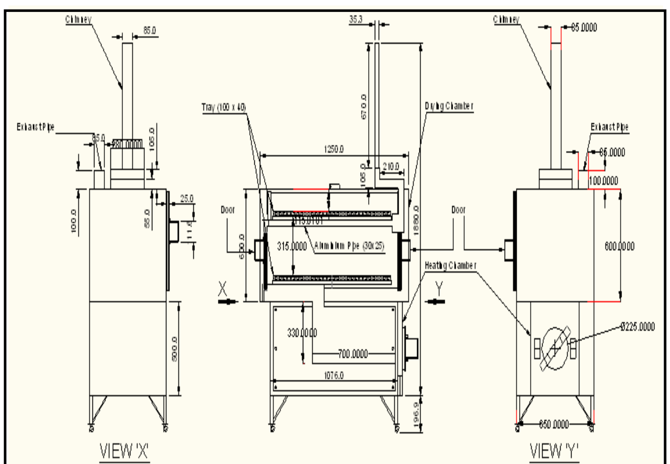

Fig. 1 : Oveall view of copra drye

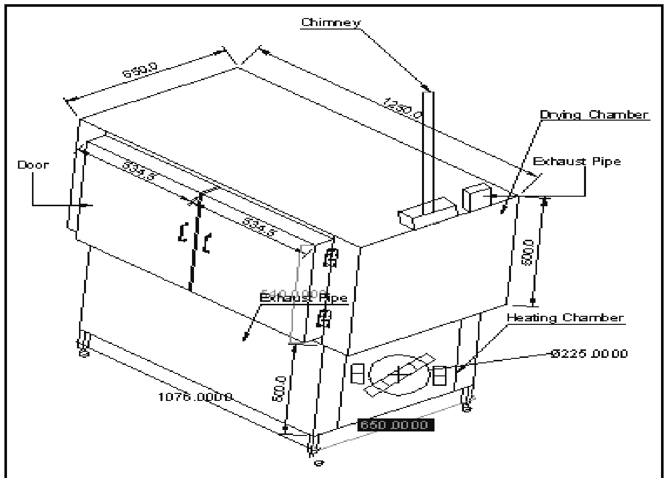

Fig. 2 : Isometric view of copra dryer

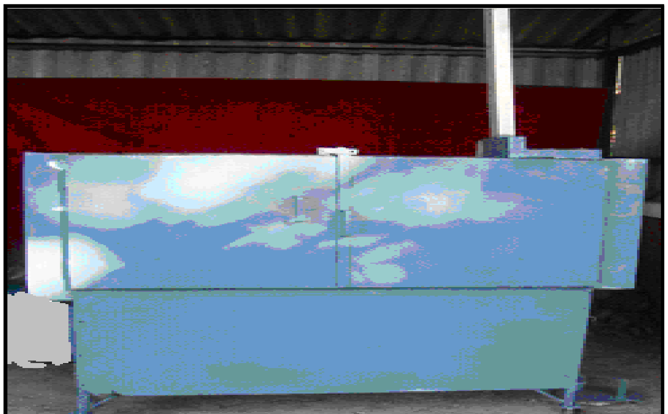

Fig. 3 : Natural convection indirect heating copra dryer

Fig. 4 : Heating chamber of copra dryer

The maximum airflow was selected as 3m^3/min, pressure drop in the dryer was 2.0m of air. Using total heat required and calorific value of coconut husk fuel rate was decided 1.67 kg/hr. Using the quantity of coconut husk required, the dimensions of heating chamber were calculated. The overall dimensions of furnace *i.e.* burning cum heat exchanger were 0.75 m × 0.35 m × 0.35 m. The overall dimensions of heating chamber were 1 m × 0.65 m × 0.50 m. Opening of furnace was circular having diameter 0.23 m. The height of chimney was decided 1m while area of chimney was 1.26×10^{-3} m^2. To avoid heat loss insulation must provide to dryer. Glass wool was used as insulating material. The thickness of insulation was determined by considering the heat loss from the heating and drying chamber. The 0.33 cm thick and 0.22 cm thick glass wool material was used as insulation for drying and heating chamber. This dryer is independent of weather conditions. The drying chamber was fabricated by using a mild steel sheet. The sheet used was of 22 gauge. Three sheets were required for the fabrication of the dryer. Angle frame of 3 mm, 1 x 1 was prepared and then three sheets were fitted in the frame and between two sheets insulating material glass wool was filled as per the dimensions. Two trays in drying chamber were made of two perforated G.I. sheet. Angle frame of 3 mm, 1 x 1 was prepared and then one sheet was fitted in the frame. This tray was used for platform for copra during drying.

For the heating chamber also M./S. sheet of 16 gauge was used. The sheet was fitted in an angle frame of 5 mm, 1 x 1. Two sheets were required for the fabrication of the heating chamber and then two sheets were fitted in the frame and between two sheets insulating material glass wool was filled as per the dimensions.

For the fabrication of the furnace 700 mm x 350 mm mild steel square sheet of 18 gauges was used. Angle frame of 3 mm, 1 x 1 was prepared and then one sheet was fitted in the frame. Furnace *i.e.* burning cum heat exchanging unit was housed at the left side of heating chamber with circular opening having 0.23m diameter fitted below the drying chamber.

Aluminum pipe having opening 3 x 2.5 was used for the fabrication of chimney. The chimney was fitted on the drying chamber as an outlet for the smoke to the atmosphere. This pipe was passed from below upper tray in drying chamber to the atmosphere. The purpose of taking this pipe through drying chamber was to utilized heat of flue gases for drying. There was as contact of smoke in drying chamber. Copra dryer occupied a total space of 0.81 m^2 for drying and heating chamber and was provided with castor wheel for easy movement and transportation.

LITERATURE CITED

Annmalai, S.J.K., and *et.al.* (2002) Design and development of a natural convection type low cost dryer for medium holdings, J. Plantation Crops, **16** (supplement): CPCRI, Kasaragod- 670-124, and KERALA. 81-90.

Anonymous (2008) India is number one in coconut production, Newspaper of Loksatta. p.4.

Basunia, M. A. and Abe T.,(2001) Design and construction of a simple three-shelf solar rough rice dryer, *J. Agric. Mechanization* in Asia, Africa and Latin America, **32** (3): 54-59.

Chakravarty, A. (2000). *Post harvest technology of cereals, pulses and oil seeds.* Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi. India.

Thampan, P.K. (1998). The coconut profile of India- Coconut *J.,* **34**(10) 3-4.

Patil, R. T. (1982). Design and development of copra dryers using agricultural waste as a fuel. PLACROSYM V, proceedings of the fifth national symposium on plantation crops. C.P.C.R.I., Kasaragod 670 124, India: 324-334.

Patil, R. T. and J. Singh (1984). Development of an improved tray type mechanical copra dryer. *Oleagineux,* **39** (1): 31-37.

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