Design and Development of Solar-Powered Mechanical Dryer for Small-Scale Cacao Processing

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Abstract –*Cacao is one of the most lucrative commodities sold in the world market. Methods of drying the cacao beans are usually by sun-drying and artificial or, forced air drying, depending on some socio-economic considerations and prevailing climatic conditions. The quality of cacao beans is dependent on the proper drying method. The need for a cacao dryer which is responsible for obtaining the appropriate moisture content of beans is considered one of the ways to increase income of cacao growers. Hence, this study was conducted to design and develop a mechanical dryer for small-scale cacao processing with the goal of increasing the income of cacao growers. It is therefore imperative that the drying operation be given utmost importance during cacao processing since it also affects the quality of cacao beans. The study employed the R& D Method which was conducted for six months. Findings revealed that the developed cacao dryer is a convenient facility for cacao drying. In like manner, the material was assessed with acceptable quality based on its simplicity, mobility design, technical efficiency, and versatility. Hence, the use of the developed cacao dryer promotes technical and economic advantages to cacao growers.*

Keywords –*cacao dryer, design and development, technological efficiency, extension project, higher income, drying cost*

INTRODUCTION

Cacao, (Theobroma cacao), also called cocoa or tropical evergreen tree grown for its edible seeds, whose scientific name means "food of the gods" in Greek is one of the most important cash crops in the Philippines. Cacao is the main ingredient in chocolate production and there is no other crop or product that can substitute it in as far as chocolate production is concerned. Among the intermediate products which can be derived from cacao beans are cocoa nibs, cocoa liquor (tablea), cocoa cake, cocoa butter, cocoa powder and chocolate confectionary blocks. Its diversified use, both for food and non-food, provides broader market opportunities [1].

The design and development of cacao mechanical dryer which is efficient for small-scale processing is considered one of the ways to help cacao growers in the Philippine countryside. Most of the farmers are commonly drying cacao beans by direct sunlight with spread out on mats or concrete floor and the process usually takes 3-4 days to dry cacao beans which is always dependent on the weather. The development of cacao dryers will improve the quality of cacao beans even weather conditions are not favorable.

Agricultural products like cocoa are harvested all year round and the beans must be dried immediately after fermentation to reduce mass losses and prevent spoilage [2]. Reported in the Philippine Road Map for Cacao [1], the Philippines is among the countries in Asia seen to have a competitive advantage on cacao production given its strategic location and climatic condition. The two (2) million (M) hectares of coconut farms are ideal for cacao intercropping supplement the industry's competitive advantage.

At present, based on the data of the Municipal Agriculturist Office of the municipality of Lasam, Cagayan, Philippines, it has a cacao plantation with around 58,528 trees that include 16, 537 trees which are fruit bearing. It has been identified that cacao processing greatly hampers from productivity particularly on the drying method of cacao beans due to varying environmental factors.

As an analysis of the problem, obtaining proper moisture levels at the completion of the drying process is of paramount importance in cacao processing. If cacao beans are too dry or over dried, flavor quality is affected. They will become brittle and produce too many broken beans during hulling. On the

other hand, if beans are too wet or not being dried sufficiently, they will mold easily causing rapid deterioration due to fungi and bacteria. Sun drying is the most popular method used by Philippines smallholders to dry cocoa beans. However, the main harvesting season usually coincides with the rainy season and the risk of mold development due to prolonged drying is possible. Labor is often needed to attend to the drying process, especially in the event of rain. Hence, the direct solar dryer was developed for smallholders because of its simplicity in design and in operation/maintenance, and ability to dry small quantities. It uses direct sunlight to dry cocoa beans placed inside a transparent enclosure. The transparent enclosure has the advantage of protecting the cocoa beans from unfavorable weather conditions. Therefore, it is important that drying operation should be given consideration during cacao processing since it totally affects the quality of cacao processed products.

