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DESIGN AND DEVELOPMENT OF A NATURAL CONVECTION TYPE LOW COST DRYER FOR MEDIUM HOLDINGS*

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ABSTRACT

A simple and cheaper dryer working on indirect heating and natural convection principle using dry agricultural waste as fuel has been designed and developed to suit medium sized plantation crop holdings and processing units. The dryer consists of a drying chamber, burning cum heat exchanging unit and chimney. The dryer can hold 1000-1200 coconuts or 375 kg of ripe arecanuts per batch and the drying time required is about 33-37 hrs for copra and about 87 hrs for arecanut. As a preliminary study, the dryer was tested for drying 75 kg green cardamom in trays but slight discolouration of the product after drying was observed. The thermal efficiency of the dryer was 18.7-23.4%. The dryer costs about Rs.4000/- only and it requires an area of 7 m^2 for housing. Economic analysis has shown that this dryer can be profitably used during monsoon months.

INTRODUCTION

Drying is an important operation in plantation commodities. Fresh coconut meat which contains 45-55% moisture (wet basis) has to be dried to 6% moisture level and fresh arecanut has to be dried from 80% moisture to 9% moisture (w.b) for safe storage and further processing.

During rainy season, when conventional practice of open 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 products become inferior in quality due to smoking and improper drying (Grimwood, 1975). The other indirect type dryers using electricity or oil or firewood as fuel are either uneconomical propositions or having very low thermal efficiency. Patil (1982) developed a dryer using agricultural waste as fuel suitable for small holders. Based on this dryer, larger version of a natural convection type low cost dryer suitable for medium plantation holdings (>5 ha) and processing units was designed and fabricated at Central Plantation Crops Research Institute, Kasaragod.

MATERIALS AND METHODS

Design of the dryer

The various dryer parameters like size of the drying chamber, plenum chamber,

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area of heat exchanging unit, air flow required, etc. were worked out based on psychrometric and heat transfer principles. The width of the dryer in relation with the diameter of the burning cylinder has been standardised and it was found that the dryer width, burning cylinder diameter ratio should be of the ratio 3:1 for better performance.

Any dry agricultural waste can be used as fuel and the burning cum heat exchanger unit and chimney have been designed accordingly. The dryer is designed to hold 1000-1200 coconuts or 375 kg of arecanut per batch. The estimated air flow received through the system for drying copra worked out to 1.6 m^3/min. at an air velocity of about 2 m/min.

Description

The dryer consists of drying chamber, plenum chamber, burning cum heat exchanging unit, chimney with regulators and support frames. The dryer was fabricated from locally available materials such as AC sheet, GI sheet and MS Angle. The list of materials required is given in Table I. Asbestos cement sheets are used for structural use as well as for thermal insulation.

The details of the dryer are shown in Figures 1,2 and 3. The overall dimensions of the dryer are 2.5 m(L) × 1.2 m(B) × 1.75 m(H) and it requires a housing shed of 7 m^2 area. The drying chamber has an area of 3 m^2 and volume of 1.2 m^3. Three doors on hinges are provided on one side of the chamber to facilitate easier loading and unloading of the produce. The plenum chamber is just below the drying chamber. It has a trapezoidal vertical cross section. Vertical area of cross section of this chamber is 1.06 m^2 and the volume of the chamber is 2.25 m^3. On either side of the plenum chamber, 15 cm wide opening is provided at the bottom along the length with baffles on hinges for fresh air flow into the dryer. The burning cum heat exchanging unit is housed at the centre of the plenum chamber longitudinally. It is a 45 cm diameter cylinder made of 22 gauge galvanised iron sheet. The volume of the cylinder is 0.40 m^3 and the surface area is 3.5 m^2. GI sheet fins

Table I. *List of materials required for fabricating the dryer*

S.No.	Material	Size	Quantity
1.	M.S. Angle	32 × 32 × 6 mm	129 kg
2.	– do –	25 × 25 × 6 mm	24 kg
3.	M.S. Flat	32 × 6 mm	35 kg
4.	– do –	25 × 6 mm	12 kg
5.	M.S. Rod	6 mm	1 kg
6.	Weld Mesh	50 × 25 mm	4.5 Sq.m.
7.	Corrugated G.I. Sheet	18G, 2 × 1 m. size	2 Nos.
8.	Plain G.I. Sheet	– do –	1 No.
9.	M.S. Sheet	18 G	1.2 sq. m.
10.	A.C. Sheet	2 × 1 M	7 Nos.
11.	Hinges (M.S.)	75 mm, 50 mm	6 Nos.
12.	G.I. Bolt nuts	25 × 6 mm	2 kg

