

Design and Development of Semi-Direct Copra Dryer for Flat Terrain

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Abstract

The study was conducted to design and develop a semi-direct dryer for flat terrain. The components of the dryer were the drying bed, plenum chamber, tunnel and firing chamber. It has a capacity of 2,000 nuts and the husks from the nuts were used as fuel for the dryer. The means of the average drying temperature on the front, middle and rear portions of the drying platform were 56.5°C, 58.2°C, and 58.4°C, respectively. The average time of drying in bringing down the moisture content of the copra from 50% to 12% wet basis was 24 hours using 66.30% of the husks. As of October, the total cost of the dryer with shed was P 62,000.00 and the computed break-even cost was P 1.82/kg. This dryer provides coconut farmers an alternative to existing dryers particularly the semi-direct since it is only suitable for rolling terrain.

Key words: Design, development, semi-direct copra dryer, terrain, copra

Introduction

Importance of the Study

The “tapahan” dryer is commonly used by the coconut farmers in the Philippines in copra processing. According to Raghavan (2010), the basic features which make the “tapahan” dryer preferred by farmers are: high thermal efficiency of the dryer, low cost of construction, simplicity of the design and low cost of fuel. However, de Castro (1978) stated that copra made from “tapahan” are most often unevenly dried and usually blackened by soot. Sudaria (1993) also mentioned there is a high probability of the “tapahan” together with the copra getting burned because the firing place is directly under the drying bed.

Sudaria (1993) developed a semi-direct type copra dryer. It has the same heating principle as the “tapahan” dryer but the firing chamber is away from the drying platform connected by a tunnel. It was also cheap using only materials available on the farm such as coconut lumber, coconut fronds and bamboo. However, this dryer is only suitable when constructed on rolling terrain. Problems occur in the construction if the terrain is flat and the water table level is high. The firing place reaches the water table and the slope of the tunnel connecting the firing place to the plenum chamber is quite difficult to excavate resulting in an uneven heat distribution on the drying bed. There are developed copra dryers suitable for flat terrain particularly indirect dryers. The problems of this dryer were low thermal efficiency and very expensive (Escalante, *et al.* 1977). This dryer was designed to provide farmers an alternative to traditional and existing dryers particularly the semi-direct dryer.

Objectives of the Study

The general objective of the study was to design and develop a semi-direct dryer, evaluate the performance and determine the break-even cost of the dryer for flat terrain.

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Materials and Methods

Design Consideration

The following criteria were formulated based on the information collected from the coconut farmers, existing copra dryers, and personal experience to develop an up to standard copra dryer: a. cost should not be higher than any alternative dryers for flat terrain, b. construction should not require special tools, c. easy to use and maintain, the lifespan of the essential dryer components should be at least five years, a dryer can accommodate 2,000 coconuts per batch, heat distribution on the drying platform must be comparatively equal, thermal efficiency of not less than 12%, fuel usage is lower than 90% of the husks of nuts loaded and the performance is comparable to the existing semi-direct dryer.

Design, Construction and Testing

The semi-direct dryer for rolling terrain of Sudaria (1993) was the basis of the design. Modifications were made for it to be suitable for flat terrain. The design of the dryer was prepared using AutoCAD 2016. The dryer was constructed at Visayas State University, Visca, Baybay City, Leyte. The materials used in constructing the dryer were bamboo slats, hollow blocks, cement, sand, gravel, deformed round bars, and lumber. The components of the dryer were the drying bed, plenum chamber, tunnel and firing chamber.

Drying Bed: It had a dimension of 320 cm x 240 cm x 70 cm. Bamboo slats were used in the construction of the drying platform and laid 2 to 3 cm between slats. Beneath the bamboo slats were nine 5.08 cm x 15.24 cm lumber. The drying bed was elevated 215 cm above the ground and stairs were provided on the perimeter of the drying platform. The sides of the drying bed were made from 10.16 cm x 20.32 cm concrete hollow blocks supported by 10 mm reinforcing deformed round bars. The drying bed has a pathway of 75 cm x 75 cm near the center.