In dried cocoa beans, the moisture content of good quality cocoa is about 7 % [3]. The long direct exposure to solar radiation results in quality deterioration of the cocoa beans [4]. Hot-air drying of crops has been receiving much attention as an immediate alternative to sun-drying in developing countries. Upon harvesting of ripe cacao pods, fresh cocoa beans were fermented in wooden boxes for 5-7 days and dried until it reaches the safe moisture level of 7.5% [5]. According to Komolafe [6], a loss of 55 to 64% in weight of cocoa beans occur during fermentation and drying of the beans.

Presently, there are several commercial dryers available in the market, but they are very expensive. After all, the operating cost of those dryers is dependent on the large consumption of kerosene, gasoline, and liquefied petroleum gas and other non-renewable energy resources to generate heat for drying. Likewise, the sources of energy are becoming house gasses that directly affect the environment leading to global warming and climate change.

The use of renewable energy is environmentally and economically sustainable alternatives to costly and polluting non-renewable fuels [9]. Applying renewable energy effectively is one way of sustaining and or accelerating quality of life of rural households such as energy for cooking and lighting, to the environmentally friendly technology required for food production activities. In addition, it is also an important source of energy supply for empowering small and medium-scale industries to process high-value crops such as cacao. Solar dryers improve the quality of cacao beans [5]. When weather conditions are not favorable, artificial drying method can be resorted to by using fan or blower to drive air across heating elements, raising the temperature and eventually reducing the moisture content of the cacao beans [7].

The solar cacao mechanical dryer was developed taking into consideration the criteria namely technical efficiency, simplicity in construction and operation, availability of construction materials, and mobility. Likewise, information on the design was derived from data published earlier by researchers, interviews, observations, and particularly the reviews of existing drying facilities and techniques.

OBJECTIVES OF THE STUDY

Generally, the project aims to produce locally made equipment for cacao processing. It specifically aims to: design and develop a cacao drying equipment; conduct testing and evaluation of the developed equipment.

METHODS

Research Design

The study employed R & D method. The method was employed in the context of designing and developing a solar-powered cacao mechanical dryer for small-scale processing. It considered the important factors along information, field observation, interviews and reviews of existing dryers with the process of designing, construction, testing and evaluating the material. This method of research is used for the purpose of improving and innovating material. This type of research is a systematic study of the design, development and evaluation process with the aim of establishing an empirical creation of instructional materials and non-instructional material products [9]. The project aims to design a cacao mechanical dryer which can be used by the cacao growers and processors

Philosophy of the Design and General Considerations

The dryer was conceived as low-cost, easy-to-fabricate and easy-to-operate equipment, using available local materials, in order to make it suitable for cacao growers and processors. It is also movable and can be used anytime, user-friendly and it can dry approximately 5 to 10 kilos of wet cacao beans in a single operation, and technically efficient.

The process of Constructing the Product

In order to design and develop the cacao beans dryer, the following process and procedure will be considered: (1) Make a design by creating a blueprint with detail and size; (2) Secure all the components and parts listed ; (3) Measure the materials according to the size of the designed drawing; (4) Cut the materials according to the size; (5) Check the coil heater temperature, Fan, and the Dynamo; (6) Review the work, and make sure that everything is correct; (7) Proceed to test to dry cacao beans; (8) Check time and the temperature needed to dry; (9) Record if what the result is.

Drying Experiment

For the drying experiment, the fresh cacao bean samples were gathered from the different mixture of verities. The first trial was conducted in January 2018 and the 2nd and 3rd trials in February 2018. Prior to the drying process, the fresh beans were fermented for 6 days using the basket method. The average of 40 kilograms of cacao beans fermented with the initial moisture content of 55% wet basis was loaded into the rotating screen basket for each drying test to satisfy the estimated high loading rate.

Moisture reduction was identified by weighing the representative sample. Drying continued until the mass of the beans remain unchanged and also in accordance with Opeke [11] that drying should stop when the color of the beans turned brown and a pressed handful of beans together gives crack shells (testa) and a bean cut with the knife gives separated cotyledons.

Evaluators, Evaluation Criteria, and Data Analysis

In this project, 15 evaluators composed of 10 faculty members and 5 cacao growers and processors were the evaluators of the product. They were taken purposively to evaluate the developed solar-powered cacao dryer. The main sources of data were the responses from the answered assessment checklist.

