Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 8 Issue 10, October - 2021

Renewable Energy Support to Farm Produce Processing: A Developed Hybrid Electric/Solar Powered Cocoa Beans Dryer

Ajibike Eunice Akin-Ponnle
Department of Electrical and Electronics Engineering,
The Federal Polytechnic,
Ile-Oluji, Nigeria.

***Abstract*— In most developing nations of the world like Nigeria, there is need to apply the concept of renewable energy support to rural and urban farming, in order to overcome poor productivity which often times occur due to deficient processing; storage facilities; and marketing. This in return usually results in a high proportion of wastage of farm products. Ambient air slow-drying of cocoa produce, which often result into partial or incomplete processing of the product in the situation of continuous or extended rainy season, thereby leading to reduced yield of the product and much losses to farmers. A 3kg capacity table top electric cocoa bean dryer has been developed; and in this paper, the use of hybrid renewable energy approach is presented; by incorporating a solar power/battery unit to the developed electric cocoa bean dryer so that drying can continue in the absence or interruption of mains electric supply. This development focuses on the need for high quality cocoa beans and for its application in small scale farming, and for peasant farmers in developing nations of the world.**

***Keywords*— cocoa beans, farm produce, hybrid electric/solar powered dryer, renewable energy, sun drying.**

I. INTRODUCTION

In many parts of the world, awareness is growing about renewable energy which has an important role to play in extending technology to farmers especially in developing countries like Nigeria to increase their productivity and annual yield of the crop. Cocoa Beans processing refers to drying of cocoa beans; which is a method of dehydration of cocoa beans by means of moisture content removal, in order to improve its shelf life, and also to prevent bacterial growth [1], [2].

Sun drying by spreading the beans under direct sunlight is mostly economical to farmers, but the product obtained by this means, is usually of lower quality due to contamination by dust, insects, pests, rainfall, and some other prevailing circumstances. Also, loss of vitamins, nutrients and unacceptable colour changes can occur to the produce due to direct exposure to ultraviolet rays of the sun; which will also take a long period of time to dry properly [3].

Poor storage infrastructure, processing facilities and marketing in many countries of the African region leads to a high proportion of wastage, which average between 10% and 40% annually [4]. This work was borne out of concerns to reduce the difficulty that most produce rural famers are facing in processing their products after harvest especially during unfavourable season of frequent and prolonged rainfalls [5].

A survey was carried out to investigate some cocoa stores in Ile-Oluji environs, which is a community with many local cocoa farmers. These stores are the immediate secondary handlers of the produce most of the time. They are in position to make perfect drying of the produce, and carry out storage in medium scales, before transferring to large warehouses, from where they are packaged for onward exportation or industrial supply. There was interaction with 20 store holders, who are experiencing varying challenges as a result of difficulties with produce processing. The outcome of the survey is shown in Fig. 1. The figure reveals varying challenges ranging from rodents' effects to impurities like stones, dusts, pebbles being introduced into the product during sun drying. Others are that some or part of the produce may be carted away by human theft during sun spreading, depending on the location where drying is taking place.

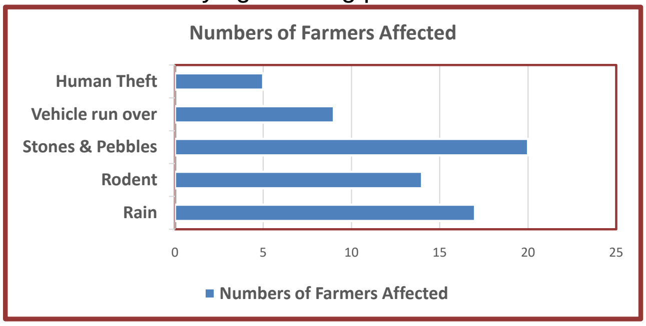

Fig. 1: Difficulties faced by handlers of Cocoa Beans at drying stage.

The mitigating effect of incessant rainfall is the major objective of this work. The work is aimed at the possibility of solving some of these problems posed by improper storage and sun drying of cocoa beans during rainy seasons. Therefore, with the use of hybrid electric/solar powered cocoa beans dryer, some or almost all of these problems stated earlier and as indicated in Figure. 1 can be prevented, and this will in return bring about proper processing of the produce.

A 3kg capacity table top electric cocoa-bean dryer had been developed at the power laboratory facilities of The Federal Polytechnic, Ile-Oluji, Ondo State, Nigeria. The functionality of this electric dryer is dependent upon constant power supply of electricity. However, owing to irregular supply of electricity as part of the challenges in the country, the possibility of solar energy harvester is introduced to the design which enables the electric dryer to harvest solar energy for storage in a battery during the day while there is sunshine and convert to thermal energy for drying the beans. This brought about a hybrid electric/solar powered cocoa bean dryer to dry the produce during rainy season as against ambient air drying. This will also ensure continuous drying of the produce at any required time or period. This developed unit though uses hybrid sources of power, but is different from solar dryers which use the sun's heat directly or indirectly; passively or actively to dry the cocoa beans.

