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An automated cocoa drying house for use in a small developing country

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Abstract: *For a number of years, sun drying has been the best method of drying cocoa because Trinidad and Tobago is a tropical country and it receives rays from the sun more directly than areas in higher latitudes. The cocoa is normally sun dried in cocoa houses which require the cocoa beans to be covered manually with changing weather conditions. This is a time consuming task. In addition, the recent trends show declining and almost nonexistent cocoa production due to the labour shortages faced. This worked looked at developing a design and testing the prototype for an automated cocoa drying house in a small country, Trinidad and Tobago. The prototype included features such as an automated roof, automatic heaters, an automated fermenter and a remote control feature for the automated components. Initial testing with farmers showed that there was interest in the product.*
Keywords: *Automatic, cocoa house, Trinidad.*

I. INTRODUCTION

Growing cocoa beans offers small-scale farmers in tropical countries a livelihood from a product that has strong foreign demand and local environmental benefits [1]. Cocoa trees can grow on small parcels of land and on poor soils, two facts that make it feasible for small farms and women growers [1]. Cocoa trees protect fragile soils from erosion, and give needed shade to tree seedlings that can help restore biodiversity to cropland. Furthermore, cocoa can be planted alongside food crops, offering a cash source to small farmers who rely on their land for subsistence. More than 85% of the world's cocoa beans are grown by small-scale family farmers. In 1992, the TAHAL Report presented an assessment of the situation with respect to the cocoa industry in Trinidad and Tobago. The Report stated that:

'Ecologically and environmentally, cocoa is one of the most suitable crops for many parts of Trinidad and Tobago, in which it is grown at present. The germplasm available in Trinidad and Tobago is among the best in the world and has the potential to produce yields of over 1500kg/ha of flavor cocoa, which fetches premium prices on the international market. Average yields at present, however, are only about 230kg/ha.'

Trinidad and Tobago is still one of the principal producers of fine flavored Trinitarian cocoa. Relatively few origins continue to produce fine flavor cocoa. Fine flavor cocoa now contributes only around 2 to 3 percent of world production, but continues to be sought by up-market confectionery companies, who are still prepared to pay a premium for this cocoa. Harvested crops, which are to be stored for any length of time, must have their moisture content reduced to a safe level before storage. This moisture is reduced by drying the crop. Storage of the crop with moisture content above the safe level could contribute to the deterioration of the crop. In the case of cocoa, mould infection and loss of quality occurs. The drying of the cocoa bean is thus a very important step in the production of cocoa. For a number of years, sun drying has been the best method of drying cocoa in Trinidad and Tobago since it is a tropical country. This has been found to be a cheap method of drying cocoa. It is currently though a very time consuming task for farmers with the main threat being changes in weather conditions. In this traditional sun-drying process, weather conditions are monitored by humans. If the rain threatens to fall before nightfall, when the relative humidity is high, the crop is covered. Failure to correctly gauge the weather results in the process being lengthened. This work looked at designing an automated cocoa drying house which could provide a solution to this problem.

II. LITERATURE REVIEW

Harvested cocoa beans go through a series of processing stages before the final product (i.e. polished, dried beans) is obtained. Variations in the drying and "dancing" or polishing stages are indicated in the block diagrams below.

PROCESS NO. 1

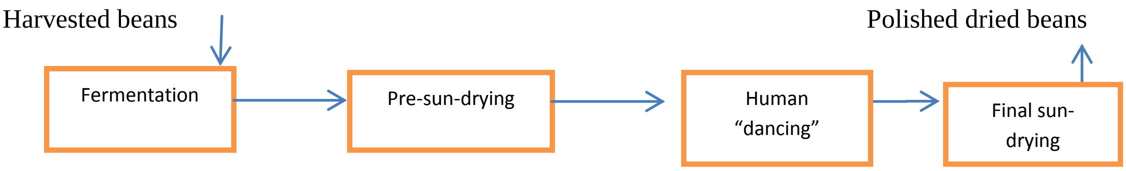


Diagram 1:Showing the cocoa production process with “human dancing”