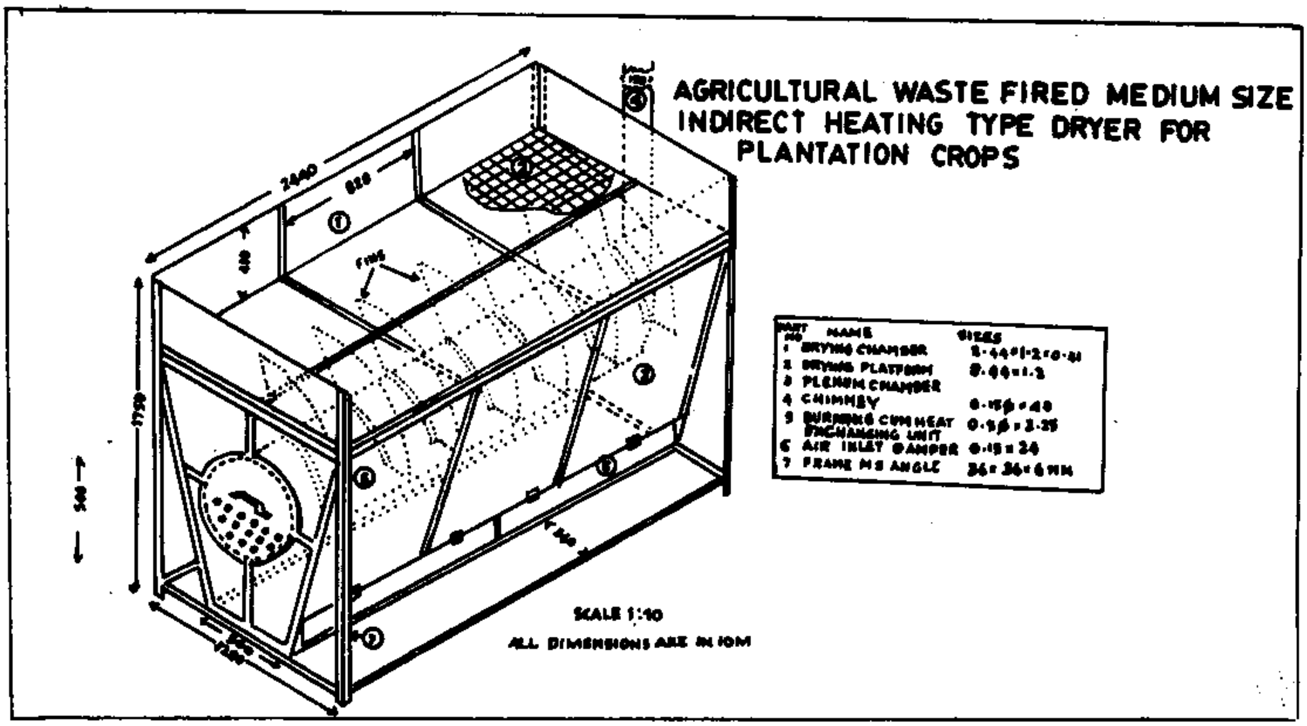
AGRICULTURAL WASTE FIRED MEDIUM SIZE INDIRECT HEATING TYPE DRYER FOR PLANTATION CROPS
2440
820
FINS
NAME
SIZES
1 DRYING CHAMBER
2 DRYING PLATFORM
3 PLENUM CHAMBER
4 CHIMNEY
5 BURNING CUM HEAT EXCHANGING UNIT
6 AIR INLET DAMPER
7 FRAME MS ANGLE
36×36×6 MM
SCALE 1:10