Plenum Chamber: It was made of compacted soil and has a spoon-like design with a parabolic curve with 1 m center depth from the drying platform.

Tunnel: It had an inner dimension of 55 cm x 55 cm with 10% inclination. It was made from 10.16 cm x 20.32 cm hollow blocks reinforced with 10 mm deformed round bars. The tunnel

has a wide opening with dimension of 150 cm x 240 cm near the drying platform. The tunnel has a total length of 300 cm.

Firing Chamber: The firing chamber was connected to the tunnel. It has a dimension of 80 cm x 190 cm.

A preliminary test was done after the construction. The dryer was tested without load using dry coconut husk as fuel. Laboratory thermometers were placed on the front, middle and rear portions of the drying platform. The temperature was monitored for 2 hours. The dryer was further modified and tested until the temperature on the different portions of the drying platform was comparatively even and ready for final evaluation. Figure 1 shows the orthographic views of the dryer.

Preparation of Coconuts

Mature nuts of Baybay Tall variety were used in this study. The coconuts were de-husked using a traditional dehusker. The removed husks were kept in a dry place and used as fuel for the dryer. The shell was cracked open by using a machete resulting in two almost equal "cups". The coconut water was drained off and the "cups" were dried with the meat still attached to the shell. The "cups" were immediately loaded on the drying platform with the first layer in a vertical position. The succeeding layers were placed in an inclining position and the topmost layer was placed with the kernel facing down.

Performance Evaluation

Twelve samples were collected randomly from the pile. Each sample was weighed using a digital weighing scale to determine the initial weight of the meat with the shell. The samples were labeled and placed on the bottom and top portion of the pile on the different location (right and left side of front, middle and back portion) of the drying platform. Laboratory thermometers were placed near the samples to determine the drying temperature and outside the dryer to determine the ambient temperature.

During the drying process, the weight of the samples and temperature were measured and recorded at an hourly interval. A constant feeding rate of 9 to 11 husks per 10 minutes of drying was observed to control and regulate the drying temperature. The drying was accomplished after 3 stages, i.e. 8 to 9 hours