PROCESS NO. 2

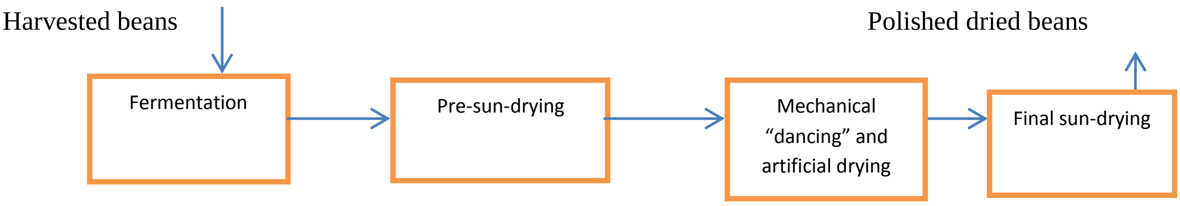


Diagram 2:Showing the cocoa production process with mechanical “ dancing” and artificial drying

PROCESS NO. 3

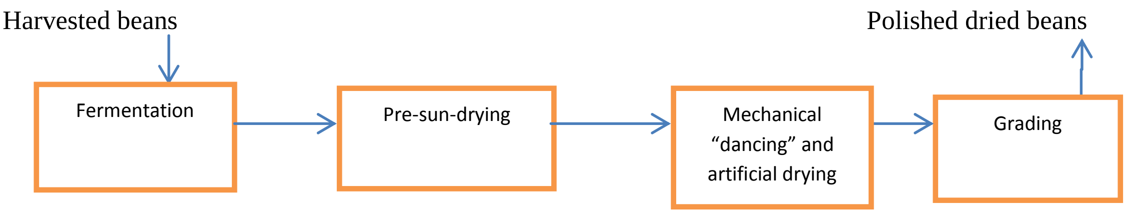


Diagram 3: Showing the cocoa production process with grading included

In process No. 1, moisture is removed by sun-drying only. This takes approximately 6 to 8 days in the dry season and as long as two weeks in the wet season. In process No. 2, the crop is pre-sun-dried for 2 to 3 days before mechanical “dancing” and artificial drying take place. In process No.3, artificial drying is used for a shorter period before “dancing” and artificial drying take place.

Some of the advantages of sun drying are:

1) The direct solar energy used costs nothing.
2) The sun-drying process is slow – in the case of cocoa, it appears that slow drying is preferable and that majority opinion is that slowly dried cocoa is of better quality and more aromatic.

Sun-drying of the crop takes place in a sun- or natural dryer which makes use of direct solar radiation and air movement to achieve drying process [3,4]. In Trinidad, the crop is sun-dried roughly between 8 to 17 hours.

The following operations are done during the sun drying process:

i. Foreign matter and immature and defective beans are removed and beans which are stuck together are separated.
ii. The beans are stirred with wooden rakes at various intervals.
iii. Weather conditions are monitored by humans. Should the rain threaten, the crop is covered with a mobile roof.

“Dancing”: Before the beans are “danced” by humans, they are sprayed with water. The beans are “danced” to give them a high polish which reduces the possibility of mould infection.

2.1 Existing cocoa bean dryers

There are a few types of dryers that are seen in the industry inclusive of solar dryers, glass roof dryers and intermittent solar dryers.

The use of solar dryers is very expensive over other types of dryers, but the solar dryer gives a better quality product with respect to taste, aroma and color. The dryer is generally placed on the roof of a house, which has about 50 square feet per meter of solar collection panels. Dryer cabinets are normally installed on the first floor of the building. Cabinet partitions for the dryer are made of glass that is used to capture more radiation and sheets for constructing the panel are pre-coated, which reduce cost in fabrication and painting. . The drying rate of the product will depend on the following factors - solar intensity radiation, rate of air flow, humidity, size of the product, initial moisture content of the product, final moisture content of the product and thenumber of drying trays and design of the solar dryer.