Fig. 1

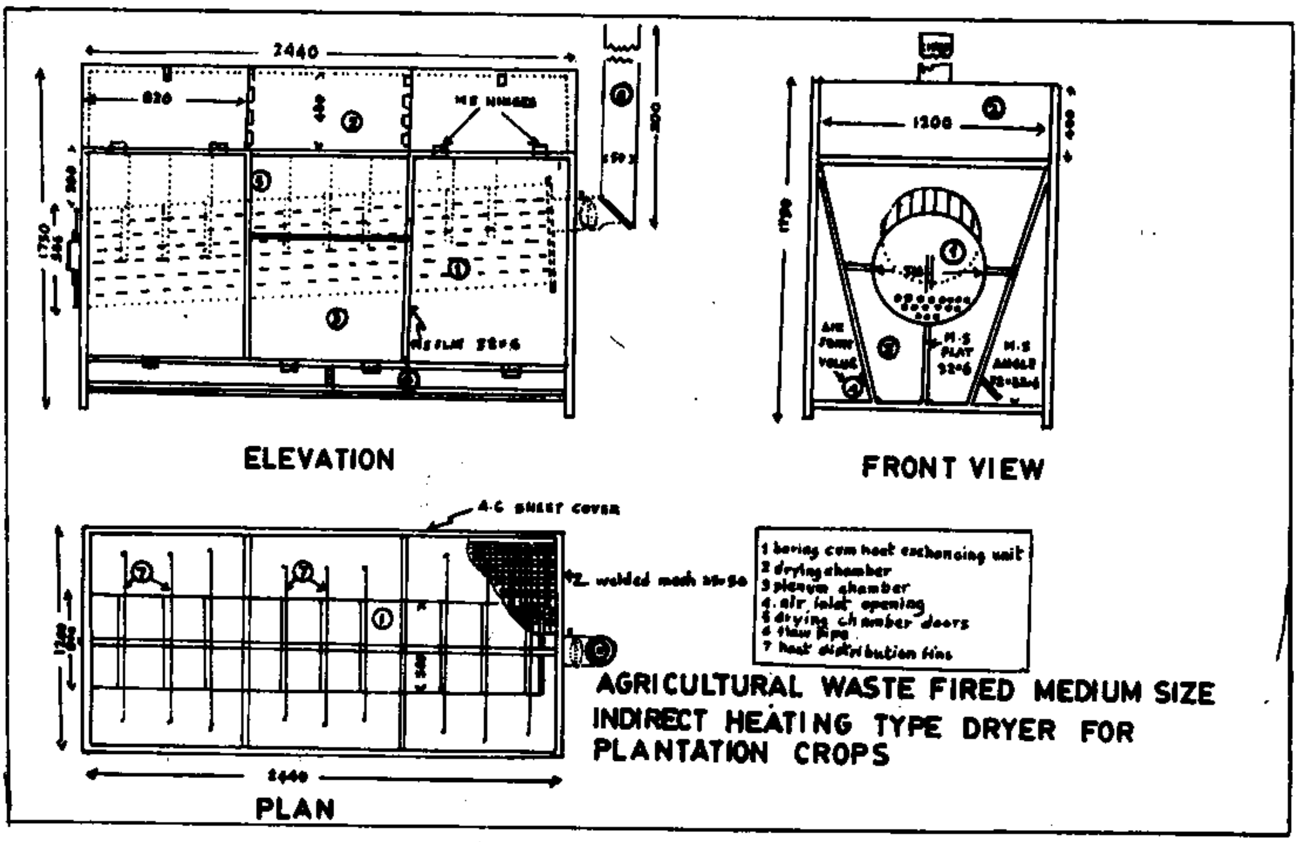
2440
820
MS HINGES
1200
ELEVATION
FRONT VIEW
A.C SHEET COVER
1 burning cum heat exchanging unit
2 drying chamber
3 plenum chamber
4. air inlet opening
5 drying chamber doors
7 heat distribution fins
PLAN
AGRICULTURAL WASTE FIRED MEDIUM SIZE INDIRECT HEATING TYPE DRYER FOR PLANTATION CROPS

