

# Design and Performance Evaluation of Pit Dryer for Copra Drying

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## Abstract

A pit dryer with indirect hot air aeration was developed. The design and performance of the drying system were evaluated for copra drying and the drying characteristics are discussed. The result of performance evaluation exhibited that the utilization of chimney to suck the smoke of combustible biomass increased the driving forced of hot air for drying. The average drying rate was 1.2% w.b./h, and cumulative energy consumption was 20.3 kcal/h from the combustion of coconut husks and shells. The cumulative drying efficiency was 10.72% and the average quality of dried copra those were analyzed comprised of oil content (62.1%) and free fatty acid (1.4%).

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## Introduction

Drying process is a critical period in post-harvest handling of agricultural products to prevent the development of a favorable environment for the growth of molds and insects that normally cause spoilage.

Copra is dried as the initial process of oil extraction from coconut (*Cocos nucifera*) in conventional method. Generally, in developing countries where coconuts are grown farmers produce copra by natural drying such as solar energy utilization. This method is the cheapest but completely dependent on weather and takes 4-5 days to reduce the moisture content of coconut meat from 45-55% w.b. to 7-11% w.b. (Grimwood, 1976). Another method, copra is dried by direct heating treatment on the racks or above the conventional stoves. This method could reduce the drying time between 36 and 40 h and results in dark-brown dried copra with low extracted oil quality. In this regard, there is a need in rural areas of developing countries to establish a modern drying system

applying appropriate technology. The objective of this study is to design a pit dryer with indirect hot air aeration and to discuss the performance of the drying system.

## Description of Pit Dryer

The schematic design of a pit dryer is shown in Fig.1. The dryer was established at the faculty of Agricultural Technology, Bogor Agricultural University, Bogor, Indonesia. The main construction was comprized of bamboo, coconut leaves and concrete blocks. The combustion chamber of biomass-fuel was established below the ground with 355 cm in length, 130 cm in width and 130 cm in depth from the earth surface. The drying chamber was covered by bamboo mats divided into two stories. The lower part was used for the first period of drying and the upper part contains 12 drawers for the second step drying. The top part of drying chamber is opened as the exhaust duct for evaporating the material's water vapor. The exhausted earth-clay-chimney with 450 cm in height

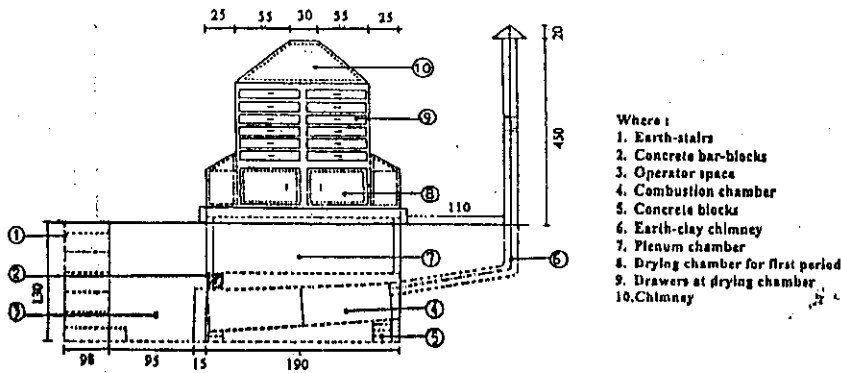


Fig. 1 Schematic design of pit dryer.

from the earth surface is established to suck the smoke from the combustion chamber.

The design of combustion chamber located underground is presented in Fig.2. The chamber was constructed from two cylindrical drums where the husks and shells of coconuts were combusted to heat the wall's chamber. Due to the accumulation of conduction and free convection, heat transfer and buoyancy force employed by the chimney effect, the hot-air is forced from the wall of combustion chamber to the drying chamber through a plenum, while the combusted biomass's smoke is sucked through the exhaust chimney to the environment. To protect from rainy season and bad weather, the dryer was shaded by wooden roof with coconut leaves as roof tiles.

