DESIGN AND DEVELOPMENT OF COPRA DRYER USING AGRICULTURAL WASTE AS SOURCE OF ENERGY

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ABSTRACT

Keeping in view the pressure on land in Kerala, the main coconut growing state in India which restricts the use of dryers needing permanent building and high initial investment, a small capacity dryer was designed and fabricated from materials such as MS angle, GI sheet, and AC sheets. This dryer consists of a drying chamber, plenum chamber and burning-cum-heat exchanging unit. A chimney is provided to control the rate of combustion and thus drying air temperature. An adjustable damper is provided to control the entry of fresh air for drying. The dryer could accomodate a maximum of 400 nuts per batch. Any dry agricultural waste could be used as fuel. The drying air temperature is kept at 70 to 80°C and time required for drying is 37.5 hours. The cost of the dryer is only Rs. 1000/- and it needs only 2m² area for housing.

INTRODUCTION

Fresh coconut meat contains about 45-50 per cent moisture on wet basis and it has to be dried to 6 per cent moisture for safe storage and further processing. A dryer for use during rainy season, when conventional practice of sun drying is not possible, has been a long felt need. Copra being easily susceptible to infestation by micro-organisms, cannot be dried even with intermittent supply of solar energy in the beginning and at the end of the monsoon season. The average land holding being 0.2 ha and about 90 per cent farmers holding less than 1 ha of land (Thampan, 1981), makes the other highly developed copra dryers (Grimwood; 1975, Gartia, 1978; Anonymous, 1980) impractical and uneconomical. The low cost kiln dryers could also not be used due to inferior and non-uniformly dried copra obtained from them.

The indirect type of small dryer, with provision to control the drying air temperature and using low cost easily available agricultural waste as fuel, was designed and developed by the author at the Central Plantation Crops Research Institute, Kasaragod.

Description of the Dryer: The dryer was fabricated from M.S. angle, Asbestos Cement sheets, G.I. sheets and asbestos rope as raw materials. The cost of the materials required is given in Table 1.

Table 1. Materials required for the fabrication of the dryer

Material	Size	Quantity
M S Angle	38mm 38mm 3mm	20 m
M S Flat	38mm 3mm	22 m
M S Flat	25mm 6mm	5 m
G I sheet (corrugated)	22 gauge	1.5 m^2
G I sheet	22 gauge	1.5 m^2
Asbestos sheet	4mm	6 m^2
Asbestos rope	12.5 mm	10 m
G I bolts and washers	—	2 pkts.
Hinges	5 cm	6 nos.

The dryer as shown in Figures 1a and b has the following components.

Drying chamber: It is made of asbestos cement sheets on the sides and wire mesh tray at the bottom, supported on an M.S. angle frame. The volume of the chamber is 0.34 m^3.

Plenum chamber: It is an inverted prism-shaped chamber. It is made of asbestos cement sheets supported on M.S. angle frame. The volume of the chamber is 0.68m^3. At the bottom of the chamber an adjustable opening is provided to regulate the entry of the fresh air for drying. The burning cum heat exchanging unit is also located in the centre of the plenum chamber.

Burning-cum-heat exchanging unit: It is a 30 cm diameter cylinder made of 22 gauge galvanised iron sheet. Bottom half is made of plain GI sheet whereas upper half is made of corrugated GI sheet to get more surface area for heat transfer. The volume of the chamber is 0.085 m^3 and the surface area is 1.15 m^2. The length of the chamber is equal to the length of the plenum chamber. One end of the chamber is covered by asbestos cement sheet lined with GI sheet damper containing holes for the entry of air required for combustion. The other end is connected to a 10cm diameter chimney

