

Development of Cocoa Pod Husk Fueled Dryer for Rural Cocoa Farmers

Lawrence Atepor

Department of Mechanical Engineering, Cape Coast Technical University, Box AD 50, Cape Coast, Ghana.

Corresponding author email id: ccprector@gmail.com

Abstract – In order to help Ghanaian rural cocoa farmers, a cocoa pod husk fueled dryer has been designed and a prototype manufactured. It uses the husk heater for producing hot air and drying a drying chamber for accommodating the products to be dried. Performance characteristics of the dryer has been evaluated experimentally based on drying of 20Kg of wet cocoa beans. Analysis showed that the moisture reduction from 60.01% to 7.47% was achieved within 8 hours using the cocoa pod husk fueled dryer at an average drying temperature of 61.4 °C, and from 60.01% to 7.93% within 36 hours in open sun drying. The even drying efficiency of the dryer is above 91%. Hence, adopting the dryer will be beneficial to the rural cocoa farmer and will eventually help boost cocoa production for economic gains of the country.

Keywords – Cocoa, Cocoa Pod Husk, Dryer, Moisture Content, Time.

I. INTRODUCTION

Cocoa (*Theobroma cacao*) is the chief agricultural export of Ghana and Ghana's main cash crop [8]. It is cultivated in plantations in tropical countries such as Ivory Coast, Ghana, Indonesia, Brazil, Nigeria, Malaysia and Venezuela. Ghana is the second largest cocoa producing country in the world after Ivory Coast [10], with about 812,000 tons in 2018/2019 alone [9]. Cocoa is consumed widely as chocolate. The application of cocoa can also be found in beverages, cosmetics, pharmaceuticals, toiletry products and shoe polish among others [12].

Many small-scale rural cocoa farmers in Ghana have adopted open sun drying for cocoa bean processing. In open sun drying, cocoa beans are spread uniformly on mats, cement floors, rooftops and exposed to direct sunlight. The direct sun drying dries the beans raising its internal temperature without uniformity destroying the vitamins, flavor and colour of the cocoa beans. More over direct sun drying affects high products loss due to inadequate solar radiation during rainy cloudy days and its unavailability at night time. In open sun drying the beans are also affected by encroachment of insects, contamination by wind blown dust and dirt and rodent damage. Other drying methods such as solar and electricity are cost expensive for the peasant farmer. Therefore there is the need of sustainable solution to overcome the present problems faced by the poor rural cocoa farmer. Musa-Makama [6] has proposed hot-air drying of crops as a suitable alternative to sun drying in developing countries. The hot air in contact with the wet cocoa beans supplies heat and carries away the vapourised moisture. Biomass technology is the right and suitable option for drying cocoa beans because it is locally available on the farms and environmentally friendly and sustainable.

Cocoa processing consists of two major steps namely: fermenting and drying. The fresh beans are usually fermented using the heap, tray or box methods for 5 to 7 days [7]. In Ghana, the cocoa harvest season falls within the raining season, making it more important for a weather independent and affordable drying system.

Researchers like Asiedu [1], Fagunwa et al. [2] and Yeboah [11] have reported on using solar and other artificial drying methods for drying cocoa beans. However, literature survey shows that no research work has been carried out on the use of cocoa pod husk as fuel for drying cocoa beans. The cocoa pod husk is one of

biomass potential, which has been unused. It is an underutilized by-product of cocoa and some 800,000 metric tons of it are produced annually in Ghana [4]. It is the residue produced after removal of cocoa beans from the fruit. This paper therefore proposes the use of cocoa pod husks as fuel for a locally manufactured dryer for drying cocoa beans. This goal will be achieved by decreasing the over dependence on trees as a source of fuel in our rural areas. Adopting the use of cocoa pod husk as an alternative source of fuel will be at no cost to the rural farmer and in turn reduce deforestation which has had a significant contribution towards climatic change. In Ghana, majority of the people in cocoa business are the rural, illiterate and peasant farmers who cannot afford the costly and complex modern day dryers. Thus, this work presents a simple heated air cocoa beans dryer using cocoa husk as fuel which is cheap, simple to construct and operate, environmentally friendly and independent of weather conditions.