Fig. 2

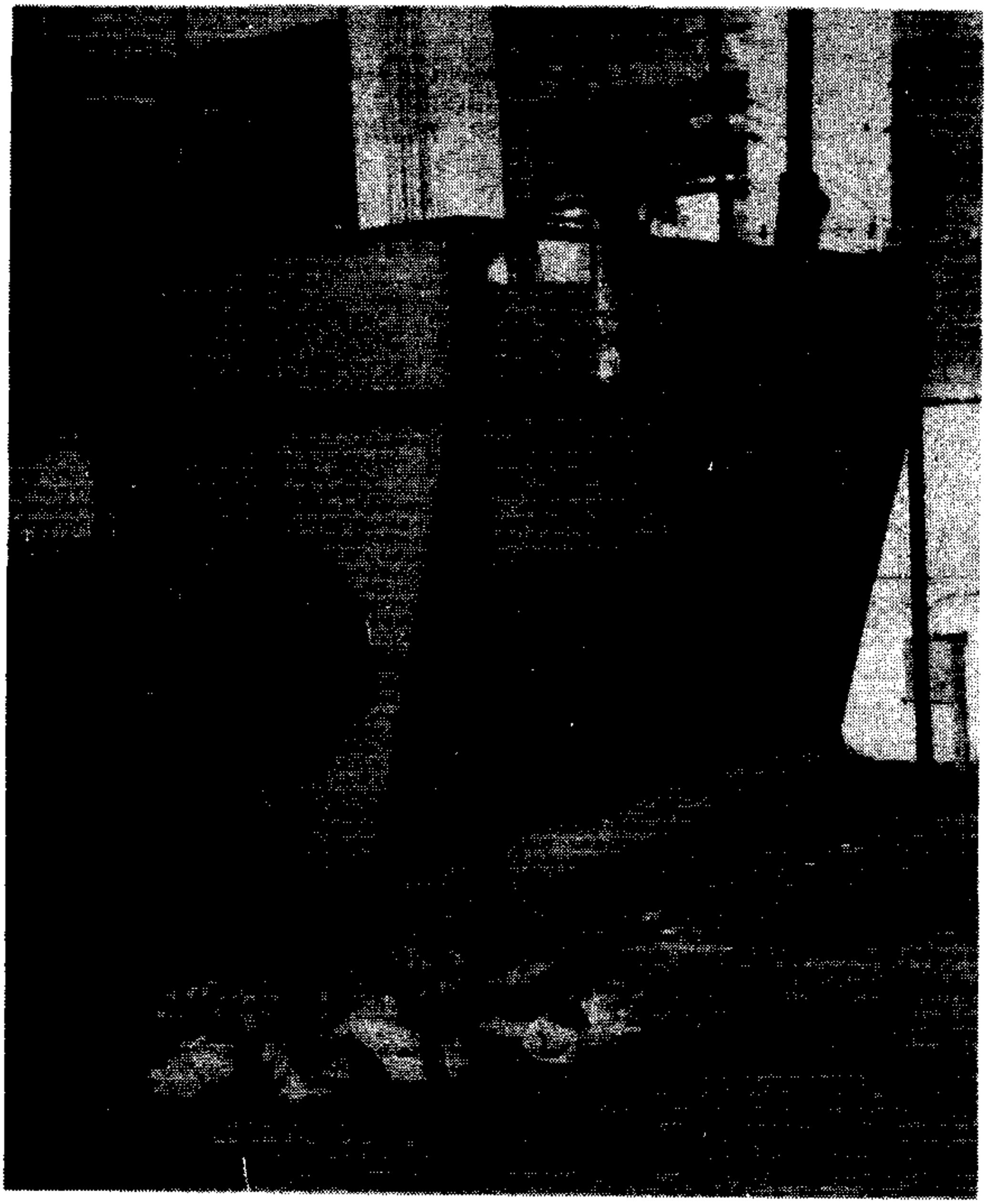

Fig. 3a. Overall view

have been provided on the upper half of the cylinder for better heat transfer. The cylinder is placed at a vertical inclination of 4°C for smooth flow of flue gases to the chimney. The lower end of the cylinder is fixed on plenum chamber wall with a damper having holes for entry of air required for combustion of fuel. The other end is connected to a 15 cm diameter chimney which lets out flue gases after combustion. The chimney is provided to a height of 3 meters for better draught. The fuel is burnt inside the cylinder in a M.S. flat tray of size 100 × 43 × 15 cm. Two butterfly valves are provided in the chimney to regulate the escape of flue gases. This in turn regulates the entry of air for combustion and thus controls the rate of combustion of fuel and the drying air temperature.