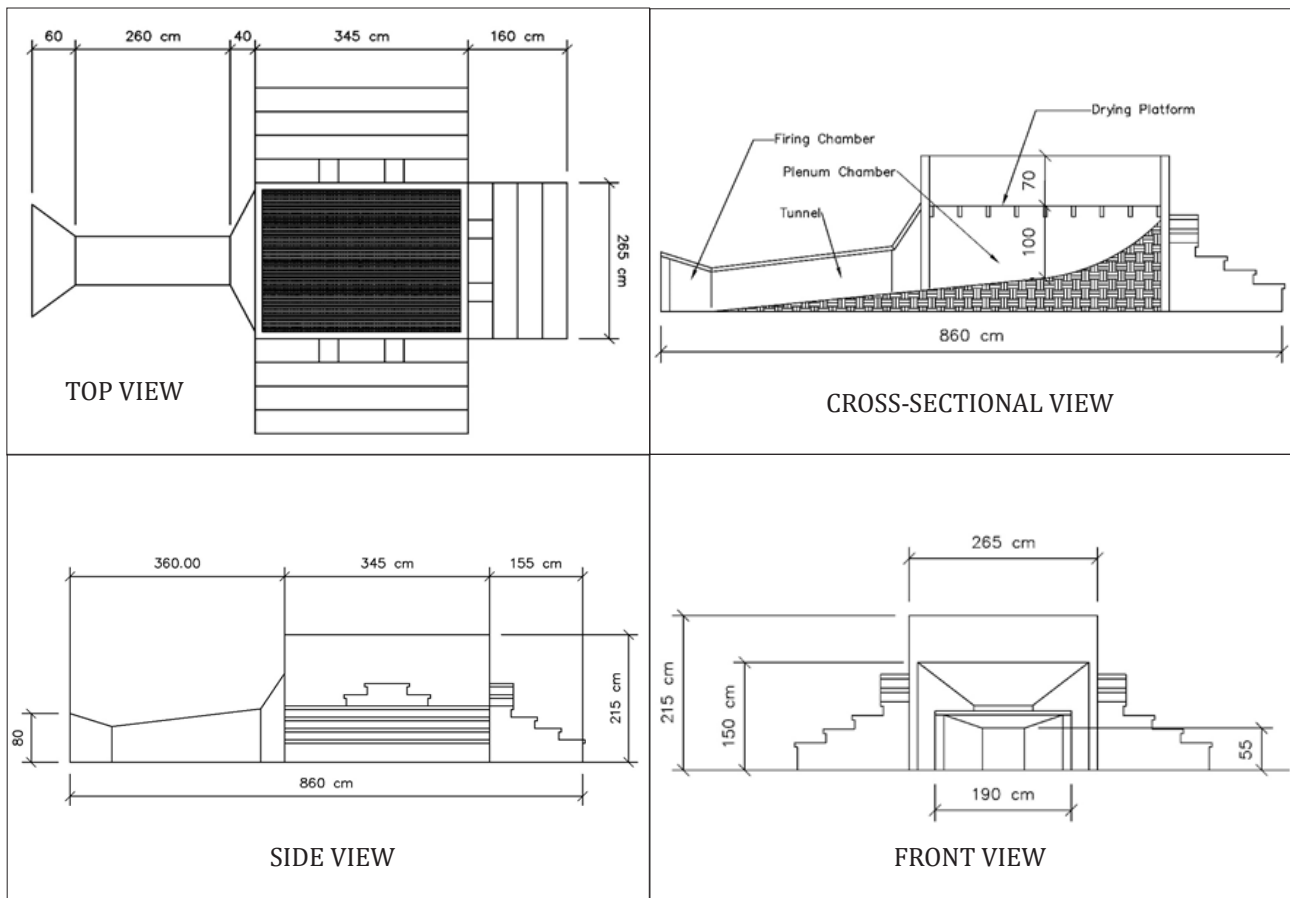


Figure 1. Orthographic view of the dryer

of continuous firing at daytime and allowed to cool-off during the night. At the 3rd stage of drying, the shell and meat were separated using a scooper when the shell and meat were partially detached. The weight of the shell was measured. The drying was stopped when the copra had reached a moisture content of 12%, the moisture content level where local coconut farmers sold their copra to village traders at a discounted price. This is referred to as the “pasa” system.

The drying was replicated thrice using 2,000 nuts per replication. The total drying time was recorded. The used coconut husks were counted to determine fuel consumption. The appearance of the copra produced was observed. The temperature difference on the different portion of the dryer was compared using one-way analysis of variance.

Estimation of Drying Efficiency

The drying efficiency of the semi-direct dryer was estimated using equation 1.

Eqn. 1

$$\text{Thermal Efficiency } (\eta_t) = \frac{\phi\lambda (M_o - M_f)}{WC (100 - M_o)} \times 100$$

Where, M_o = initial moisture content of coconut (% wet basis), M_f = final moisture content (% wet basis), ϕ = quantity of the final dried product at M_f moisture content (kg), λ = latent heat of vaporization of water in kcal/kg, W = quantity of fuel used (kg), and C = calorific value of fuel used (kcal/kg) (Sing *et al.*, 1999).

Determination of Break-even Cost

In determining the break-even-cost (BEC), the procedure discussed by Henderson *et al.* (1976) was used. It considered both the cost of the dryer and its output. BEC was computed in terms of amount per kilogram of copra.

