CHAPTER THREE

Materials and Methods

3.1 Design Considerations

The Hybrid dryer design was influenced by the following factors:

- The quantity of moisture that needs to be taken out of a specific amount of cocoa bean.
- The period of time during which the drying is needed.
- The number of hours of sunlight per day for determining the total drying time.
- The amount of air required for drying.
- The daily solar radiation to determine the energy received by the dryer per day.

3.2 Description of the Hybrid Dryer

The dryer is composed of a solar collector (triangular prism) and a solar drying chamber constraining rack of drying trays both being integrated. The air allowed in through the air inlet is heated up in the solar collector and channeled through the drying chamber where it is utilized in drying the cocoa bean. The dimensions of the drying chamber so designed were 62cm x 50cm (length x width), the solar collector so designed were 40cm x 50cm x 25cm (height x base x width). The locally available materials that was used for the construction were glass collectors, mild steel sheets, fiberglass, square pipe, angle iron, silicon gum, hinges & locks, and consumables.

3.2.1 Collector

Collector captures solar energy and convert it into heat. The transparent top of the dryer which was made of glass, acts as the collector. It allows sunlight to pass through and heat the air inside the dryer.

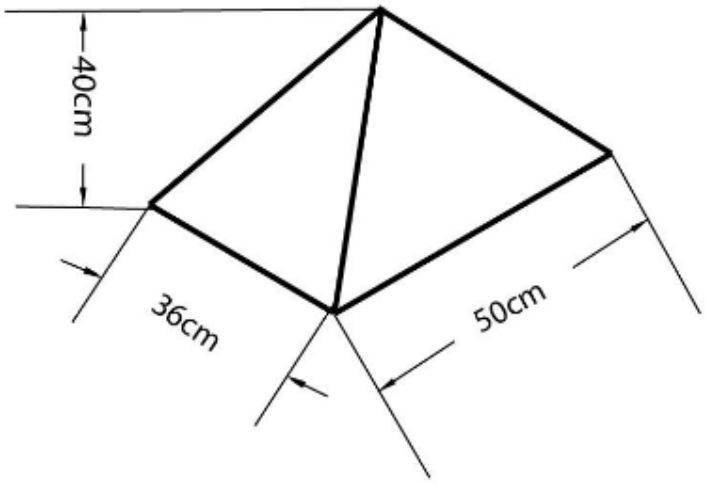


Figure 3.1 Collector

3.2.2 Drying chamber

Drying chamber houses the cocoa bean to be dried. This is the enclosed space where the cocoa bean is placed on trays. It's designed to retain heat and provide a controlled environment for drying. The dark colour of the interior enhances heat absorption.

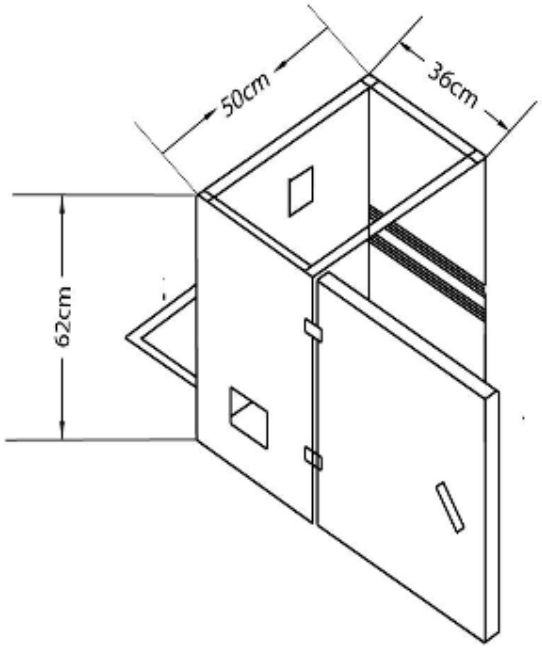


Figure 3.2 Drying chamber

3.2.3 Trays

Trays holds the cocoa bean to be dried. These trays were made of metal mesh to allow for good airflow and even drying. The cocoa bean was spread out on the trays to maximize exposure to the hot air.