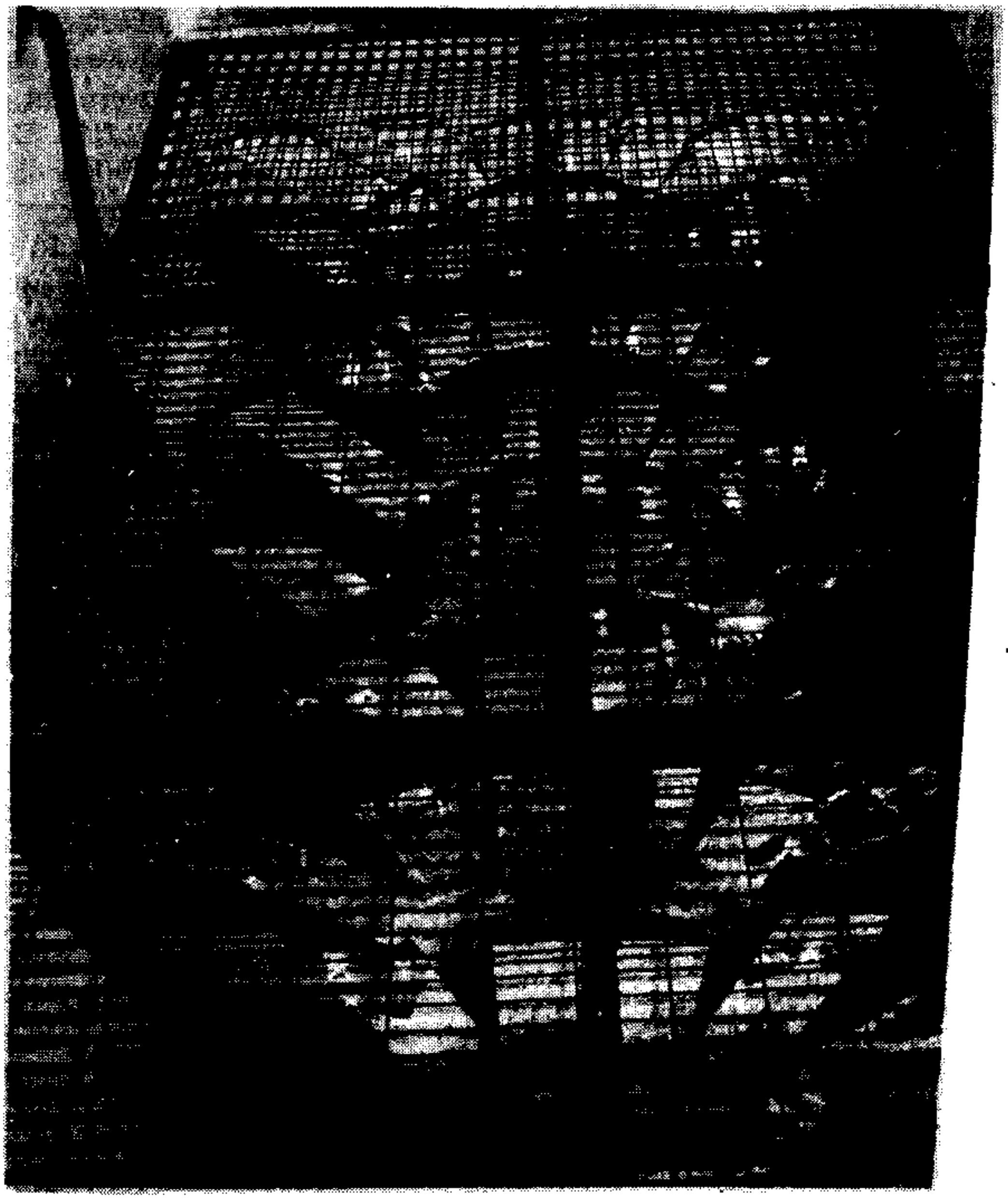

Fig. 3b. Internal view showing fins

Operation of the dryer

The fuel is burnt in the firing tray inside the burning cylinder. The temperature of the flue gases is about 180-190°C. The heat from the GI sheet surface which is at 100°C, is transferred by radiation to the surrounding fresh air entering from the bottom of the plenum chamber and this heat transfer generates a convection air current. The hot air moves up through the wet produce kept in the drying chamber and the hot air laden with moisture escapes from the top of the drying chamber. This phenomenon helps in the natural convection of the air through the drying bed.

Copra and arecanuts were dried in this dryer by bulk drying as a thin bed (bed thickness of 30 cms). The dryer was tried for cardamom drying also as a preliminary study. To facilitate the drying of cardamom in thin layers in trays, angle iron runners at four levels have been provided in the drying chamber so that 12 numbers of aluminium wire mesh trays of size 120 × 80 × 3 cm could be kept in 4 layers. The top of the dyring chamber is covered with a GI sheet hood with exhaust air outlet.

Testing the dryer

The dryer was intensively tested for copra and arecanut drying during August-November 1985. Hourly observations on various parameters like drying air temperature at different zones, exhaust air temperature, relative humidity of ambient air and exhaust air, velocity of air flow, moisture content of the produce were taken and the dyring parameters were standardised for drying copra.

The moisture content of the samples at six different zones during the drying was determined at 105 ± 2°C for 8 hrs by standard air oven method and the average values were recorded. The temperatures of ambient air, drying air at corners and middle region in the plenum chamber just below the drying chamber, exhaust air and flue gas were measured by mercury thermometer. The relative humidity was measured with Barigos hygrometer. The air velocity was measured with Ota Anemometer. Detailed studies on drying parameters were carried out for copra only. Coconut husk and shells were used as fuel and total fuel consumption for each batch of drying was found out.