RESULTS AND DISCUSSION

Semi-direct Dryer for Flat Terrain

The components of the semi-direct dryer were the drying bed, plenum chamber, tunnel and firing chamber. The drying bed had a volume of 320 cm x 240 cm x 70 cm with a capacity of 2,000 nuts. A passageway was made on the drying bed to ease the maintenance of the dryer. The firing chamber was 300 cm away from the drying platform connected by a tunnel. The tunnel connects the plenum chamber and the firing chamber and facilitates the flow of the hot air. The size of the tunnel was 55 cm x 55 cm for the first 260 cm and the remaining 40 cm was an enlarged cross-section going to the drying platform which regulates the airflow to have an equal distribution of heat throughout the drying bed. It had an inclination of 10% which ensures that the burned fuel from the firing chamber is not blown into the plenum chamber where it could burn the copra. The plenum chamber had a spoon-like design with a 100 cm center depth from the drying platform. The spoon-like design of the plenum chamber allows the dryer to evenly distribute the hot air including the corners of the drying platform which results to an equally cooked copra. A shed was constructed for continuous drying throughout the rainy season. Figure 2 shows the semi-direct dryer for flat terrain.

Development of the Semi-direct Dryer

The semi-direct dryer of Sudaria (1993) was modified particularly the inclination of the tunnel. Sudaria (1993) mentioned that the tunnel inclination for semi-direct dryer would be around 20 percent. However, the dimension was not suitable for the flat terrain. The height of the drying bed is 260 cm which is difficult when loading and unloading the copra. The tunnel inclination was modified to 10 percent to achieve a feasible height of 215 cm of the drying bed. Other dimensions i.e. volume of the drying bed, tunnel size, and firing chamber size were followed.

A preliminary test revealed that the heat distribution on the drying platform was uneven. The temperature on the front section of the drying platform was very high compared to the temperature on the middle and back sections of the drying platform. The temperature difference between the front and back section of the drying bed is about 15°C to 20°C. According to Sudaria (1993), the size and inclination of the tunnel affect the heat distribution on the drying platform. The total length of the tunnel was 300 cm. It was divided into two sections. From the firing chamber, for the length of 260 cm the cross section of the tunnel was 75 cm x 75 cm. The remaining 80 cm was an enlarged cross section going to the drying platform. By decreasing the



Figure 2. Semi-direct dryer for flat terrain

size of the tunnel, the air velocity increases thus the hot air could reach the back section of the dryer. The size of the tunnel was then reduced to 55 cm x 55 cm with a length of 260 cm and the remaining 40 cm was the enlarged cross section as shown in Figure 1. Reducing the tunnel size further would cause difficulty in maintaining the tunnel. The dryer was tested again with the modification. Result of the test revealed that the heat distribution on the different sections of the drying platform was comparatively equal with a temperature difference of 2°C to 3°C.

Performance of the Semi-direct Dryer

The average drying temperatures on the drying platform were 56.5°C, 58.2°C, and 58.4°C, on the front, middle and back portion, respectively. Figure 3 illustrates the mean temperature generated during drying. Table 1 shows the average temperature on the different portions of the dryer and the ambient temperature. Result of the one-way analysis of variance revealed that there are no significant differences of the temperature on the different portion of the dryer. The temperature at the

	Replication			Mean
	1	2	3	
Front	55.70	56.60	57.20	56.50 a
Middle	57.90	57.70	59.00	58.20 a
Rear	58.20	57.60	59.40	58.40 a

*Means having the same letters are not significantly different from each other at 5% level

Table 1. Average temperature (°C) of the different portions on the drying platform