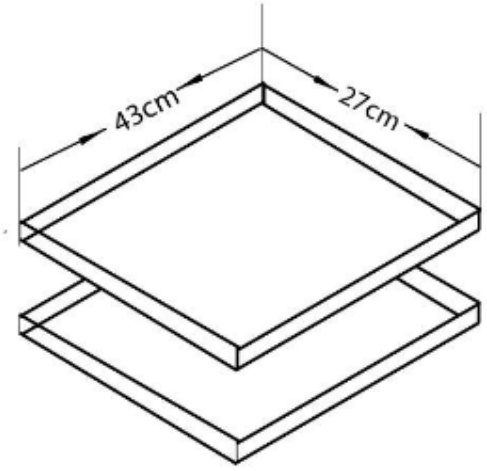


Figure 3.3 Trays

3.2.4 Fans

The fan circulate air within the dryer. The capacity of the fan is 0.44A(amps) and 12V. There was three fans in this design;

Side fans: These two fans draws in fresh, outside air into the dryer, helping to maintain humidity levels and prevent moisture buildup.

Top fan: This fan extracts moisture-laden air from the drying chamber, accelerating the drying process and creating negative pressure to pull in more air.

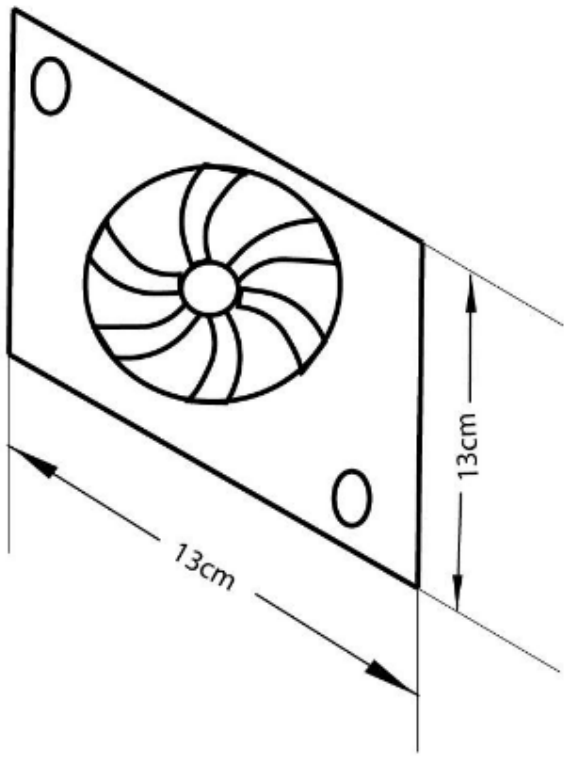


Figure 3.4 Fan

3.2.5 Frame

The frame provides structural support for the dryer. It was made of metal and gives the dryer its shape and stability.

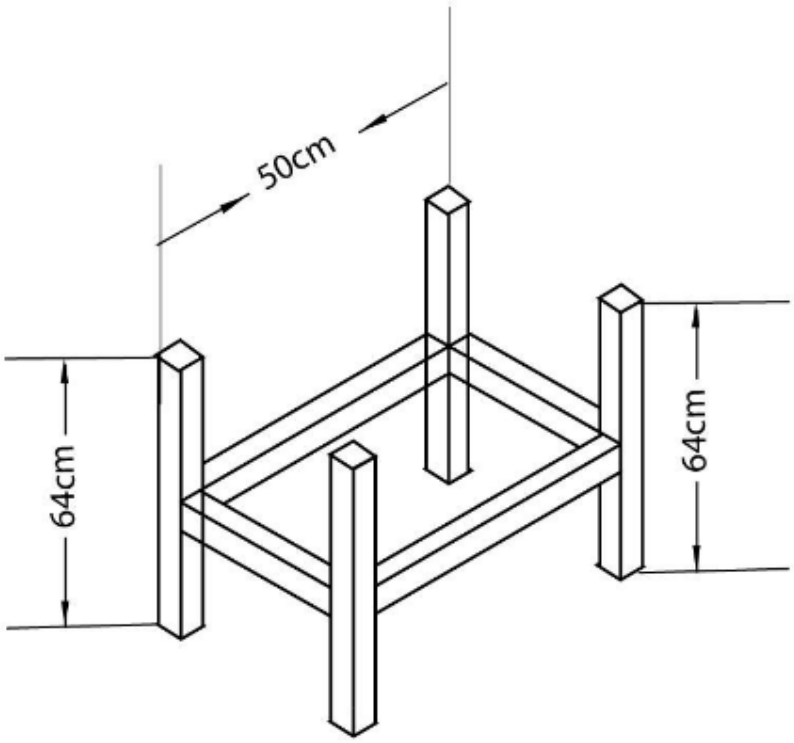


Figure 3.5 Frame

3.2.6 Monitoring equipment

It monitors conditions of the environment. It includes instruments to measure temperature and relative humidity of the environment. The monitoring equipment houses charge controller, solar battery, hygrometer and thermometer.