II. MATERIALS AND METHODS

The cocoa pod husk dryer is developed as an alternative to direct sun drying, solar dryer, firewood dryer and electrical dryer. The quality cocoa beans and waste cocoa pod husks (see Fig.1) were obtained from Cocoa Research Institute of Ghana (CRIG), Akim Tafo, Ghana. The materials used for the construction (see Figs. 2 and 3) are burnt mud bricks for the drying chamber (3), stainless steel for the drying plates (2) and cover (7), galvanized metal sheets for the chimney (1), heating duct (4) and paddle head and mahogany wood for the paddle handle. Air inlet holes (5) are provided for the flow of natural air into the drying chamber. Thermocouples for measuring the drying air temperature are installed at points (6).

The cocoa pod husk fueled dryer developed at Takoradi Technical University in Ghana used in this work is a modified version of a batch dryer by Komolafe et al. [5] and it is shown in Figs. 2 and 3. The mud brick walls of the drying chamber helps to reduce heat loss. In the drying chamber is the heating duct where dried cocoa pod husk is burnt to heat the incoming air. One end of the heating duct is opened for fuel loading and air inlet, while the other end is connected to the chimney through which the fumes are expelled. The floor of the heating duct are perforated to enable ashes from the burnt husk to drop on a collection tray. Two perforated drying trays are placed inside the drying chamber from the top. A cover with locking facility is provided for loading and unloading of cocoa beans from the top of the drying chamber.

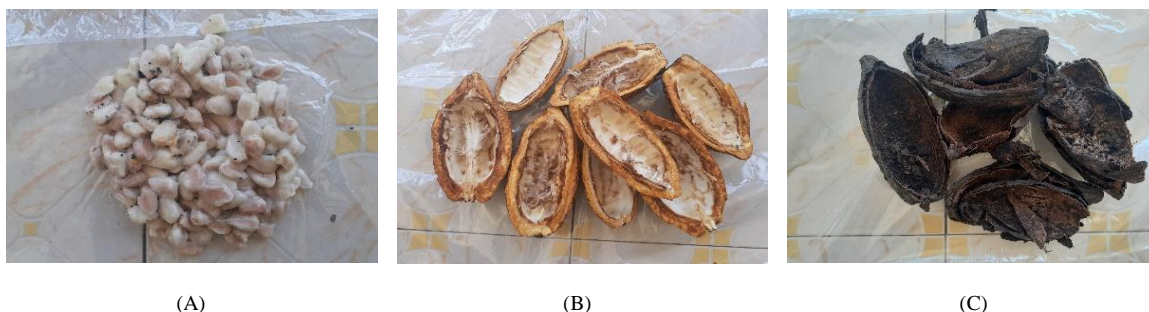


Fig. 1. Pictures of (a) wet cocoa beans (b) raw cocoa pod husk (c) dried cocoa pod husk from CRIG.

III. EXPERIMENTAL PROCEDURES

Drying experiments were carried out to study the performance of the dryer. 20 kg of fresh cocoa beans with an initial moisture content of 60.01% were procured. These were weighed and spread uniformly on the trays. Drying was started after burning of the dried cocoa pod husk fuel in the heating duct. Weight loss of the beans

were measured every one hour and recorded in Table 1 until the beans reach the required moisture content. The same weight of fresh cocoa beans were also dried in the open sun and the weight loss measured every two hours and recorded in Table 2. The experimental results obtained from the two drying processes are then compared.

