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A Portable Electronic Cocoa Bean Dryer As An Alternative Implement for Small-Scale Farmers

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***Abstract*— Cocoa beans must be dried to reduce its moisture content to a safe level for storage. The drying process is also a continuation of the oxidative stage of fermentation of the beans, thus, further reducing the constringency and bitterness of the product. Properly dried beans, at about 6-8% moisture content (wet basis) usually have reduced acidity and are characterized by the familiar 'chocolate' brown colour. Methods of drying the beans are usually by sun-drying and artificial or, forced air drying, depending on some socio-economic considerations and prevailing climatic conditions. Sun drying is simple and cheap, not requiring the expensive mechanical devices used in the artificial dryers, but it is labour-intensive and there is much concern for a stable weather condition. Hence, this paper presents the development of a prototype portable electronic cocoa bean dryer for drying of the produce in the face of unfavourable weather conditions, and also for improving the quality of the produce and preventing it from contamination. The dryer cabinet is of dimension 61 cm by 41 cm by 35 cm, with the capacity to reduce moisture content of cocoa beans of 3kg per batch from its initial content to 7.5%. This was within two hours of continuous drying at an average temperature of 68^{o}C, and the dryer was at 89% efficiency**.

Keywords*— *cocoa bean; chocolate; electronic dryer; rainy season; forced-drying

I. INTRODUCTION

The end products from cocoa (known as Theobroma cacao L.), especially chocolate and beverages are basic food in many countries of the world. However, the quality of these end products is a function of how they are processed, [1]. Cocoa is third in the world ranking of exported agricultural products after coffee and sugar. In the majority of cases, it is produced by small scale farmers with 90% of the production in rural zones [2]. Nigeria cocoa represents 0.6% of her total exports, [3]. Trade Standard Organisation tackles the problem of the quality of cocoa bean through standard references defined in the sales contract. The French standards, which is a bit different from the American or English standards stipulate that "the delivered goods must be reasonably free of foreign broad beans tastes from the cocoa and of defective broad beans" [4]

Currently, in the world market, there is a level of rating of cocoa beans coming from Nigeria, and the drying system among other factors is responsible for the approximate quality of the Nigerian cocoa, [5], since cocoa beans must be dried immediately after fermentation to reduce mass losses and prevent spoilage. Inappropriate handling in drying process can result to nothing less than 15% loss in post-harvest of tropical crops, [6]. As a consequence of; insufficient drying resulting to molding of the product, the smell of smoke and tar in bean, or the presence of pebbles in dried beans as a result of sun drying on bare floor. Drying is the process of dehydration of food products by reducing the moisture content from the food to improve its shelf life and also preventing bacterial growth.

In this paper, the objective is focused on how to ease farmers of the tedious drying process of cocoa beans especially during rainy season and also to reduce pest, infection and contamination through exposure to sunlight by the use of our developed electronic cocoa bean dryer. This was achieved by developing a portable electric powered and electronic temperature controlled dryer for the removal of moisture content of cocoa beans as an alternative means to the conventional sun drying process of local farmers. This dryer at the same time is meant to create a safe and conducive environment for cocoa beans during drying process in order to prevent contamination from pests and external conditions. The description of the dryer design, and some tests and results are presented in this paper.

II. MATERIALS AND METHODS

A. *The Cabinet Of The Dryer*

The dryer construction consists of an embodiment which is a cabinet that houses the cocoa beans to be dried and other components. The cabinet is made of coated metal steel; metal steel is preferred because of its ability to absorb heat without any side effects aside from the high heat conduction which makes the body hot. In the cabinet, there are two metal trays laid in; the upper tray and lower tray, and are temporarily fixed. The upper tray gives space for cocoa beans while the lower tray contains the heat emitter (heating element).

The outer body of the cocoa beans dryer cabinet is where other components such as the switch, digital temperature control unit, contactor and indicators (lights) are fixed. The wiring connections of the components are made inside the cabinet, which means that holes are drilled on the cabinet body to achieve this. The block diagram that illustrates the construction of the cocoa bean dryer is as shown in Fig. 1.