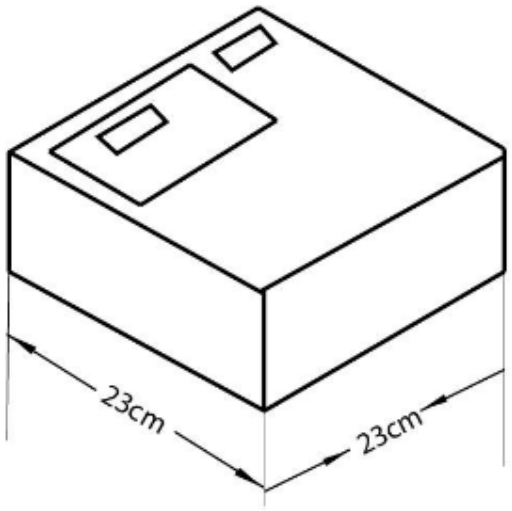


Figure 3.6 Monitoring equipment

3.2.7 Hinges and locks

Hinges are used to attach the door of the hybrid dryer together. It allows the panels to open and close smoothly, making it easy to access the contents of the dryer. Locks were used to secure the door of the hybrid dryer when it is closed. This helps to protect the products inside the dryer from the elements and theft.

3.2.8 Solar battery

A Panasonic 12V 7Ah lead- acid battery was used because of its affordability and reliability. It stores the energy generated by the solar panel for use when there is no sunlight.

3.2.9 Solar panel

It collects energy from the sun in form of sunlight which will help power the monitoring instrument.

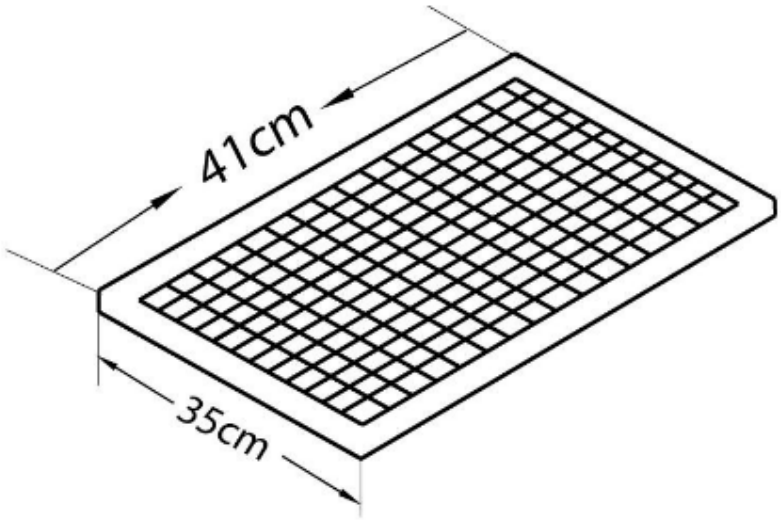


Figure 3.7 Solar panel

3.2.10 Charge controller

The charge controller maintains batteries at their highest state of charge without overcharging them to avoid gassing and battery damage.

3.3.Hybrid Dryer Parts Design

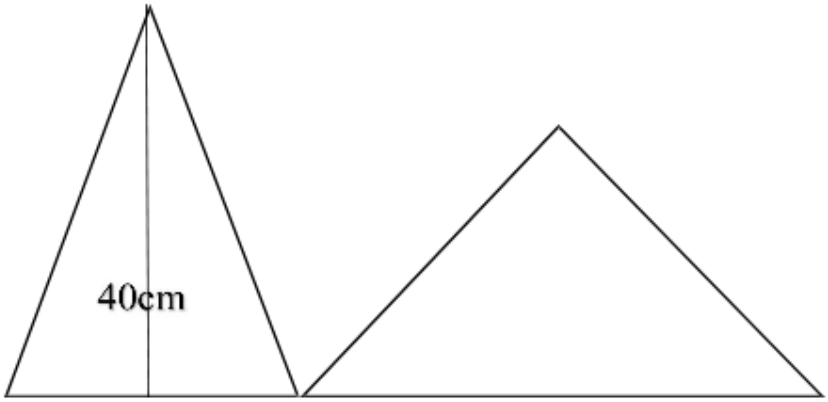
(a) Solar collector area

The solar collector is a triangular prism and it is an isosceles triangle. The solar collector area is given by;