Solar dryers are specialized devices that dry products using the heat from the sun either directly or indirectly, passively or actively. They control the drying process and protect agricultural products from damage by insect pests, dust and rain, instead of direct sun-spreading in the open air. A comparison was made between sun drying and solar drying, and it was obtained that solar dryers generate higher temperatures, lower relative humidity, lower product moisture content and reduced spoilage during the drying process than sun drying [6]. Research works have demonstrated that the drying time in case of solar dryers compared to open air drying is reduced by about 20% and produces better quality dried products [7]. Solar dryers are available in a range of sizes and design such as tunnel dryers, hybrid dryers, horizontal and vertical-type dryers, multi-pass dryers, and active and passive dryers [8].

In this paper, the earlier developed electric dryer is briefly presented. In this work, an external solar power/battery unit that can be connected to the dryer was developed. The process of harvesting solar energy which is by means of solar panel is excluded from the scope of this paper. However, the external solar power unit to the dryer is discussed, and the improvement recorded in drying and produce constituents are also reported.

II. MATERIALS AND METHOD

A. Description of the Table Top Electric Cocoa Bean Dryer

The developed table top 3kg capacity Electric Cocoa-Bean Dryer is shown in Figure. 2, and its functional block diagram is shown in Figure. 3.

Fig. 2: The developed electric cocoa-bean dryer. The solar power unit is at the back of the dryer.

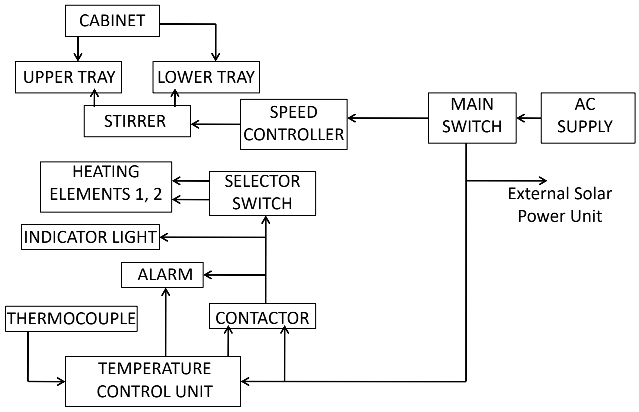

Fig. 3: Functional block diagram of the developed Electric Cocoa Bean Dryer.

Alternating current (AC) at 220-250V range is supplied to power the device through the main switch. The main switch also supplies power to the solar power unit for charging. The mains supply goes to the electrical section which handles the electrical part and electronics part of the device. The materials for the electrical section include; heating elements, switches, indicator lights, stirrer, speed regulator, insulator, contactor and thermocouple acting as temperature sensor. That which is for the electronics section include; potentiometer, triac, diac, temperature control unit, and electronic display.

The temperature control unit is an electronic unit which controls the temperature of the cabinet, and regulates the switching of the contactors to supply high current to the heating elements. It has an electronic display unit to indicate the cabinet temperature and the set temperature values. The thermocouple acts as temperature sensor that senses the heat in the cabinet and sends its output to the control unit which in turn set OFF the contactor when the set point is reached and as well set ON when the sensor senses a lower temperature to the set point. The thermocouple used has temperature rating from 0-400^{o}C.

The contactor switches high current to the heating elements. Two heating elements (round ring elements) are used but one at a time. This is achieved by incorporating a selector (rotary) switch between the contactor and the heating elements to switch either of the heating elements at a time to the contactor. This allows for the continuous usage of the machine even if one of the elements is faulty. In addition to the heating elements, a separate low power 12V DC filament type heater is put in the cabinet, which is connected to the external solar/battery power unit during mains power supply failure to continue drying.

In between the contactor and the rotary selector switch lies the pilot indicator light used to indicate that the contactor has produced current for the selector switch to power the elements. The temperature control unit also monitors the output of the contactor and controls a buzzer to raise an alarm in case if after the main set off temperature has set, the controller has triggered the contactor OFF, but the contactor did not set OFF, probably due to friction or arcing between the coils. The alarm will therefore be triggered thereby bringing the user to notice that the system has need to be shut down and properly maintained.

The mechanical section includes the cabinet, the two trays and the stirrer. A simple AC speed regulator using potentiometer, diacs, triacs and AC motor is used to control the speed at which the stirrer stirs the cocoa beans within the trays inside the cabinet.