For copra drying, coconuts broken into two halves were stacked with first two layers facing up and the remaining cups were arranged in inverted position in brick fashion. Drying was carried out intermittently giving overnight tempering after 12 hrs of drying. The shells were removed after 8-10 hrs. The shells found difficult for shell removal were placed at the bottom. By the end of 16 hrs, shells from all the cups could be removed. The copra cups were mixed every two hours after that for uniform drying. The drying was continued till the moisture content of copra reached below 6% level. The drying air temperature was maintained at 60-70°C.

For arecanut drying, fresh ripe arecanuts were loaded in bulk into the drying chamber and drying was carried out intermittently with overnight tempering of the produce. The drying air temperature was kept at 60-70°C. Frequent mixing of the produce was done for uniform drying.

For drying cardamom, the green capsules were loaded in trays into the drying chamber and the drying was carried out continuously. The doors of the drying chamber were opened every one hour to exhaust the moist air. The trays were interchanged and the capsules were raked every hour for uniform drying.

The temperature of drying air was kept at 45-55°C. The trials for cardamom were conducted as a preliminary study.

The thermal efficiency of the drying was calculated by using the formula:

$$\eta t = \frac{Q\lambda\,(Mo - Mf) \times 100}{WC\,(100 - Mo)}$$

Where ηt = thermal efficiency of the dryer in %

Mo = Initial moisture content per cent, wet basis
Mf = Final moisture content per cent, wet basis
Q = Quantity of the final dried product at Mf moisture content in kg
λ = Latent heat of Vapourization in Kcal/Kg.
W = Quantitiy of fuel used in kg
C = Calorific value of fuel used in Kcal/kg.

RESULTS AND DISCUSSION

The drying performance data of the experiments are given in Table II. 1000-1200 coconuts could be dried from 43-51% moisture to 5-6% moisture (w.b) in 33-37 hr using about 110 kg of fuel. 350 kg of fresh ripe arecanuts could be dried from 71% moisture to 8% moisture (w.b) in 87 hr (11 days) using about 240 kg of fuel. In the preliminary experiments on cardamom, 75 kg of fresh capsules were dried in 23-28 hours using 34-37 kg of fuel. The thermal efficiency of drying was 18.7% for copra, 19.2% for arecanut and 23.4% for cardamom respectively (the calorific value of the fuel was assumed 4500 Kcal/Kg).

The reduction in moisture content of the produce during drying is shown in Fig. 4. It can be seen that rate of drying of arecanut is slow as the migration of moisture from the kernel to the husk is slow. Normally by the conventional method of sun drying, the ripe arecanuts require about 45 days for drying and hence very often it is noticed that sudden intermittent rains during the process of sun drying accelerates fungal infection in the kernel. The drying of arecanuts in this dryer resulted in unifromly dried product of good quality, free of fungal infection with percentage of cracks developed during drying being less than 5%. Very rapid drying of arecanut may result in cracking of the nuts.

The rate of removal of moisture from cardamom was found to be rapid as it can be seen in Fig. 4. However, the quality of the dried cardamom was not satisfactory as there was slight discolouration of the capsules due to condensation of moist vapour. Since it was only a preliminary study for cardamom, the dryer needs to be slightly modified for quicker removal of the moist exhaust air to retain the green colour as desired in the international markets.

Table II. *Dryer performance data.*

S. No.	Produce	Qty.	Drying air temp. °C	Initial m.c. %	Final m.c. %	Total drying time hrs.	Qty. of final product kg	Fuel used	Qty of fuel used kg	Thermal efficiency
1.	Copra	1000-1200 coconuts	60-70	43-51	5-6	33-37 (3 days)	145-160	Coconut husk + shell	110	18.70
2.	Arecanut	350 kg	60-70	71.0	8.0	87 (11 days)	170	-do-	240	19.20
3.	Cardamom	75 kg	45-55	82	7.8	23-28	14.5	-do-	34-37	23.40