Total surface area = 2 x (area of triangular base) + 3 x (area of rectangular side)

(3.01) Area of the isosceles triangle base = (√3/4) x side2(3.02)

Area of the rectangular sides = length x width(3.03)



25cm50cm

Side view of the collectorfront view of the collector Where;

Base of the isosceles triangle = 50cm

Height of the isosceles triangle = 40cm

Width = 25cm

Area of the rectangular sides = 25cm x 40cm = 1000cm2

Area of the isosceles triangle base = (√3/4) x $(50cm)^2$

=1082.53 Total surface area = 2 x (1082.53) + 3 x (1000) =

5165.06cm2

(b) Absorber Surface Area,

The surface area of the absorber Aab is approximately equal to the area of the collector surface area, Ac; this is related to the length, Lc and width, W of the solar collector as follows:

Aab = Lc x W(3.04)

Lc = height of prism + height of drying chamber

= 40cm + 62cm =102cm

Aab = 102 x 50

= 5100cm^2

Aab = Absorber surface area of the

collector Lc =Length of the collector

W=Width

(c) **The total area of the dryer,**

Area of the dryer (rectangle) = L x H(3.05)

= 62 x 50

= 3100cm^2

L = length of the

dryer H = Height

3.4 Moisture Content (M.C.):

The moisture content is given as:

MC (%)= [Mi -Mf]x100%; wet basis(3.06)

Mi

Where;

Mi = mass of sample before drying

and Mf = mass of sample after

drying.

3.5 The mass of water evaporated or moisture loss

Moisture loss is given as;

mw = mi [Mi -Me](3.07)

100 - Me

Where:

mi= initial mass of the food item (kg);

Me = equilibrium moisture content (% dry

basis); Mi= initial moisture content (% dry

basis).

Also this can still be obtained by using equation 3.05

mw = (mi– mf)(3.08)

Where;

mi is the mass of the sample before

drying mf is the mass of the sample

after drying

3.6 Average drying rate

Mdr, would be determined from the mass of moisture to be removed by the solar

heater and drying time by the following equation:

$$Mdr = \frac{Mw}{td} \quad (3.09)$$

Where:

Mdr = average drying rate, kg/hour;

Mw = mass of wet products

and td = overall drying time

3.7 Principle of Operation of the Hybrid Dryer

Solar energy is captured by the collector in form of sunlight which heats the air inside the dryer. The side fans bring in fresh air while the top fan extracts moist air, creating a continuous airflow. The hot air then circulates around the products, removing moisture and drying it. A humidity sensor and temperature sensor is used to monitor the environment temperature and relative humidity and controls the drying process.

3.8 Experimental procedure

The apparatus used in this experiment were stopwatch, which was used for taking more accurate timing, weighing scale, cocoa bean, grain moisture-meter and the solar dryer.

The solar dryer consists of two trays, two fans for blowing air into the dryer, a fan for sucking the air out of the machine.

The machine was firstly test run with small quantity of cocoa before the main drying to know if there was any fault or any adjustment to be made.

The dryer was placed to face the direction of the sun. The three fans were switched on, the speed of the fans blowing air inside the solar dryer was regulated to be at an average.

The wet cocoa bean was weighed and the moisture content was known and recorded. The two trays were brought out and the weight of the trays were known and recorded. Tray 1and tray 2 were filled with an equal amount of wet cocoa bean and the weight of the trays filled with wet cocoa bean was recorded, the trays were then placed in the solar dryer. The temperature and relative humidity was recorded as well. The stopwatch was set at an interval of one hour.