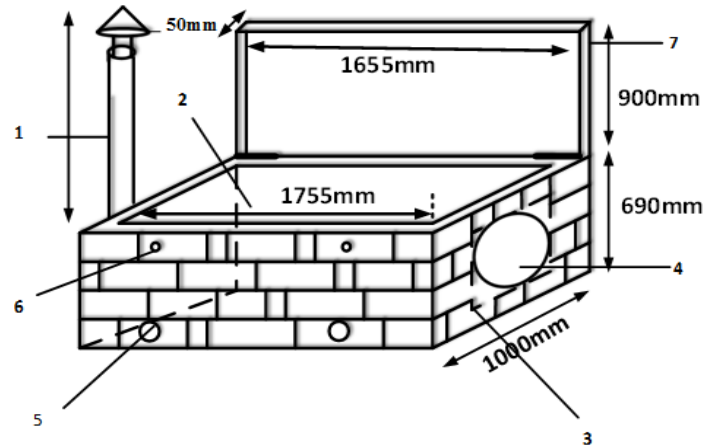


Fig. 2. 3-D view of the Cocoa pod husk fueled dryer.



Fig. 3. The Cocoa pod husk fueled dryer.

IV. DETERMINATION OF THE MOISTURE CONTENT

The following parameters were calculated to assess the performance of the cocoa pod husk fueled dryer.

4.1. Moisture Content

This is the percentage of moisture present in the cocoa beans. The moisture content on wet and dry basis is calculated using the following equation.

$$M_C = \frac{M_i - M_d}{M_i} \times 100, \text{ Where, } M_i \text{ is the initial mass and } M_d \text{ is the dry mass at any given time } t.$$

4.2. Drying Rate

This is the decrease in the water concentration during the time interval between two subsequent measurements divided by this time interval t .

$$D_r = \frac{M_c}{t}$$

4.3. Drying Chamber Efficiency

This is the ratio of difference between the drying chamber inlet and outlet temperatures to the difference between the drying chamber inlet and ambient temperatures.

$$\eta_c = \frac{(T_1 - T_2)}{(T_1 - T_a)}$$

V. RESULTS AND DISCUSSION

5.1. Cocoa Husk Fueled Drying

The wet cocoa beans were dried in the cocoa pod husk fueled dryer, and moisture content was calculated at different drying time intervals as shown in Table 1 and data were analyzed. The variation in moisture content against the drying time for the cocoa beans samples are plotted as shown in Fig. 3. It was observed that the moisture content of the samples decreases as drying time increases. The drying was carried out at an average temperature of 61.4°C. The moisture content decreased from 60.01% to 7.47% in the drying period of 8 hours. From Table 1 and Fig. 3, it is clear that the moisture content of the cocoa beans decreased with increase in drying time.

Table 1. Drying rate of cocoa beans using cocoa pod husk fueled dryer.

Initial Mass = 20kg

Initial Moisture Content = 60.01%

| Drying Time (hr) | Average mass (kg) | Average Temperature (°C) | Average Moisture Content (%) |
|------------------|-------------------|--------------------------|------------------------------|
| 0 | 20 | 61 | 60.01 |
| 1 | 14.12 | 62 | 30.61 |
| 2 | 12.20 | 62 | 21.01 |
| 3 | 11.09 | 60 | 15.46 |
| 4 | 10.06 | 61 | 10.31 |
| 5 | 9.16 | 61 | 9.10 |
| 6 | 8.34 | 62 | 8.13 |
| 7 | 6.94 | 62 | 7.47 |

Table 2. Drying rate of cocoa beans using open sun method.

| Drying Time (hr) | Average mass (kg) | Average Temperature (°C) | Average Moisture Content (%) |
|------------------|-------------------|--------------------------|------------------------------|
| 0 | 20 | 27 | 60.01 |
| 2 | 19.26 | 29 | 48.89 |
| 4 | 18.18 | 32 | 46.15 |
| 6 | 16.60 | 30 | 42.13 |