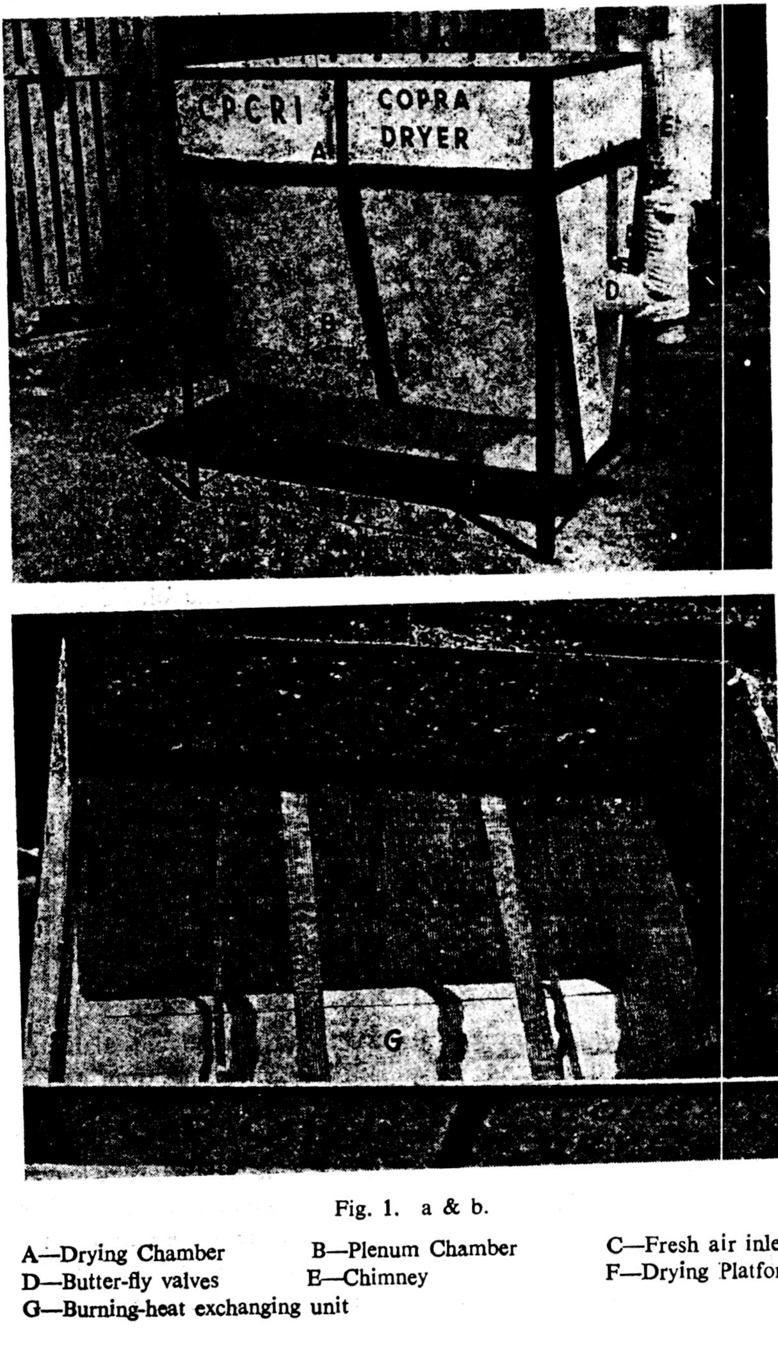

Fig. 1. a & b.

A—Drying Chamber B—Plenum Chamber C—Fresh air inlet
D—Butter-fly valves E—Chimney F—Drying Platform
G—Burning-heat exchanging unit

which lets out the flue gases after combustion. The cylinder is placed at an inclination of 3° for the smooth flow of gases. The fuel is burnt in that chamber in a welded wire mesh tray of 30cm × 15cm × 15cm.

In the chimney, two butterly valves are provided to regulate the escape of flue gases. This in turn regulates the entry of air for combustion and thus controls the drying air temperature. The chimney is covered by asbestos rope with plastering by plaster of Paris to avoid the danger of scalding during handling.