B. The Solar Power Unit

As stated earlier that for continuous drying of the cocoa beans during mains electricity failure, an external solar power/ battery unit was developed which can be connected (through ports or receptacles) to the electric dryer. However, this unit only heats the cocoa beans through a separate filament heater, and charges the battery. It does not operate or control the whole electric dryer. This provision of an external solar power/battery unit for the dryer is possible because the dryer is a portable table top type of 3kg capacity, hence the low power filament heating with solar/battery operation can still be tolerated, and the whole unit can be affordable to peasant farmers. The solar power unit in functional block diagram is shown in Figure. 4.

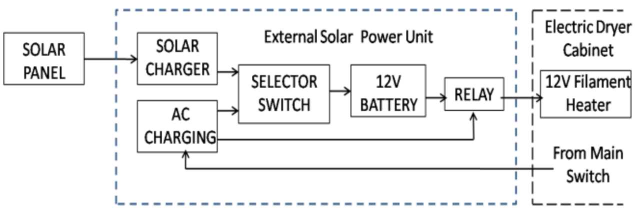

Figure 4: Functional block diagram of the developed external solar power unit.

A separate low power 12V DC filament type heater is put in the cabinet of the electric dryer to continuing drying of the beans whenever there is mains power failure. The external solar power unit consists of a solar charger, an AC charging unit, a selector switch, a 12V battery and a relay. The 12V battery is charged from a solar panel (external) through the solar charger, and the output of the battery is connected to the 12V filament heater in the dryer through a relay. The relay allows connection to the battery in the absence of the mains power supply, but senses the presence of the mains supply through the AC charging unit and cut off the battery connection to the filament heater. This is to prevent the filament heater, and the other high current heating elements from operating at the same time when the electric dryer is supplied with mains electricity. The AC charging also perform additional role of charging the battery when there is mains power supply, and this is made optional for the user by incorporating a selector switch between the solar charger, the AC charging unit, and the battery. Thus, the user can switch in between solar charging or AC charging of the battery as so desired. The power to the charging unit comes from the main switch in the electric dryer. The solar power unit is connected to the electric dryer through two ports – one for the 12V filament heater, the other for the main switch connection. The solar panel used is of 300W.

C. Testing Methods

System testing was carried out after the initial setup of the device. Two methods of testing were conducted to be assured the system is safe from any potential hazard. One of these tests was conducted when the heat emitter was connected. This test is known as the insulation test. It was discovered that there was leakage of electricity to the metal tray where the heating elements were placed. Therefore, mud was used as an insulator to stop current leakage to the tray and the cabinet body. The other test which was conducted is the earthing test. The earthing test was conducted to prevent over current and also to eradicate the remaining current which might be flowing on the cabinet. The earth cable is connected to the body of the whole appliance.

The drying method used in this work is the conversion of electrical energy to thermal energy; and solar energy to electrical energy to thermal energy. The material used for this process is the heating element which is housed in the cabinet. Heat temperature produced by the heating element is from 45ºC and above depending on the input current. Three drying tests by the device were conducted on the same quantity of cocoa beans batch, setting the device temperature at 60°C, 65°C and 70°C. An additional test of sun drying the same quantity of cocoa beans batch by spreading in the sun was also conducted.

Another test was also conducted by machine drying three batches of the cocoa beans at different temperatures of 60°C, 65°C and 70°C, and for different periods of time of 30, 60, 90 and 120 minutes. All were at initial moisture content of 80%, and the final moisture content for each period was noted. The addition of the solar power/battery unit as an alternative power source whenever there is power failure ensures continuous drying of the cocoa beans though at a reduced rate and lower temperature during the period of mains supply interruption.

III. RESULTS AND DISCUSSION

The results in Table 1 shows the quality test result of cocoa constituents when it is sun dried and when it is machine dried at different temperatures of 60°C, 65°C and 70°C using the hybrid dryer.

Table 1: Quality Test Results.

Condition	Free Fatty Acid (mg/g)	Acetic Acid (mg/g)	Pit Value	Taste	Colour
Sun Dried	0.40	3.50	5.30	Mild Bitter	Light Brown
Machine Dried (60°C)	0.67	9.50	4.60	Bitter	Dark Brown
Machine Dried (65°C)	0.73	10.30	4.50	Bitter	Dark Brown
Machine Dried (70°C)	0.80	11.10	4.40	Bitter	Dark Brown

The table shows the free fatty acid content, the acetic acid content, and the pit value of the cocoa beans for each case of drying. The resulting taste and colour of the dried cocoa beans are also indicated for each case. The fatty acid and the acetic acid contents increases with drying at higher temperature values with the sun drying having the lowest value (this is expected of spread sun drying) and drying at 70°C by the developed device having the highest value. The pit value decreases with drying at higher temperature values with the sun drying having the highest value and drying at 70°C by the developed device having the lowest value. It can be observed that the difference in the pit value between the sun dried ones and the machine dried at 60°C is significant, while the differences in the pit values of the machine dried at 60°C, 65°C and 70°C are very small. In drying of cocoa beans, the values of the free fatty acid content, the acetic acid content, and the pit value are very important.