The Cocoa Research Centre of Brazil (CEPEC) did work on a glass roof dryer. The dryer is sized lengthwise along the north-south axis and consists of two parallel rows of drying platform, each 12m long, 1.76m wide and 0.8m high, with a central passage 1m wide for an operator to facilitate the loading on either platform with cocoa beans for drying. A long rake is provided to turn the cocoa beans and transfer it onto sacks for cooling. The top of the platform is provided with a ridge 10cm high along the edge and the drying surface is made of galvanized iron wire mesh laid over wooden beams fixed across the platform at a pitch of 0.5m. This is for the heating rays from the low cost gas heaters, located underneath the platform to easily pass through the wire mesh. A fixed glass roof above the drying platforms allows the heating rays of the sun inside the dryer and prevents rains or dew of the night to come in contact with the cocoa beans. The entire surface of the drying house is painted black to facilitate the absorption of heat from the sun. Glass sheets, 3mm thick of commercial type are used as roofing material. It is relatively cheap and has good transmission characteristics of all ultra violet, visible and infrared regions of the sun's spectrum. Under sun drying conditions, the temperature inside the glass house dryer is higher than the temperature outside the dryer, while the humidity of air inside the house roof dryer is lower than ambient. The combination of these two factors produces a faster drying rate for the cocoa beans. Under gas drying conditions, the maximum drying temperature for the cocoa beans is about 70°C to 75°C, in its initial stage and is lowered as the moisture content is reduced to around 15% to 12%. The final moisture content of the cocoa beans after eight days was 8.4% for the glass roof dryer compared to a wood fuel dryer which was 9.2%.

The intermittent solar cocoa dryer is mainly made from wood and consists of the following major components; the solar collector, the drying chamber and the heat storage chamber. An air duct connects the upper end of the solar collector to one of the drying chamber. The other three sides are partitioned internally 125mm wide, to form the heat storage chambers. The collector, the drying chamber and the heat storage chambers are covered with glass doors. A five speed axial fan is located inside the air duct, to blow hot air into the chamber. The beans are dried by a combination of convective heating of hot air and direct radiation through the glass cover. The intermittent solar cocoa dryer is mounted on wheeled frame made from angle iron 50mm x 50mm x 3mm. This prototype is designed to hold a batch of 50kg wet cocoa beans.

2.2 Methods of drying cocoa worldwide

There are a few methods of drying cocoa worldwide. The section below shows a few of the methods that specifically focus on roof designs.

Cocoa drying in Venezuela is done via a solar drying facility with a mobile roof and by nested solar drying trays. The mobile roof design is designed in a way where the trays which the cocoa are spread on are covered by a roof which is manually opened or closed depending on rainfall or sunlight.

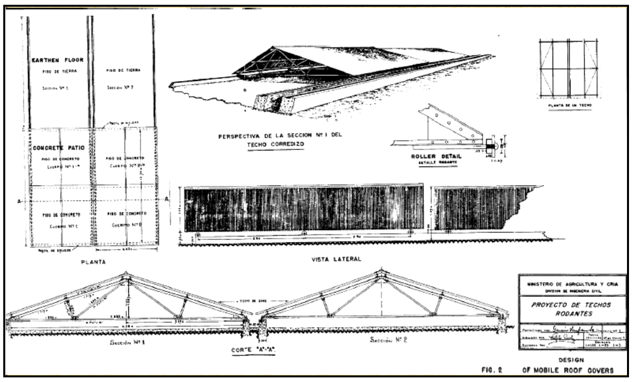


Diagram 4: Showing mobile roof solar cocoa dryer schematic used in Venezuela, Taken from Sukha, 2009

Diagram 5: Showing actual mobile roof solar cocoa dryer used in Venezuela, Taken from Sukha 2009

Jamaicans use sun drying trays on roof tops as shown in diagram 6 below.