Principle of Operation: When the fuel is burnt in the burning chamber, due to higher temperature of flue-gas the GI sheet is heated up. The heat from GI sheet is transferred by radiation to the surrounding fresh air entering from the bottom. The hot air being light comes in contact with the wet material in the drying chamber. The hot air laden with moisture escapes in to the atmosphere from the top of the drying chamber. This phenomenon also helps the natural convection of the air through the drying bed. The dial thermometer was fixed just below the drying platform to measure the temperature of the incoming hot air to the drying chamber.

Operation of the Dryer: The nuts were cut into two halves after dehusking and nut water was drained off. The nuts were kept in inverted position for 15 min to remove the adhering moisture. Then the cups are loaded in the drying chamber, the first two bottom layers with the cups facing up and the rest of the cups being kept face down until full capacity is reached in brick fashion. The fuel is then kept in the welded wire-mesh tray and fired. The tray is kept in the centre of the cylinder (burning chamber) and fuel is fed as and when required to keep the fire burning. The temperature in the dryer is recorded on the dial thermometer, and if found more, the valve positions are adjusted to maintain the required temperature.

MATERIALS AND METHODS

The dryer was tested for drying time required at 70°C for 150, 250 and 400 coconuts per batch capacity. The first two layers were stacked facing up and the remaining cups were arranged in the inverted position in brick fashion. Drying was carried out from 07.00 to 17.00 hours each day, On the second day, the shells were removed when possible. The cups found difficult for shell removal were placed at the bottom facing up. The bottom two layers were occupied by the cups with kernels inverted above them. The shells from the bottom layer were removed at the end of second day. The drying was continued till the moisture content of copra reached 6 per cent. The copra cups were raked after every two hours during drying.

The fuel used was husk, shell and a mixture of husk, shell, petiole and spathe. The temperature of drying air for drying time test was kept at 70°C for all three capacities of 150, 250 and 400 nuts. The moisture content of the composite sample was determined at 105±2°C for 8 hours by standard oven drying method. The temperature of hot air just below the drying platform was measured by bimetallic dial thermometer. The temperature of air leaving the drying chamber, flue gas, and ambient air was measured by mercury thermometer.

A detailed study of all the drying parameters was done only at 400 nuts per batch capacity. The relative humidity of the air leaving the material and ambient air was measured by the Assmans' psychrometer. The moisture content of the sample was recorded at every 4 hour interval. Two tests at 400 nuts per batch capacity were also conducted for two stage drying, namely, initial temperature at 80°C and later at 75°C.

The efficiency of the drying was calculated by using the following equation No. 1.

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

Where,

ηt=thermal efficiency of the dryer in per cent.
Mo=initial moisture content per cent, wet basis.
Mf=final moisture content percent, wet basis.
Q=quantity of dried copra at Mf moisture content in Kg
λ =latent heat of vapourization in KCal/Kg.
W=quantity of fuel required in Kg.
C=calorific value of fuel required in Kcal/Kg.

RESULTS AND DISCUSSION

The initial moisture content of all the samples was found to be 46 per cent on an average (wet basis). The drying time, fuel required, and efficiency of drying are given in Table 2. The time required was (28 hours) minimum at 150 nuts per batch capacity whereas maximum time required was for 400 nuts per catch capacity i.e. 37.5 hours. The thermal efficiency of the dryer was maximum at 400 nuts capacity (20.67 per cent) and least at 150 nuts capacity (11.9 per cent). Even at 400 nuts capacity the efficiency varied with the kind of fuel used. The highest efficiency was observed when fuel used was shells (21.7 per cent). The type of drying also had an effect on the drying efficiency. With shells as fuel the drying efficiency increased by 13.1 per cent due to double stage drying. The reason for getting a higher thermal efficiency in case of shells as fuel may be due to its higher calorific value compared to husk and mixed fuel (4800 Kcal/Kg, 4400 Kcal/Kg and 4500 Kcal/Kg for shells, husk and mixed fuel respectively). The fuel required, on an average, was about 30 Kg (29.7 Kg) i.e. about 250 shells or 100 husks at maximum capacity. The average quantity of copra obtained per batch (400 nuts) was 64.5 Kg.