After the design and development of the material, a score sheet was developed by the researchers to evaluate the quality of the output. The following criteria were technical efficiency, simplicity, mobility, design, and user-friendliness. The performance characteristics of the material employed in three trials.

The following scale of means was used by the researchers to assess the quality of the product: 1.00-1.79- Not Acceptable/ Not Capable; 1.80-2.59- Acceptable/ Capable; 2.60-3.39- Moderately Acceptable/ Moderately Capable; 3.40-4.19- Much Acceptable/ Much Capable; 4.20-5.00- Very Much Acceptable/ Very Much Capable.

RESULTS AND DISCUSSION

Design Features of the Material

The developed cacao beans dryer and its general features are presented in Figure 1 which shows the isometric view of the cacao mechanical dryer. The dryer measures 126 cm long and 90 cm width. Its front and back walls measure 20 cm and 35 cm in height, respectively.

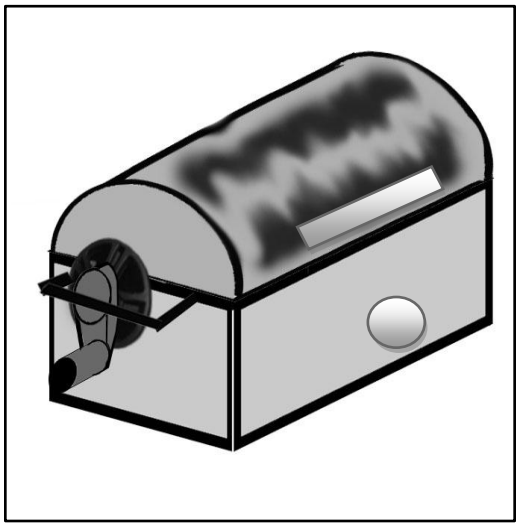

Figure 1. Isometric View of the Cacao Mechanical Dryer

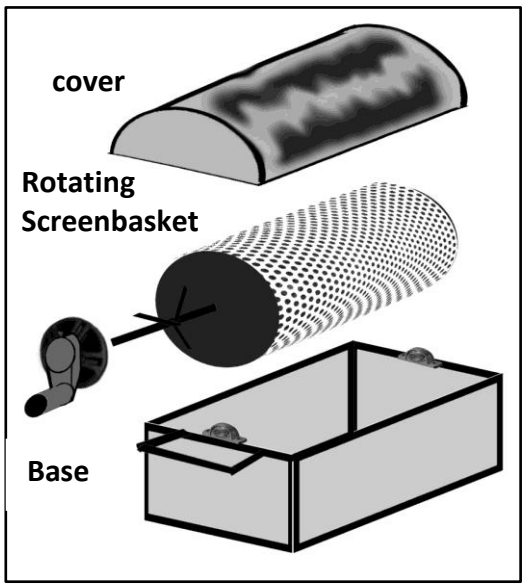

Figure 2. Isometric View of the Cacao Mechanical Dryer with Major Assembly Parts

The cacao dryer consists mainly of the cover, drying roller, and the base as shown in Figure 2. It consists mainly of three major parts.

The cover and base portions are made up of metal while the roller screen inside the machine has a size ½ pillow block. The circle diameter inside the box is made up of no. 12 screen. The drying roller holds the beans during drying which is made of stainless steel. Electric component of the machine was also installed. Coil heater is also installed in the material. A 12 volts dynamo is attached to the axel of the rolling screen. The inner walls of the compartment are lined with heat absorbing materials like a galvanized iron sheet.

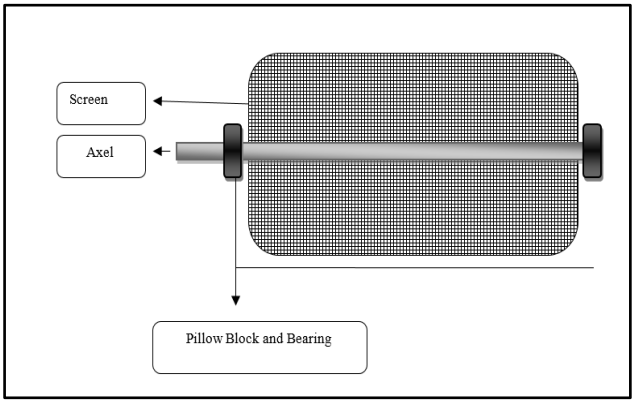

Figure 3. Isometric View of the Rolling Dryer Screen

Figure 3 shows the isometric view of the rolling dryer screen where cacao beans are dried. The axel connects with the dynamo gearbox holding the screen while the pillow block and bearinghold the axel being rotated.