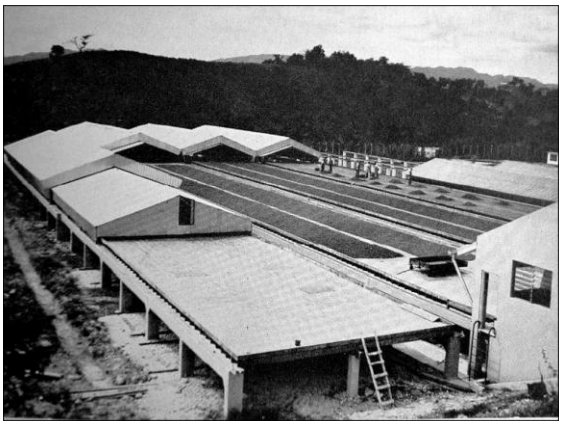


Diagram 6: Sun drying trays at Morgan's Valley, Fermentary, Jamaica

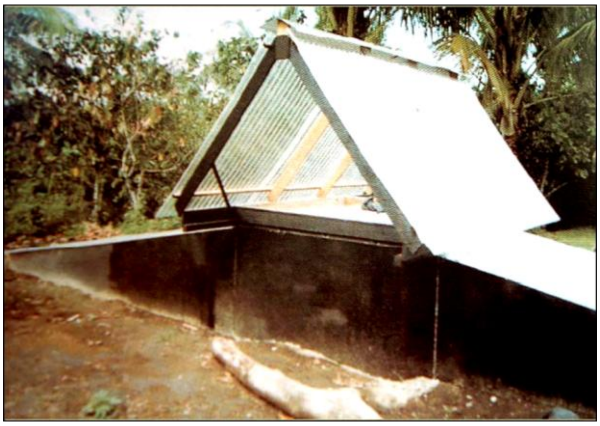


Diagram 7: Showing shows solar dryer with central rock solar collectors and polycarbonate sheet roof

Solar dryers with rock solar collectors and polycarbonate sheets on roofs are a design mainly used in Papua New Guinea. A transparent polycarbonate sheet roof is used so that sunlight can pass through it and heat the cocoa beans. It also covers the drying chamber made from concrete block walls. Rocks such as basalt rock are placed to the bottom of the solar dryer which absorbs heat during the day. At night or when there is a lack of sun, the heated rocks keep the drying chamber warm. This is seen in diagram 7 above.

Cocoa bean dryers in Guyana use a combination of solar and artificial drying. They incorporate a heat exchanger to aid in the drying of the beans. This can be seen in diagram 8 below. Cocoa dryer designs in Trinidad include the traditional wooden floor sliding roof design, the modern wooden floor sliding roof design, convection cabinet dryers and hybrid bed dryers with solar collectors. These may be seen in diagram 9 below.

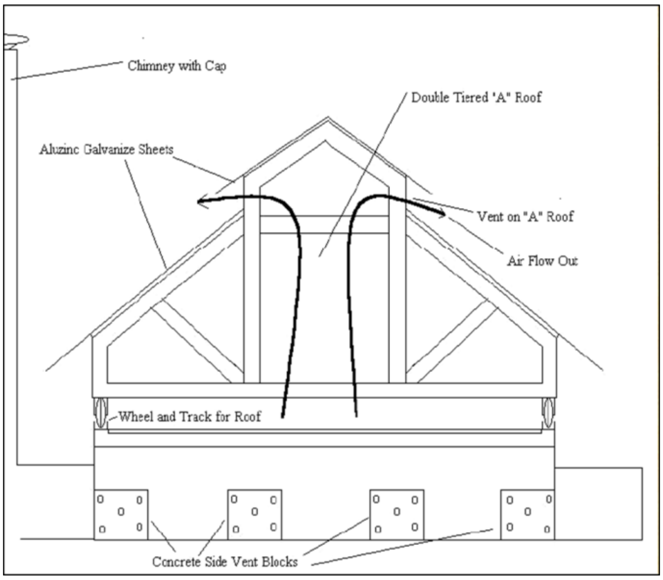


Diagram 8: Showing a design using a combination of solar wooden and artificial drying used in Guyana modern wooden floor

Diagram 9: Showing the traditional floor sliding roof design and the sliding roof design used in Trinidad

The traditional designs use static roofs and houses for drying which need manual operation in changing weather conditions.

III. DESIGN

An automated cocoa drying house which reacts to the changes in weather is proposed.