Table 2. Drying test results

Capacity nuts/batch	Quantity of copra (Kg)	Quantity of fuel (Kg)	Type of fuel	Time of drying (hr)	Thermal efficiency %	Calorific value Kcal/Kg
150	25.20	21	mixed	28.00	11.90	4500
250	42.25	25	mixed	35.00	16.44	4500
400	63.60	33	husk	40.00	18.60	4400
400	66.00*	26**	shells	36.50	23.52	4800
400	64.00	30	shells	36.00	19.82	4800

*average of two tests
**two stage drying

In the two-stage drying, the air temperature was kept at 80°C till the temperature leaving the material reached 65°C. It was found that upto 20 hours of actual drying the difference between the two temperatures was reduced from 35° to 80°C. When the cooling effect due to evaporation of moisture was reduced to nil, the material temperature also might have reached the same as drying air

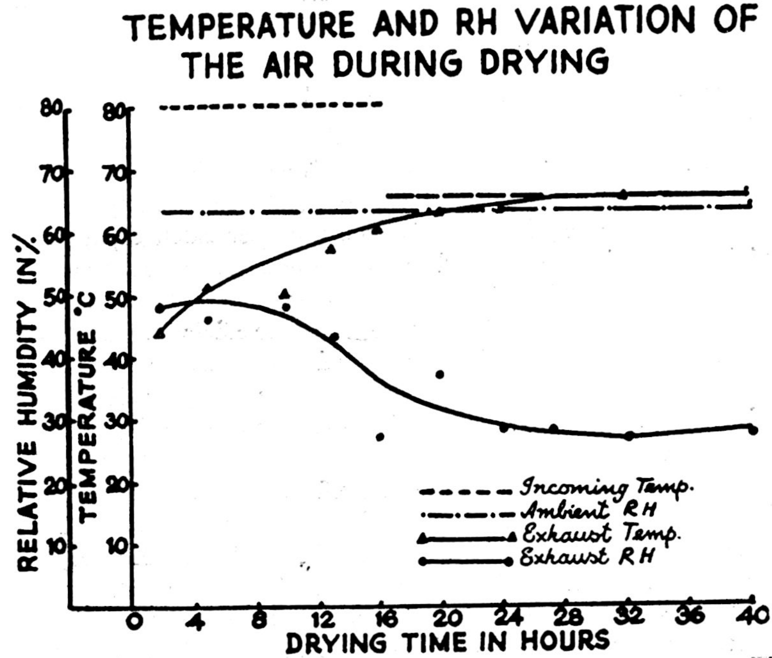
TEMPERATURE AND RH VARIATION OF THE AIR DURING DRYING
RELATIVE HUMIDITY IN %
TEMPERATURE °C
80
70
60
50
40
30
20
10
0
4
8
12
16
20
24
28
32
36
40
DRYING TIME IN HOURS
Incoming Temp.
Ambient RH
Exhaust Temp.
Exhaust RH