| Drying Time (hr) | Average mass (kg) | Average Temperature (°C) | Average Moisture Content (%) |
|------------------|-------------------|--------------------------|------------------------------|
| 8 | 16.13 | 26 | 41.37 |
| 10 | 15.05 | 27 | 38.60 |
| 12 | 14.43 | 30 | 36.99 |
| 14 | 14.24 | 32 | 27.83 |
| 16 | 14.01 | 32 | 25.14 |
| 18 | 13.14 | 27 | 23.82 |
| 20 | 13.02 | 27 | 22.22 |
| 22 | 12.88 | 31 | 19.98 |
| 24 | 11.73 | 32 | 13.61 |
| 26 | 10.06 | 32 | 12.24 |
| 28 | 9.31 | 28 | 11.07 |
| 30 | 8.15 | 27 | 9.64 |
| 32 | 7.89 | 31 | 9.51 |
| 34 | 7.21 | 32 | 8.32 |
| 36 | 6.98 | 32 | 7.93 |

5.2. Open Sun Drying

The same quantity of cocoa beans sample was spread on a mat and dried in open sun for a total period of 36 hours. The drying period spanned from 9.00 am to 5.00 pm for the first and subsequent days until we had a total of 36 hours. During the drying process, the moisture content of the sample was determined at every two-hour interval and this is shown in Table 2. The variation in moisture content against the drying time for beans sample are plotted as shown in Fig. 5. From Fig. 5, it was observed that the moisture content decrease from 60.1% to 7.93% in a total period of 36 hours and that the decrease in moisture content was slow and the rate of decrease was not consistent. This may be due to the varying intensity of the sun during the period.

In this particular case the average drying temperature was 29.7 and the moisture content decreased from 60.01% to 7.93% in 36 hours.

The graphs in Figs. 4 and 5 indicate that the drying was taking place in falling rate regime for both methods of drying as observed in most agricultural materials [3]. As compared to open sun drying, the cocoa pod husk fueled drying method saved about 28 hours of drying time.

5.3. Quality Evaluation

Physical appearance and color of the dried cocoa beans were observed visually. The surface colors were observed critically, and the Fig. 6 shows photographs of grading operation of the dried cocoa beans. Sun dried

beans in Fig. 6(a) were a bit darker in color and their quality got deteriorated from observation point of view. The dryer dried beans in Fig. 6(b) looked better and brighter in color.

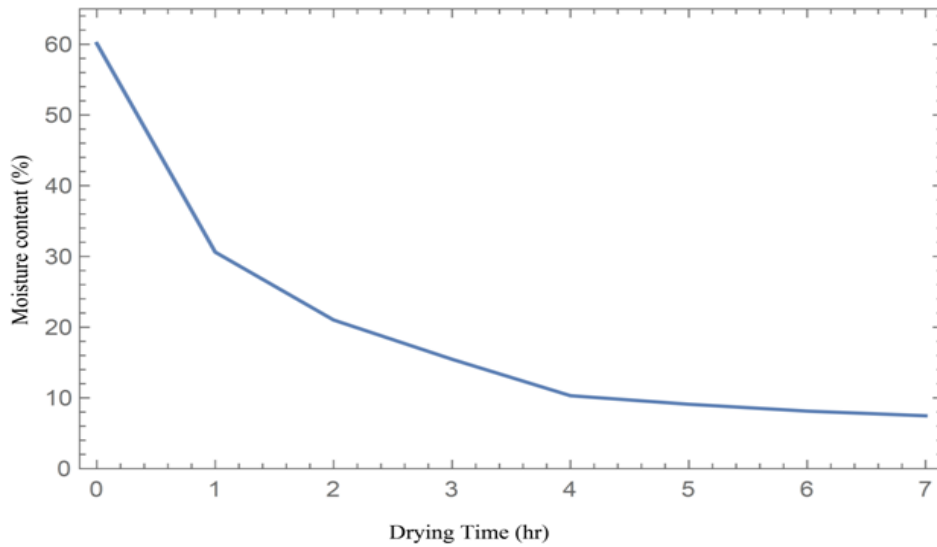


Fig. 4. Variation of moisture content against drying time in Cocoa pod husk dryer.