The slopes of the chimney and top part of drying chamber were

designed based on the critical driving force of dew-bulb from the water vapor (Fig.3). To prevent the dew-bulb drops to the copra's layer, the chimney's slope at the upper part of drying chamber meets the required driving force of dew-bulb movement. Theoretically it is stated in equation 1) (Hall, 1980):

- Where:  $F_s$  = driving forced(newton)  
 $g$  = gravitational force ( $m/s^2$ )  
 $S$  = stress of water surface  
 ( $= 6.62 \times 10^{-2} N/m$  at  $80^\circ C$ )  
 $f \bar{I}$  = specific weigh of water ( $kg/m^3$ )  
 $f \bar{A} E$  = angle of wall's slope  
 $F$  = vertical component of force (newton)

$W$  = resultant of force (newton)

## Evaluation Procedures

The performance testing of the pit dryer was conducted three times with 300 nuts (320 kg of coconut meat, including the shells). The average initial moisture content was 53% w.b. The drying process was divided into two periods, in the 12 h of first period, raw coconut with their shells were dried in the half slices for ease in removing the shells from the meats, then in 26 h of second period, the half dried coconut meat only (without the shell) was dried. Temperatures of the system were measured by copper constantan thermocouples transmitted to an analog recorder graphically. Air velocity was measured by a thermistor anemo-meter, while air relative humidity was measured by a hygrometer. The moisture content of copra was tested by sampling method in each drawer with infrared moisture meter. Sampling was conducted every 2 h for the first period of drying and every four hours at the second one. The oil content of the dried copra was evaluated using Soxhlet (Woodman method, 1941) and the Free Fatty Acid (FFA) was evaluated by Mehlenbacher method(1960).

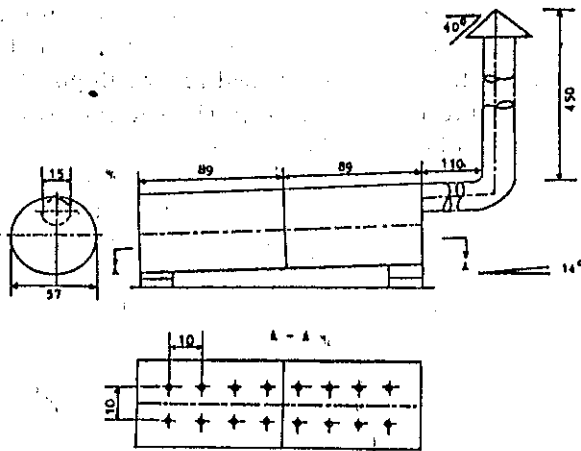


Fig. 2 Design of combustion chamber.

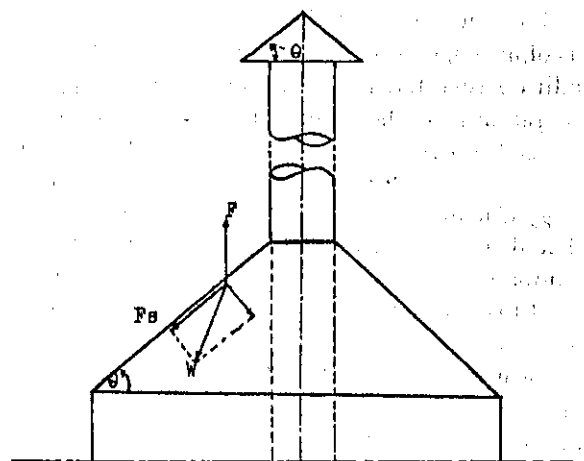


Fig. 3 The slope of chimney cover at the drying chamber.