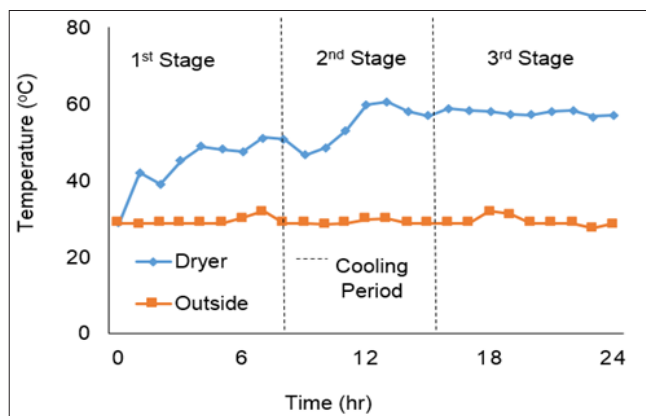


Figure 3. Drying temperature of the dryer

front, middle, and back portions of the drying platform were comparatively equal. The average drying time to bring down the moisture content from 50% to 12% was 24 hours using 66.30% of the 2,000 coconut husks. Figure 4 shows the drying curve of the copra. Sudaria (1993) reported that the existing semi-direct dryer has an average drying time of 23 hours to bring down the moisture content from 50% to 12% using 62.15% of the 2,000 coconut husks.

Drying Efficiency of the Semi-direct Dryer

The estimated thermal efficiency of the semi-direct dryer calculated using equation 1 was 12.6% to 14.3%. The existing dryers specifically the “tapahan” and modified kukum dryer have a thermal efficiency of 12.7% while the COCOPUGON dryer has a thermal efficiency of 15% (Dippon and Villaruel, 1996).

Appearance of the Copra

The color of the copra ranged from light to dark brown as shown in Figure 5. The appearance of the copra was similar to the copra produced by the existing semi-direct dryer.

Break-even Cost Analysis

The factors considered in getting the BEC were the cost of the structure, labor and the output of the dryer. The total cost of the structure (including the shed) and labor as of October 2020 was P 62,000.00. The total weight of the copra produced from 2,000 nuts was 504 kg. The computed break-even cost of the dryer was P 1.82/kg copra. The break-even cost of the existing semi-direct dryer and “tapahan” dryer ranges from P 0.60/kg to P 1.00/kg. Though the break-even cost

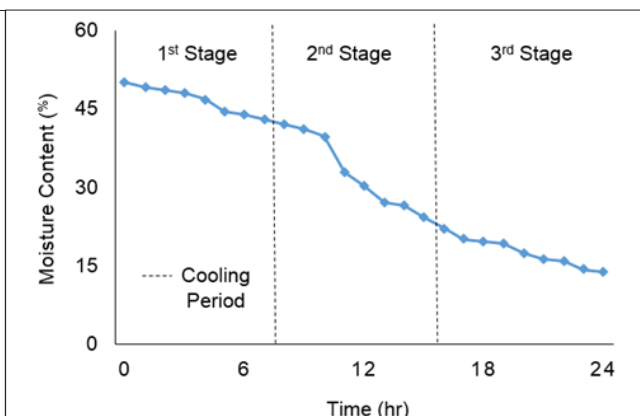


Figure 4. Drying curve



Figure 5. Appearance of the copra

of the existing dryer is lower than the new drier, when considering the life span of new drier, it has added advantage for the processors.

Summary, Conclusion and Recommendation

The study was conducted to design and develop a semi-direct dryer for flat terrain. Specifically, it aimed to design and construct a semi-direct dryer for flat terrain, to evaluate the performance of the dryer and to determine the breakeven cost of the dryer.

The components of the dryer were the drying bed, plenum chamber, tunnel and firing chamber. It had a capacity of 2,000 coconuts. The fuel used was the husk from the dried coconuts. The means of the average drying temperature on the front, middle and rear portions of the drying platform were 56.5°C, 58.2°C, and 58.4°C, respectively. The average time required to bring down the meat moisture content from 50% to 12% was 24 hours using 66.30% of the coconut husks. The estimated drying efficiency was 12.6% to 14.3%. The total cost of the materials was P 62,000.00 with a computed break-even cost of P 1.82/kg of copra. The color of the copra ranged from light to dark brown. The performance of the dryer was comparable to the existing dryers. It is recommended as an alternative to traditional and existing dryers, particularly the semi-direct and indirect dryers.

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