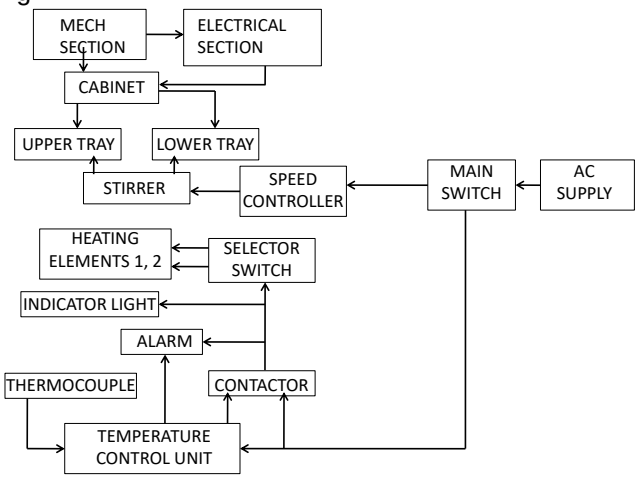

Fig. 1: Design Block Diagram of Cocoa Bean Dryer.

B. *Maintaining the Integrity of the Specifications*

In this section some of the materials used in the construction of the cocoa bean dryer and the functionalities are here presented:

i. Metal sheet, ii. Glass, iii. Tray, iv. Paint, v. Heating element, vi. Switch, vii. Contactor, viii. Electronic (digital) Temperature control unit (TCU), ix. Indicator lights, x. Thermocouple, xi. Connecting cables, xii. Insulator, xiii. Plug, and xiv. Mesh wire.

*Metal Sheet:*A metal copper sheet of diameter of 2mm was adopted for this work, this thickness in diameter is chosen so as to prevent overheating of the dryer, and to avoid excessive weight. The material is also preferred because of its ability to absorb heat. A metal copper sheet has a good thermal conductivity and possesses other desirable features in heat exchange such as resistance to corrosion, biofouling, stress and thermal expansion. Copper is a type of metal that conducts rapidly, it however also allows for heat absorption and radiation across its surface [7].

Glass: A glass of 35.5cm long and 21.5cm width is fitted into the front layer of the cabinet. The glass is a tempered glass. Tempered glass are glass that are cut into desired shapes, and here, they are sandpapered to remove sharp edges, after which they are sent into tempering oven, which heats it to 620ºC, and later went through quenching (a high pressure cooling procedure) which makes the surface cooler inside. As a result of this, the outer space goes into compression and the inner part remains in tension. This glass has durability capability, safety characteristics and above all low conduction capability. This type of glass was selected to withstand high heat while simultaneously keeping the dryer at a steady temperature and as well provide a clear view of what is going on inside the dryer

Tray and Paint: Two (2) trays were used for the cabinet, one at the upper layer of the dryer known as the upper tray, which creates space for the wet cocoa to be inserted into the dryer and the other is the lower tray which houses the clay on which the heating elements are placed. The tray sizes are 39cm by 33cm each of the same length and breadth. As earlier mentioned, a tray dryer allows for the spreading of the raw materials to be dried. The two trays however are placed 14.5cm in terms of height to each other so as to allow for heat radiation from the heating element on the lower tray to the cocoa available space on the upper tray. The type of tray used as upper and lower layers are as shown in Fig. 2.

Flat paint was used in this research due to unavailability of heat resistance paint. This mixes with other product like rust preventive enamels and latex enamel to create a very long lasting finish.

Fig. 2: Tray

Heating Element(s): The heating element is one of the major parts of this fabrication as it has to do with heat generation, that is needed for drying of the cocoa beans. Hence, it converts electrical energy to heat energy through the process of resistive or joule heating, making electric current passing through the elements to encounter resistance, resulting in heating of the elements. Two heating elements were adopted

in this work; in which each can be used differently but not together.

Temperature Control Unit (TCU): A temperature controller is an electronic device that controls temperature by taking an input from a temperature sensor such as a thermocouple and providing an output to a control element in order to reach or maintain a required temperature or set point.

An electronic temperature controller is preferable to a thermostat in this study because of its instant automatic regulation which must have been pre-set; ability to digitally display the temperature in the drying room: and that we are able to set to a specific temperature (digital) which would trip off the contactor when the set temperature clocks and trip on back when it is below the set temperature. It is as well preferred because of its ability to raise an alarm, (if connected), when an over temperature set point is reached. The TCU has 9 ports, and it is as illustrated in Fig. 3.

Fig. 3: Electronic Temperature Control Unit

Thermocouple: A Thermocouple is a temperature measuring sensor. Thermocouples consist of two wire legs made from different metals. The wires legs are welded together at one end, creating a junction. This junction is where the temperature is measured. When the junction experiences a change in temperature, a voltage is created. The voltage can then be interpreted using the temperature control unit. A Thermocouple is however selected in this work because of its low cost, high temperature limits, wide temperature ranges and durable nature.