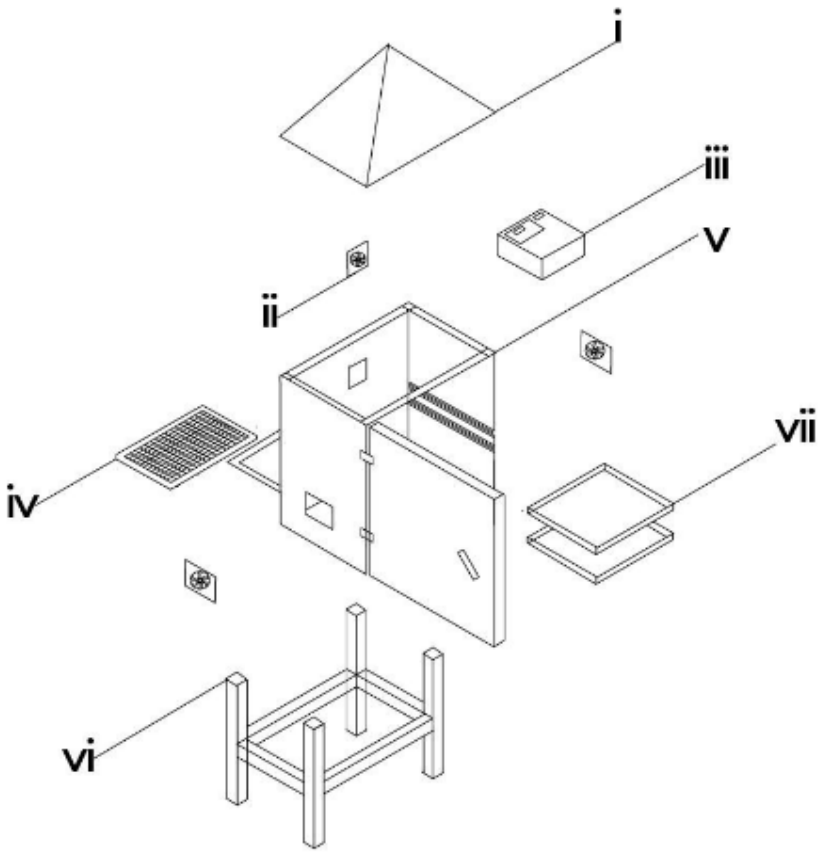
After an hour, the trays were brought out to be weighed, and they were placed back after weighing. Then, the temperature and relative humidity was recorded. The stopwatch was set to an interval of an hour again.

This procedure was repeated till the wet cocoa bean was dried to a constant weight three times.

3.9 Material used for construction of solar dryer

- Mild steel sheet
- Square pipe
- Glass collector
- Angle iron
- Fibre glass
- Silicon gum
- Hinges & locks
- Consumables
- 12V 7ah battery
- Dc fan
- 20w solar panel
- Temperature and humidity sensor
- Box

- Wires and clips
- Charge controller



MACHINE PARTS' LIST		
S/N	KEYS	PARTS' NAME
1	I	COLLECTOR
2	II	FAN
3	III	MONITORING EQUIPMENT
4	IV	SOLAR PANEL
5	V	DRYING CHAMBER
6	VI	FRAME
7	VII	TRAYS

Figure 3.8 Exploded view and labeling of components of the hybrid

dryer.