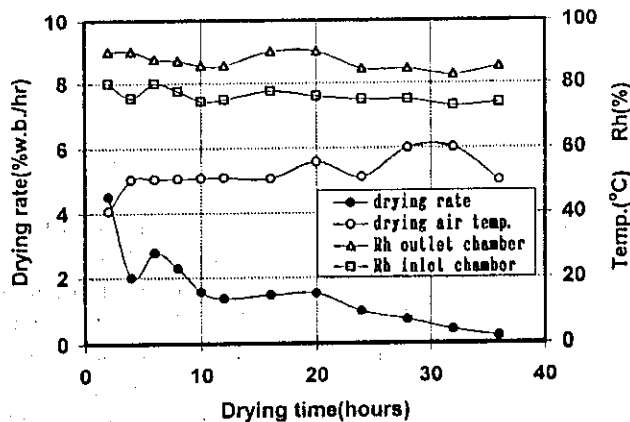


Fig. 4 Drying rate for copra.

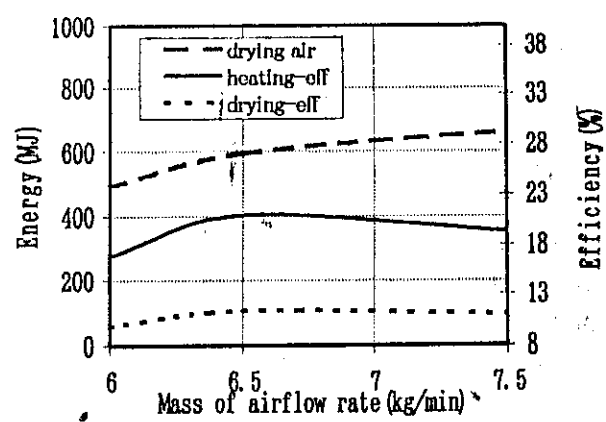


Fig. 5 Efficiency and consumed energy.

**Results and Discussion**

**Drying Rate**

The evaluation on drying performance was conducted in three replications. The performance of one experiment is presented in Table 1. The fluctuation of drying temperature in the drying chamber was 50°C-60°C with relative humidity of 70%-80%. This condition led to the average drying rate of copra with 2.0% w.b/h at first period of drying and the second one was 1.3% w.b/h. Graphically, the average drying rate is shown in Fig. 4. In the first period of drying, the moisture content at the surface of the materials were in a condition of free moisture which was easy to evaporate by diffuse process with drying air, while in the second step it was lower than the first one due to diffused capacity and capillary forced from the inner to the surface parts of the copra were lower. This condition resulted in the water evaporation from the surface that proceeded slowly.

**Energy Consumption**

The difference in temperature condition was due to the existence of heat loss through heat transfer process. In the case of drying air movement through the bulk of copra in drawers, the higher content of water vapor in air resulted in a lower evaporation capacity of drying air. This phenomenon exhibited by the

consumed energy in heating drying air and low drying efficiency is shown in Fig 5.

The average feeding rate of coconut husk and shell into the combustion chamber were 3.8 kg/h and 1.4 kg/h, respectively. The average of cumulative heating and drying efficiency were 19.1% and 10.7%, respectively. The difference in efficiency values was due to the heat loss by mass transfer process and the highest heat loss was through the chimney .

**Conclusion**

1. A pit dryer for copra drying was developed using low-priced materials.
2. The utilization of coconut husk and shell for combustion energy as waste product of coconut led to the advantage condition for cost saving in drying copra.
3. The application of chimney effect gave the benefit of the indirect hot air aeration and smoke exhaust.
4. It is recommended that the door/regulator at the entrance of chimney exhaust of the combustion chamber be used to reduce heat loss.

Table 1. Performance of Copra Drying

Components	Values
Initial weight(included shells)	320 kg
Initial moisture content	52.2 %w.b.
Drying time	38 h
Final moisture content	11.4%w.b.
Biomass fuel consumption:	
Husks	131.9 kg
Shells	42.7 kg
Dried copra quality :	
Oil content	62.1%
Free Fatty Acid (FFA)	1.2%
Water content	10.6%

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