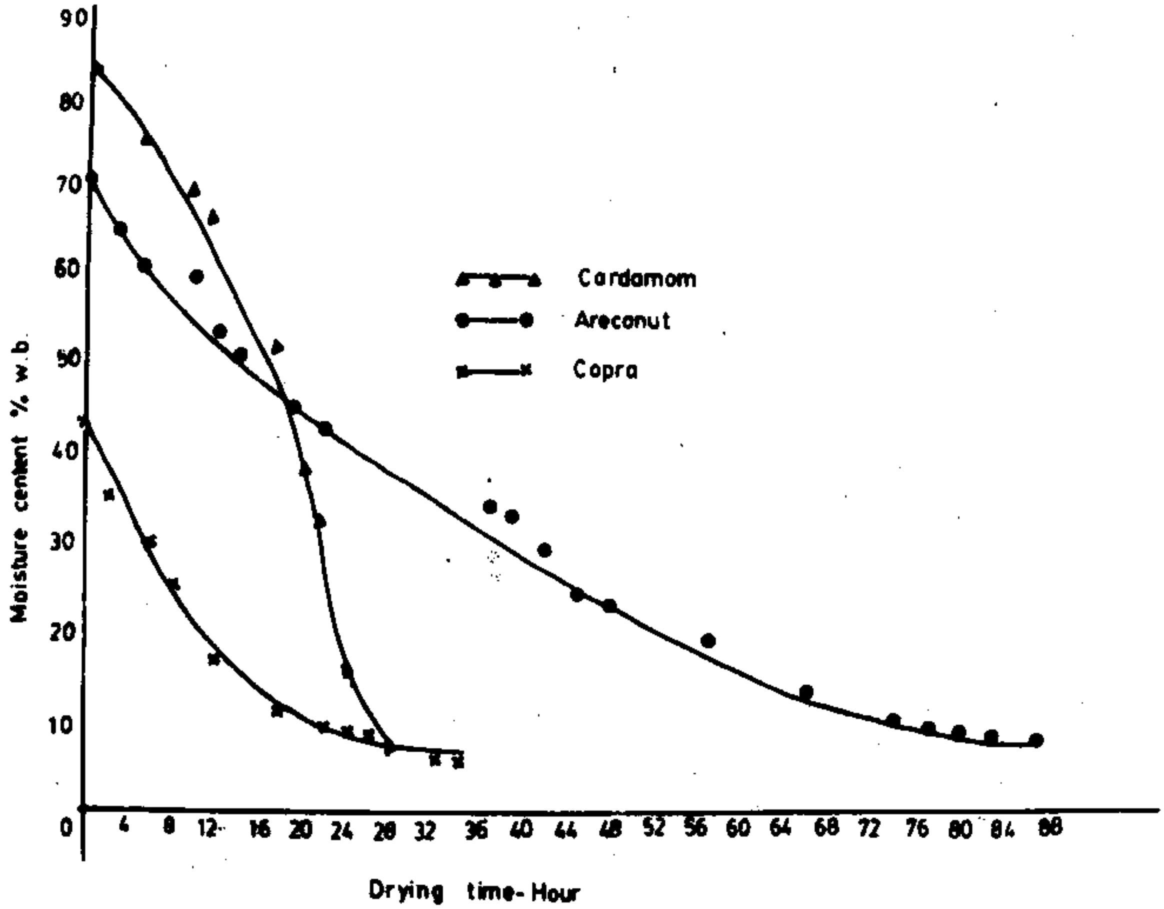

Fig. 4. Drying curves for produces in the dryer

The rate of removal of moisture from copra is found to be rapid in the initial 10 hrs due to the free moisture available in the produce and subsequently the moisture removal is found to be slow. The quality of copra dried in this dryer was very good with 70-85% of the produce as I grade copra, free of any microbial infestation.

The temperature and relative humidity of the air during copra drying are shown in Fig. 5. The temperature of drying air in the central region just below the drying chamber was about 60-75°C while the temperature of air in the corners was 50-60°C. There is a variation of about 10°C temperature between corners and the central region and hence frequent mixing of the produce was required to effect uniform drying. These variations did not affect the drying process much. The temperature of the exhaust air was about 40°C initially and later on it rose to 55-58°C. The relative humidity of the exhaust air was high initially due to the quicker removal of moisture and after 10 hr, the relative humidity was about 70% while the ambient air relative humidity was 90%. The velocity of exhaust air was ranging from 3-10 m/min.