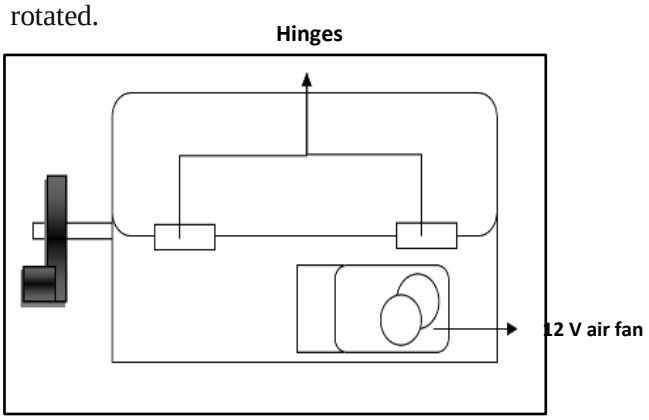

Figure. 4. Isometric View of the back portion of the cacao dryer

Figure 4 shows the back-view portion of the cacao dryer.the hinges are connected to the door of the machine and the 12 volts intake air fan is used to inhale air from the outside in order to maintain the temperature of the machine avoiding the beans to be over roasted and dried. The 12-v air fan has time delay switch operated within 20 seconds and will turn off in 3 minutes then operate again. Figure 6 shows the actual material painted with a hard coat primer and outside top coating using black metal paint.

Figure 6.Actual Picture of the designed and developed cacao mechanical dryer

A solar cacao dryer is mainly made up from galvanized sheets and wood consists of the following major components; the solar collector, the drying chamber and the heat storage chamber [13]. An air duct connects the upper end of the solar collector to one of the drying chambers. Investigations have been undertaken and reported on drying of cocoa beans using solar and artificial drying methods in comparison with traditional/ open sun drying [13], [12],[15].

Technical Performance of the Cacao Dryer

Results of the test are presented in Table 1 shows that the weight of cacao beans varying from 9.4 kg to18.6 kg and initial moisture content ranging from 59.0% to 61.2%. At a drying temperature range of 50.2 to 51.1°C, the drying time varied from 9.2 to 10.0 hrs. To get the capacity, the weight of cacao beans

dried over a period of time expressed in kg/hr has been considered. The Table above also presents that the drying capacity of the cacao dryer varied from 1.03 to 1.02 kg/hr. This suggests that the designed and developed cacao dryer is a good substitute for open sun-drying method, particularly when being isolated from the sun is low because it is dependent on the weather. Therefore, the dryer is expected to help boost the cacao processing in the Municipality of Lasam, Cagayan.

Table 1. Performance of the Cacao Dryer

Design	T1	T2	T3
Initial Weight (kg)	18.3	19.3	18.2
Final Weight (kg)	9.4	10.1	9.3
Initial Moisture Content % w.b.	59.5	61.2	59.0
Final Moisture content, % w.b.	11.4	12.2	11.1
Drying Time, hr	9.24	10.0	9.2
Drying Temperature (°C)	502.	51.1	50.2
Dryer Capacity, kg/ hr	1.04	1.02	1.03

Dried beans produced have the distinct chocolate flavor at a loading rate of 40.5 kg/m^2 [10]. Indirect solar dryer for fermented cacao beans improved quality of dried cacao beans.