C. Methodology

The dryer is aimed at reducing the moisture content of the cocoa bean of 3kg per batch from its initial moisture content to 7.5% within 2 hours of continuous drying at a drying temperature of 65 – 70ºC, when the cabinet is fed with an input voltage between 220 and 250V. This temperature was regulated using the temperature controller set on 65 – 70ºC. This can be changed depending on the user, but the chosen temperature is best advisable so as to prevent burning of cocoa beans.

The design, construction and fabrication of cocoa bean dryer was carried out in this research to ease the tedious sun-drying process usually undertaken by rural farmers, particularly in the face of incessant rainfalls. At the beginning, we made layouts and sketches of what shape of dryer we wanted to come up with by drawings, having taking measurements to ensure if the cabinet for drying will suit our objectives. After carefully drawing out parts as shown in Fig. 4, this was followed by materials selection to specifications, after which fabrication and welding of parts was carried out. Meanwhile, a light metal sheet was carefully selected for this design because of ease of drilling and its quality to absorb heat, while being able to emit less fraction of the heat absorbed in order to avoid excessive heat loss within the cabinet chamber.

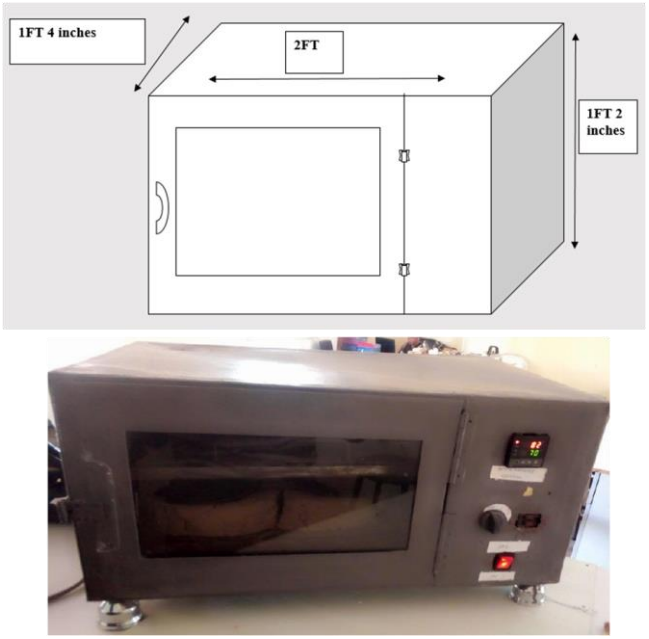

Fig. 4: The Portable Cocoa bean dryer cabinet design and outlook

The next stage was the assembling and connection of heating elements on the lower tray. The lower tray was chiseled in the middle to form four rectangular shapes to be able to get the heating element affixed on it. Before connecting this to the source, a continuity test was conducted on the heating element. Other components were connected and testing was carried out. This was then followed by experimental set-up for test drying of the cocoa beans.

III. RESULTS AND DISCUSSION

The developed electronic cocoa beans Dryer was tested and the results obtained is presented in Table 1.

Table 1: Drying Rate of Cocoa Bean Dryer.

Replicate 1			
Drying Time (min)	Mass (kg)	Temperature (^{o}C)	Moisture Content (%)
30	2.72	66^{o}	40.02
60	1.83	65^{o}	29.54
90	1.64	66^{o}	16.23
120	1.33	67^{o}	7.50
Replicate 2			
Drying Time (min)	Mass (kg)	Temperature (^{o}C)	Moisture Content (%)
30	2.72	65^{o}	40.02
60	1.83	65^{o}	29.54
90	1.64	66^{o}	16.23
120	1.33	67^{o}	7.50
Replicate 3			
Drying Time (min)	Mass (kg)	Temperature (^{o}C)	Moisture Content (%)
30	2.33	70^{o}	39.45
60	1.54	74^{o}	27.74
90	1.32	75^{o}	13.31
120	1.25	73^{o}	7.09
Average			
Drying Time (min)	Mass (kg)	Temperature (^{o}C)	Moisture Content (%)
30	2.62	65^{o}	40.65
60	1.76	67^{o}	29.46
90	1.55	67^{o}	16.08
120	1.33	68^{o}	7.54

*Initial mass = 3Kg, Initial moisture content = 80% (db).

The table shows that the electronic cocoa being dryer dried 3kg of cocoa beans from initial moisture content of 80% to 7.54% in 2 hours in comparison with an open sun drying of about 7 days depending on weather condition. The dryer was found to have a high average drying efficiency of 89%. The electronic cocoa beans dryer can be expanded for community and commercial utilization.

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