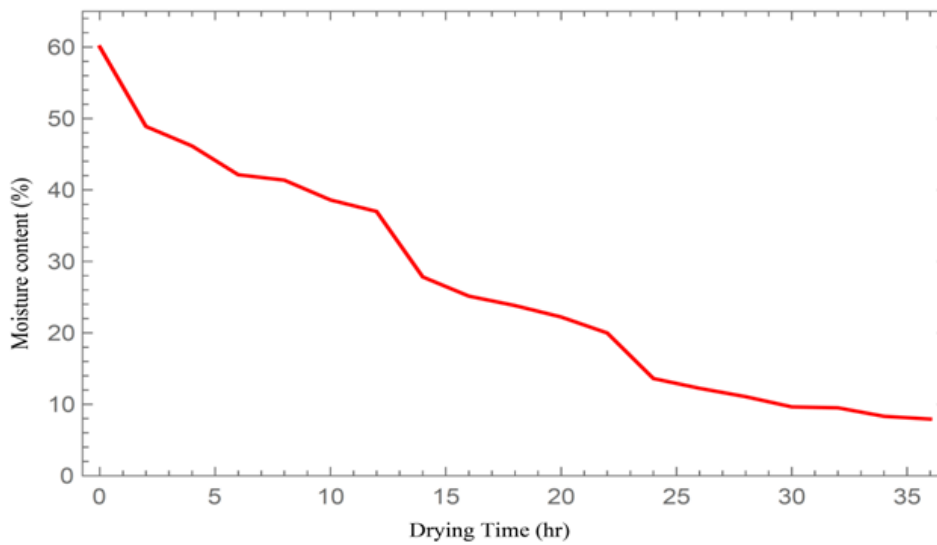


Fig. 5. Variation of moisture content against drying time in Open sun drying.



(A)



(B)

Fig. 6. Visual appearance of the dried cocoa beans. (a) Open sun dried beans and (b) Cocoa husk fueled dryer dried beans.

VI. CONCLUSION

The cocoa pod husk fueled dryer was designed, constructed and tested at Takoradi Technical University, Ghana for drying cocoa beans. Based on the experimental results the following conclusions can be drawn.

- The developed dryer is suitable for drying maximum of 20 kilograms of cocoa beans in one batch from initial moisture content of 60.01% to 7.47% in 8 hours.
- The average drying chamber temperature of 61.4 °C was obtained.
- The maximum biomass system even drying efficiency of 91.5% was obtained.
- The technology can improve the life style of the rural community cocoa farmers in Ghana.

The cocoa pod husk fueled dryer can be recommended for rural community utilization. Biomass fuel such as cocoa pod husk are easily obtained and are in abundance on the farms. Being operated under a shed reduced the effect of rainfall and other environmental affecting factors. The total cost of about Seven hundred and seventy-six Ghana cedis (GH¢ 776.00) which is equivalent to about one hundred and twenty-nine United States of America dollars (USD 129.00) is considered cheap and can be adopted by the rural cocoa farmers for timely and effective drying of cocoa beans as an alternative to open sun drying method.

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AUTHOR'S PROFILE



Lawrence Atepor is an Associate Professor of Dynamics. He had his M.Sc. in Mechanical Engineering from Tashkent Institute of Engineers of Irrigation and Agricultural Mechanization, Tashkent, Uzbekistan, U.S.S.R in 1992. He had his P.h.D. in Mechanical Engineering from University of Glasgow, Glasgow, UK. in 2009. He is now with the School of Engineering, Mechanical Engineering Department of Cape Coast Technical University, Ghana. His research interests are in Vibration Analysis and Control of Structures, Linear and Nonlinear Dynamics of Structures, Mechatronics/ Automobile Control, Renewable Energy and Applied Human Factors and Ergonomics. He has published 10's of research papers in international journals and conferences and has authored 3 books. email id: lawrence.atepor@cctu.edu.gh