Fig. 2

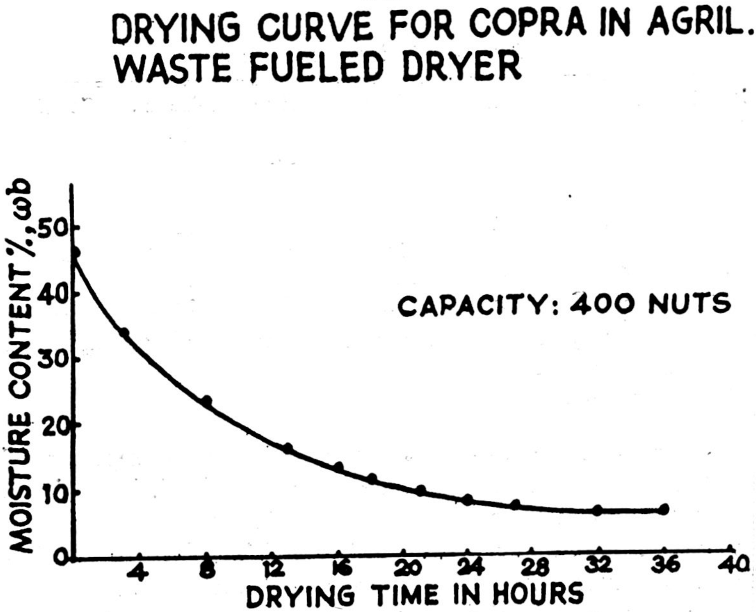
DRYING CURVE FOR COPRA IN AGRIL. WASTE FUELED DRYER
MOISTURE CONTENT %, wb
CAPACITY: 400 NUTS
50
40
30
20
10
0
4
8
12
16
20
24
28
32
36
40
DRYING TIME IN HOURS

Fig. 3

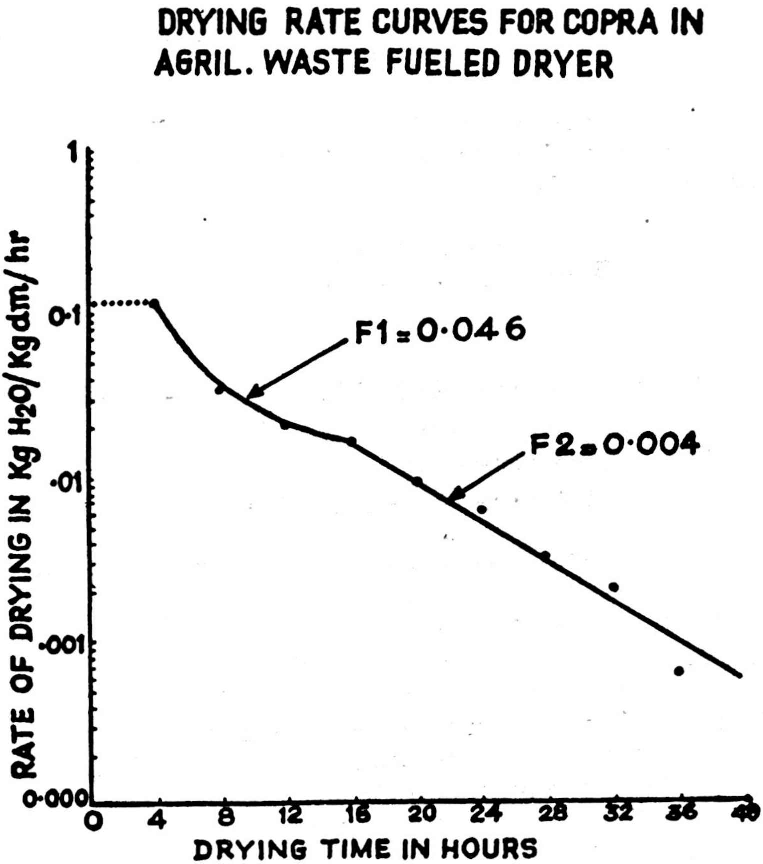
DRYING RATE CURVES FOR COPRA IN
AGRIL. WASTE FUELED DRYER
RATE OF DRYING IN Kg H2O/Kgdm/hr
1
0·1
·01
·001
0·000
F1=0·046
F2=0·004
0
4
8
12
16
20
24
28
32
36
40
DRYING TIME IN HOURS

Fig. 4

temperature. Since charring has been reported due to the higher temperature of material (Rajshekharan *et al.*, 1961) from 16 hours onwards when the material temperature was approaching 65°C, the hot air temperature was further maintained at 65°C, till the end of the drying. The variation in moisture content of copra with drying time is shown in Fig. 2, and the variation in temperature and relative of humidity of ambient air and air leaving the dryer during drying is shown in Fig. 3.