Figure. 5 illustrates the graph of cocoa bean moisture content against the drying period (in minutes) in the hybrid electric/solar powered dryer. The figure shows final moisture content of the cocoa beans for the different drying period at different temperatures of 60°C, 65°C and 70°C. The initial moisture content of all is 80%. The final moisture content reduces with longer drying time. Also, the moisture content reduces faster at 70°C than for the other two temperatures. Careful observation of the figure shows that for each drying period, the final moisture contents are almost the same within the temperature of 60°C and 70°C. This agrees with literature that the required temperature needed for extracting the moisture from the cocoa beans ranges from 65ºC to 70ºC, with a stabilising temperature around 68°C. The advantage of the hybrid electric/solar powered dryer is that it ensures continuous drying of the cocoa beans during period of mains power failure or interruption.

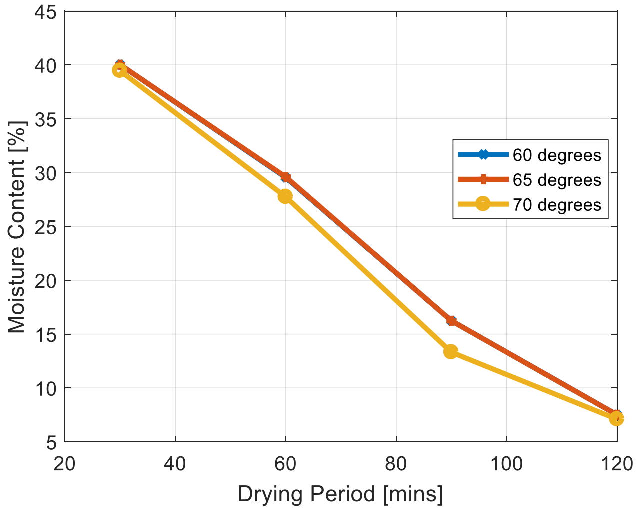

Fig. 5: Graph of bean moisture content against drying minutes: the electric cocoa dryer.

IV. CONCLUSION

A hybrid renewable electric/solar powered cocoa bean dryer has been developed and presented in this paper. This dryer dries cocoa beans faster than spreading in the sun for drying. It also ensures continuous drying of the cocoa beans during period of mains power supply failure or interruption. It can dry 3kg of cocoa beans within a period of 2 hours. The provision of an external solar power/battery unit for the dryer is possible because the dryer is a portable table top type of 3kg capacity, hence the low power filament heating with solar/battery operation can still be tolerated, and the whole unit can be afforded by peasant farmers. This hybrid electric/solar powered dryer is recommended for use in the immediate community of The Federal Polytechnic Ile-Oluji, Nigeria, and the developing nations of the world, to avail small scale farmers and store owners an improved design of the electric dryer with reduced cost of production. Also there will be improved yield and minimal wastage of the produce.

REFERENCES

[1] R. J. Fuller, “Solar Energy Conversion and Photo Energy Systems- Solar Drying- A Technology for Sustainable Agriculture and Food Production”, UNESCO- EOLSS, France, 2002.

[2] A. F. Alonge and O. A. Adeboye, “Drying rates of some fruits and vegetables with passive solar dryers”, International Journal of Agriculture and Biological Engineering, Vol. 5 Issue 4, pp. 83-90, 2012.

[3] C. L. Hii, C. L. Law, M. Cloke and S. Suzzana, “Thin layer drying kinetics of cocoa and dried

product quality", Biosystems Engineering Journal, Vol. 102, pp. 153-161, 2009.

[4] C. A. Komolafe, A. O. D. Adejumo, O. Awogbemi and A. D. Adeyeye, "Development of a cocoa beans batch dryer", American Journal of Engineering Research (AJER), Vol. 3, Issue 9, pp. 171-176, 2014.

[5] A. Kanmogne, Y. Jannot, and J. Nganhou, "Design and realization of a cocoa hybrid dryer for a rural zone", International Journal of Mechanical Engineering and Technology (IJMET), Vol. 4, Issue 6. pp. 201-213, 2013.

[6] J. K. Yohanna, I. N. Itodo, and V. I. Umogbai, "A Model for Determining the Global Solar Radiation for Makurdi", Nigeria Journal of Renewable Energy, Vol. 36, Issue 7, pp. 1989-1992, 2011.

[7] S. J. Sharma, V. K. Sharma, J. H. A. Ranjana and R. A. Ray, "Evaluation of the performance of a cabinet type solar dryer" Energy Conversion Management, Vol. 30, Issue 2, pp. 75–80, 1990.