3.1 Design method
A design methodology was used which utilized the following steps:

1. Identify problems with previous designs
2. Generate ideas to solve the problems
3. Implement various improved prototypes
4. Use a method to derive the most suitable design, eg, Pugh's matrix
5. Build and test the final design
6. Re-design according to testing results

3.2 The final design
The intent was to eliminate the traditional method of drying cocoa by replacing it with this fully automated cocoa bean drying house. The drying floor of the traditional cocoa house will be replaced by a rotating basket in which the cocoa will be placed. The basket will be spun at regular fixed intervals by an electric motor to ensure the uniform drying of the beans.
Also featured is the fully automated roof of the cocoa house. This roof will open and close via an electric motor, according to the conditions of the environment. Placed on the roof are a photo resistor and a rain sensor. At sunrise the photo resistors will detect the sunlight and open the roof. The roof will be programmed to open in the presence of sunlight and close when there is no sunlight present through the use of a PLC. The roof will also be programmed to close if it detects any moisture as a result of rainfall thereby keeping the cocoa dry. The closing of the roof due to fading light and moisture is a precautionary measure to ensure that the cocoa does not get wet by the rain in instances where there is sun and rain.
Additionally, the cocoa house consists of 2 heaters inside the cocoa house. These heaters will be used to dry the cocoa during the night and also when the temperature is not adequate for drying cocoa. The heaters are controlled by a microprocessor and a temperature sensor is used to sense the changes in temperature. The use of an infrared remote control is also utilized to control the roof, the heaters and to remove all power to the circuit.

The final design also features an automated fermenter. When the cocoa pods are initially split open to release the beans, the beans are imbedded in pulp. The pulp surrounding the beans undergoes a fermentation process, which develops the colour and flavour of the beans. Fermentation of the beans normally takes about three days to be completed. The automated fermenter is therefore separated into four separate chambers, with each chamber representing one day. The cocoa beans are initially placed into chamber one for the first day of fermentation. On the second day, a flap automatically pushes the cocoa into chamber two. Chamber one is now reloaded with another batch of cocoa. This process continues until the fourth day, when the cocoa beans are at chamber four. At this chamber, the fermentation of the cocoa is now complete and the cocoa falls through a hole at the bottom and is unloaded, where it is now ready to be dried.
The last unique feature is a remote control option to close the roof, open the roof and to turn the heaters on and off.

The final design drawings are shown below in diagrams 10 – 13.

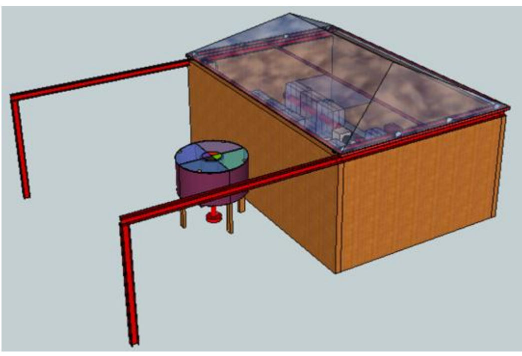


Diagram 10: Shows a graphical representation design using the automated
Baskets

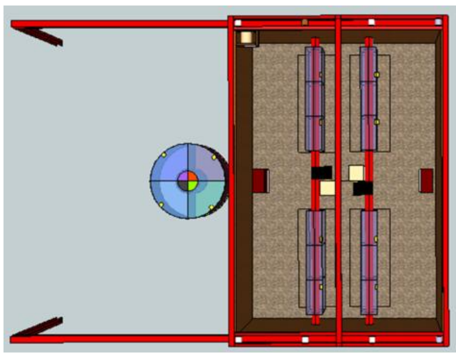


Diagram 11: shows an aerial view of design using the baskets

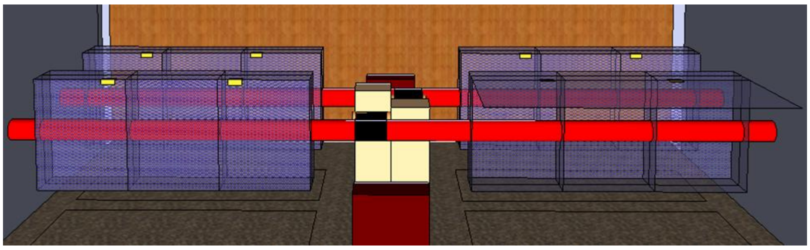
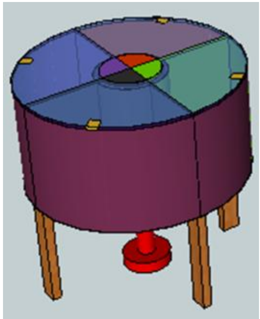
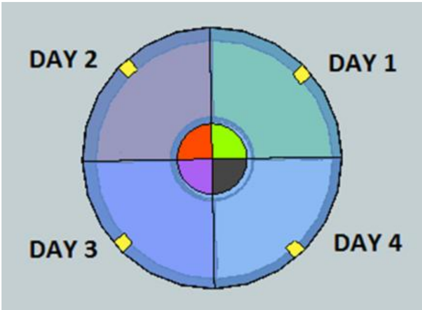