To get a clear picture of the drying process in this dryer, the drying curve was further analysed. The drying rate was calculated by the equation No. 2.

$$R = \frac{(Mo - Mi) \times 100}{(100-Mo)\,(100-Mi)\,(to-ti)}$$

Where,

R=rate of drying in Kg H_2O/Kgdm/hr

Mo=moisture content per cent, wet basis at *to*

Mi=moisture content wet basis at *ti*

and *to* and *ti* are respective drying times.

The graph of drying rate versus drying time (Fig. 4) on the semi-log paper showed that the rate of drying was faster in the beginning for first four hours. The rate was more or less constant at 0.105 Kg H_2O/Kgdm/hr, and may be due to availability of free moisture. The rate was further reduced to average 0.046 Kg H_2O/Kgdm/hr from 4 to 16 hours. It may be due to the moisture migration by capillary action and at later stage at 0.004 Kg H_2O/Kg dm/hr (second falling rate period) may be due to moisture migration by diffusion. The average rate of drying was found to be 0.052 Kg of H_2O/Kg dm/hr.

Economic Analysis of the Dryer:

The construction cost of the dryer was estimated at about Rs. 1000/- and expected life of the dryer was at least 10 years. The use of the dryer for copra and other crops can be at minimum of 200 days per year. The straight line method of depreciation was adopted to calculate annual depreciation. The interest rate was assumed at 12 per cent per annum for the half initial cost as capital every year. The cost of low quality dry agricultural waste was considered at Rs. 0.10 per Kg of fuel. With all these assumptions and considerations the cost analysis was done as shown in Table 3. The cost of the drying came to only Rs. 0.35 per Kg of copra when household labour was used for firing. The cost of open drying has been reported to be about Rs. 0.20/Kg of copra (Anon, 1981), which shows that the drying cost was only Rs. 0.15 more per kg of copra compared to open drying.

Table 3 Economic analysis of the dryer

Coast of the dryer: Rs. 1000.00	
Expected life of the dryer: 10 years	
Use of the dryer in a year: 200 days	
Time required for drying in days per batch: 4 days	
FIXED COST:	
Depreciation: Rs. 100.00	
Interest @ Rs 12 per annum: Rs. 60.00	
Maintenance: Rs. 10.00	
Total fixed cost: Rs. 170.00	
VARIABLE COST:	
Dehusking charges @ Rs. 20.00/1000 nuts:	Rs. 8.00
Splitting and deshelling charges:	Rs. 8.00
Cost of low cost fuel:	Rs. 3.00
Total cost of operation per batch: Rs. 22.40	
Cost of drying per Kg of dried copra: Rs. 0.35	

Special Features of the Dryer:

(1) It needs only about $2m^2$ for housing. Temporary shade could serve as a cover during rainy season.
(2) Two to three persons can lift and transfer the dryer to short distances.
(3) Temperature control ensures uniform and perfect drying and yielded good white copra.
(4) Controlled combustion ensures economical use of fuel
(5) Any low quality but dry fuel could be used.
(6) It is easy and very safe to operate.
(7) It could be successfully be used for drying other plantation crops also.
(8) Cheap but strong materials are used for fabrication; hence it is durable.

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References

ANONYMOUS. 1980. Sketches and construction plan of the improved copra dryer. Philippine Coconut Authority, Agricultural Research Branch, Davao city.

ANONYMOUS. 1981. Coconut processing technology information document, Part 1 (coconut harvesting and copra production.) UNIDO/APCC.

GARTIA, TT. 1979. NIST copra dryer, Philippines: personal communication.

GRIMWOOD, BE. 1975. *Coconut palm products*, FAO of the United Nations, Rome, 261 p.

RAJSHEKHARAN, N., BHATIA, DS, and PANDALAI, KM. 1961. Some preliminary studies on the mechanical drying of coconuts. *Indian Coconut. J.* 14(2): 71-81.

THAMPAN, PK. 1981. *Handbook of coconut palm*, Oxford and IBH Publ. Co. New Delhi; 311p.