Table 2. Assessment of the Quality of the Developed Cacao Dryer

Criteria	Mean	SD	DI
Simplicity	3.73	.88	Much Acceptable
Mobility	3.13	.83	Moderately Acceptable
Design	4.20	.67	Very Much Acceptable
Technical Efficiency	4.13	.83	Much Acceptable
Versatility	3.40	1.18	Much Acceptable
Grand Mean	**4.20**	**.20**	**Very Much Acceptable**

Table 2 presents the quality assessment of the developed cacao dryer. The general assessment of the evaluators obtained a grand mean of 4.20 described to be very much acceptable. This suggests that the developed material provides a convenient drying facility for cacao beans. Hence, the material is socially sounded, acceptable and adaptable for cacao processors particularly in the Municipality of Lasam since it can address the concern of the increase in the income of small cacao growers and processors.

Among the criteria, the evaluators assessed the design of the material very much acceptable with the mean of 4.20 (SD=.67). In like manner, technical efficiency rated with 4.13 (SD=.83), simplicity with the mean of 3.73 (SD=. 88), and versatility obtained the mean of 3.40 (SD=1.18) were assessed to have much acceptable quality. Finally, mobility obtained the lowest mean of 3.13 (SD=.3.13).

Design and simplicity of the material rated with very much acceptable and much acceptable qualities suggest that the developed material has ease of operation and maintenance as a drying machine. Its technical efficiency shows a good rate of moisture reduction accomplished during the drying process without damage to the cacao beans. In like manner, the versatility of the developed cacao dryer manifests the ability to handle drying of cacao beans but also can be used by the cacao growers and processors for corn, coffee, and other vegetable beans. Further, since the material is made up of galvanized metal sheets and metal bars, the dryer itself is a heavyweight.

Hii, Rahman and Man [12] suggest that a solar cacao dryer was developed for smallholders because of its simplicity in design and in operation/maintenance, and ability to dry small quantities. Having the advantage of protecting the cocoa beans from unfavourable weather conditions.

Implications of the Project

The results of the study provided the small-scale cacao growers with information about the need to constantly monitor moisture content for cacao beans in order to determine the best drying time and procedures. The main benefit of the cacao growers and processors form the cacao dryer is a cleaner, more uniformly dried cacao beans with potential for higher quality, market price, and better cacao processed products. Likewise, labor and area needed for drying are also reduced making the small farmers more productive.

As an implication of the project, advantages from the use of cacao beans dryer are classified into technological advantages and economic advantages. Among its technical advantages are: (1) appropriateness for the humid tropics, with cacao dryer, immediate drying after fermentation of cacao beans is now possible elimination of unnecessary delays and consequently the losses; (2) reduced drying time considering the material is made up of galvanized iron sheet which can increase heat absorption within the rotating basket screen; (3) the versatility quality of the material can be used for other beans thus providing the farmers to optimize its use.

As to its economic advantages, (1) the material is capable of reducing drying cost, manpower requirements or labor costs, likewise, operating costs

will be very minimal; (2) higher income of farmers is expected since it allows small grower to dry their own production at their plantation and at the same time providing them possibilities of developing cacao-based products for economiclivelihood.

CONCLUSION AND RECOMMENDATION

The designed and development of cacao mechanical dryer were carried out. Results of the technical performance showed that the material is a convenient facility for cacao drying. In like manner, the material was assessed with acceptable quality based on its simplicity, mobility design, technical efficiency, and versatility. Hence, the use of the developed cacao dryer promotes technical and economic advantages to cacao growers. The designed and developed mechanical cacao dryer for small-scale cacao processing is cheaper compared to commercial machines available in the market. The dryer was built by locally available and low-cost materials making it more affordable for local farmers. In terms of drying time, the developed dryer also produced good quality of dried cacao beans like other mechanical dryers available in the market and the traditional method of drying.

After the conduct of design, development, testing, and evaluation of the cacao mechanical dryer, the following recommendations are hereby offered: (1) the material need to be light weighted for maximum use by the farmers, hence, stand and trolley wheels should be provided for better mobility of the dryer; (2) the overall design of the dryer should be altered in size to suit the drying demands of the users; (3) the developed product should undergo longer experimental testing to come up with the most desirable output; (4) after intellectual property rights registration and deposit of the cacao dryer, the extension office of Cagayan State University through the college of technology should initiate mass production of the material for community and commercial utilization.

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