Economic analysis of the dryer for copra drying

The cost of the dryer was estimated as Rs.4000/- and the expected life of the dryer is 10 years. The use of the dryer for copra and other crops can be at a mini-

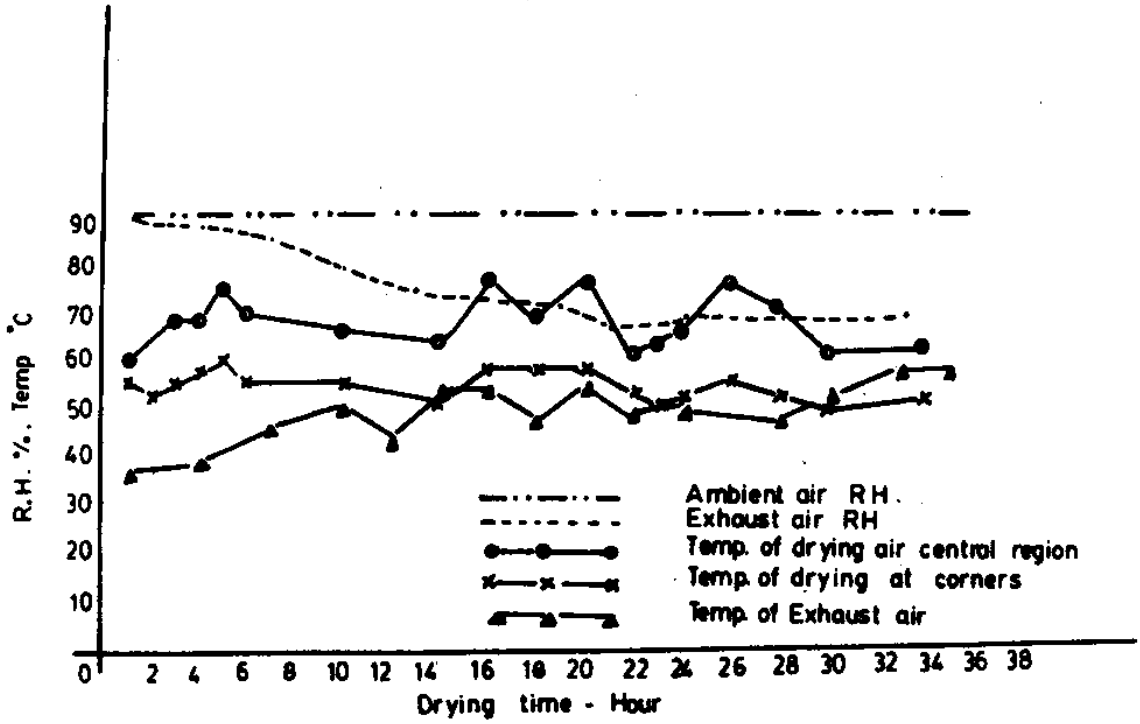

Fig. 5. Temperature and relative humidity variations of drying air and exhaust air during copra drying

Table III. *Economic analysis of the dryer for copra drying.*

Cost of the dryer	:	Rs.	4000.00
Fixed cost:			
Annual Depreciation	:	Rs.	400.00
Interest at 10% per annum	:	Rs.	400.00
Maintenance cost per annum	:	Rs.	100.00
Fixed cost per annum	:	Rs.	900.00
Fixed cost per batch	:	Rs.	18.00
Variable cost per batch:			
Average cost of coconuts during March-May '85:		Rs.	1650.00 per 1000 coconuts
(including handling & transportation)			
Dehusking charges	:	Rs.	35.00
Labour charges for 4 mandays @ Rs.25/ per day (For splitting, loading, fueling, bagging etc.)	:	Rs.	100.00
Cost of fuel at 0.50 per kg for 110 kg	:	Rs.	55.00
Total variable cost	:	Rs.	1840.00
Total cost (Fixed cost + variable cost) per batch	:	Rs.	1858.00

Returns			
A. Gross revenue from sale of 160 kg of copra at Rs. 12 per kg	:	Rs.	1920.00
Value of husk and shell	:	Rs.	150.00
Total revenue	:	Rs.	2070.00
Net income	:	Rs.	2070 – Rs.1858 = Rs.212
∴ Nett additional revenue obtained by copra drying per batch	:	Rs.	212.00
Cost of drying per kg of copra (excluding cost of coconut)	:	Rs.	1.30 per kg
Nett additional revenue that can be realised in a year	:	Rs.	10,600.00
Minimum area of holding required	:		5 ha

mum of 150 days per year especially during monsoon months. Accordingly 50 batches of 1000 coconuts each can be dried in a year. The straight line method of depreciation was adopted for calculating annual depreciation. The interest rate was assumed as 10% per annum and the maintenance cost was assumed as Rs.100.00 every year.

With the above considerations the cost analysis of copra drying in this dryer was done as shown in Table III. The cost of drying per kg of copra worked out to Rs.1.30. Additional revenue realised per batch by processing coconuts into copra instead of selling coconuts as such was Rs.212.00 and even by processing 20,000 coconuts, the investment on the dryer can be realised back. Hence use of this dryer during monsoon months is economically profitable proposition.

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