Diagram 12: Showing the design of the rotating baskets





(a) **(b)**

Diagram 13(a): Shows a graphical representation of the automated cocoa fermenter; (b) Shows an aerial view of the automated cocoa fermenter and each chamber for its respective day

The operation of the automated cocoa house is shown below.

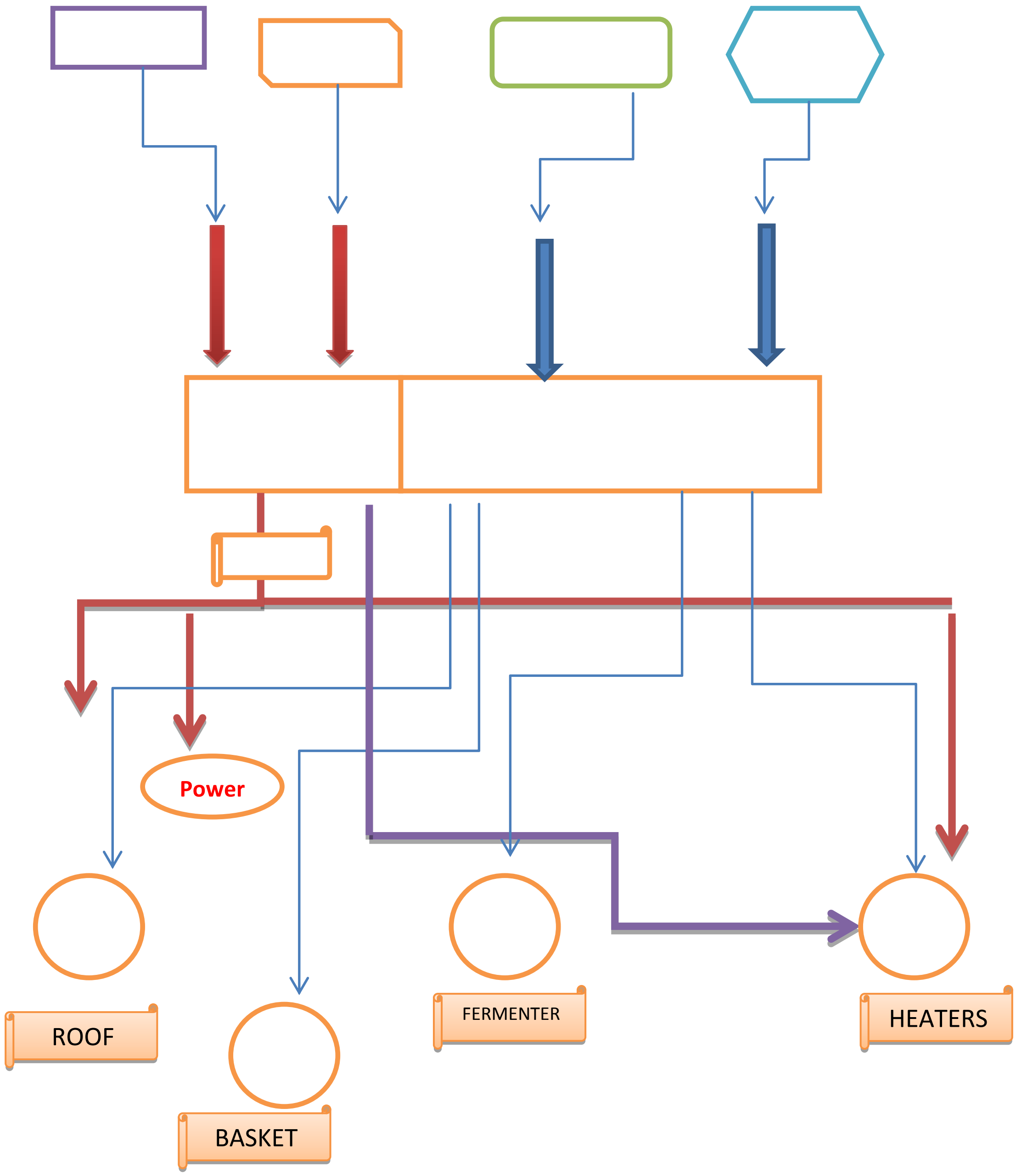


Figure 1 : Shows a block diagram of the operation of the automated cocoa house

IV. INTERVIEW WITH FARMER AFTER DEMONSTRATION

A demonstration was made to a farmer and he acknowledged the innovative design of the cocoa house prototype and made comparisons of his methods of fermenting and drying the cocoa beans to the methods used in the prototype, which are as follows.

Roof design

The farmer's roof was designed in a way that required manual opening and closing in the presence of sunlight and rainfall respectively. This improved design automatically opened and closed depending on changes in the weather. The addition of the baskets would also remove the need for spreading the cocoa beans on the roof and turning them periodically.

Heaters

Normally, the farmer would use his heated concrete pots to speed up the drying process and then move the partially dried beans to the roof where the drying process resumes. The heating lamps eliminate the need to transport the beans from the dryer to the roof and therefore save more time and labour. The beans dried at a faster rate when using the prototype.

Fermenter

The fermenter used by the cocoa farmer had a similar concept to the prototype since it consisted of three sections, with each section representing two days. The difference with the prototype fermenter is that the cocoa beans are pushed automatically to each section, whereas the fermenter used by the farmer needed manual pushing to each section.

Final thoughts of farmer

The farmer concluded that he was very old fashioned and was not keen on the idea of having the automatic roof since he wanted to have control over it. He however commended the idea of using the remote control to open and close the roof when desired from remote locations. Overall he thought that the automatic fermenter and the automatic baskets were very good ideas since it would reduce the amount of manual labour and time taken for the fermenting and drying processes.

V. RECOMMENDATIONS FOR FURTHER WORK

Recommendations include incorporating the use of solar panels, improving the transportation system post fermentation and controlling the heaters more accurately depending on the beans being used.

The incorporation of a solar panel into the design would mean a higher cost when manufacturing the dryer however, it is believed that less power would be consumed overall and an economic analysis should show therefore more money would be saved in the long run. Since Trinidad and Tobago is a tropical country, which means that it receives rays of the sun more directly than areas in higher latitudes, aside from drying the cocoa, this sunlight can be utilized using the solar panel to generate more power in an efficient manner.

During the months where there is abundance of sunlight and less rainfall, most of the drying of the cocoa would be done via sunlight. When using only sunlight for drying, the cocoa beans would be left in the sun for an average of six days, turning them every hour for four hours and then eventually stop turning them. When using both the sunlight and heaters, the cocoa beans would take a shorter amount of time to dry. The cocoa beans could be left for an average of two days in sunlight and six hours with the heaters. However when the cocoa beans are dried too quickly, it prevents the chemical processes started during fermentation to be completed. It also results in the beans becoming very acidic with case hardening. A high production of acidity in cocoa beans produces unsuitable raw cocoa for chocolate manufacture and leads to the reject of cocoa at the market. To prevent this, the heaters should not be continuously kept on. The cocoa beans could be kept for two hours in the heaters and then cooled for eight hours and then repeated two more times so that the cocoa beans are dried with the heaters for the six hours.

VI. CONCLUSION

This worked looked at producing an automated cocoa drying house in order to reduce the amount of hard work and time necessary to produce such a fine product and in turn encourage cocoa farmers both existing and future to once again gain an interest in this industry. Long term benefits include a better economy through increased international sales, employment opportunities and becoming a developed country. The introduction of new features like the automated roof, the automated fermenter ,the heaters and the remote control proved to be of interest in the industry and may eventually help as part of a solution for reviving the production of cocoa in Trinidad and Tobago.

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