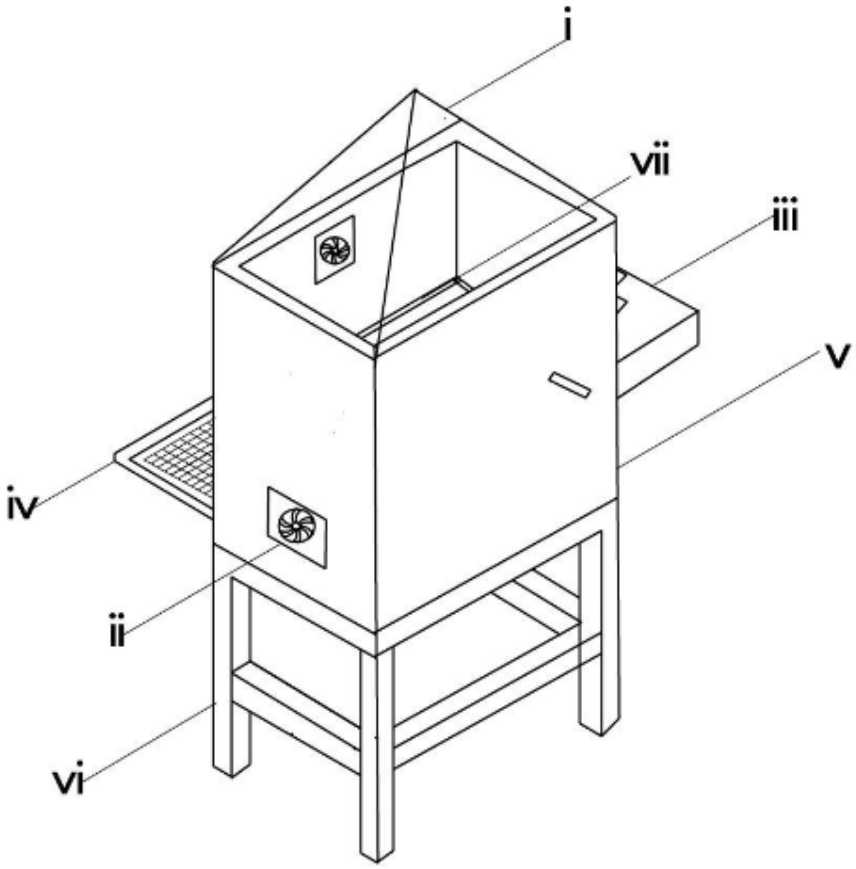


Figure 3.9 Isometric view of hybrid dryer

MACHINE PARTS' LIST		
S/N	KEYS	PARTS' NAME
1	I	COLLECTOR
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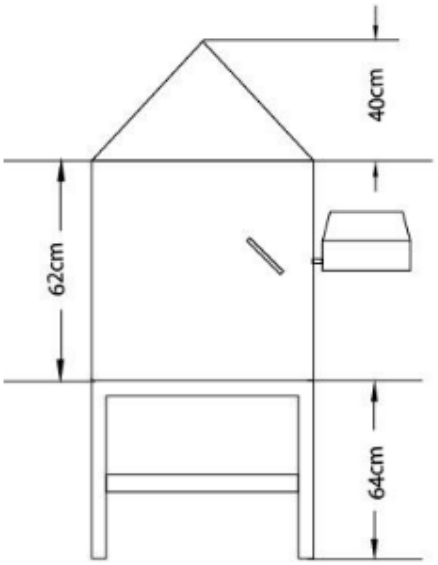
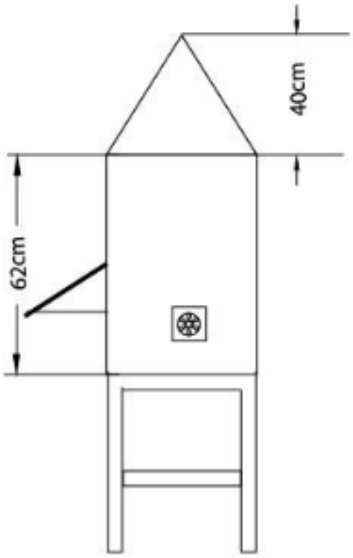
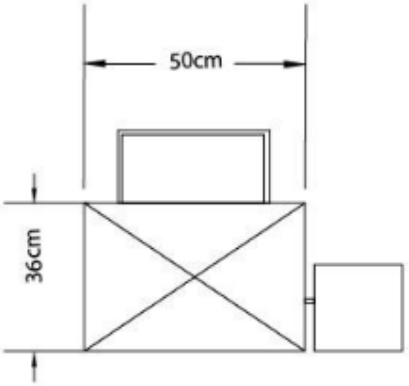
7	VII	TRAYS



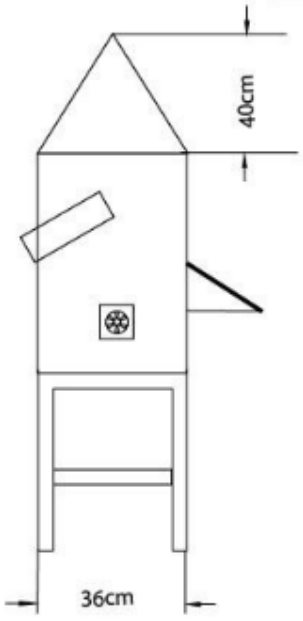
Front View



Left View



Plan View



Right View

Figure 3.10 Views of The Machine Drawing

3.10Tools and Equipment

1. Electric Arc Welding Machine: it was employed during the fabrication of the drying chamber, supporting frame and tray assembly. It was used to join metal components with high strength and durability ensuring structural integrity of the dryer.

2. Grinder/Cutting Machine: It is a power tool with a rotating abrasive disc or blade which was used for cutting and smoothing metal.It is used to cut metal sheets, pipes, or rods to required sizes and for grinding welds to smooth finishes.

3. Drilling Machine: It is a machine tool which was used for used to drill holes into materials (metal, wood, etc.). It is used to create holes for bolts, screws, or other fittings in your project components.

4. Screwdriver Set: It is a set of hand tools with different tips (flat, Phillips, etc.) which was used for driving screws. It is used for tightening or loosening screws during assembly or adjustments of electrical and mechanical parts.

5. Spanner Set: It is a set of tools which was used for for tightening or loosening nuts and bolts. It is essential for assembling and disassembling mechanical parts such as frames, joints, or supports.

6. Multimeter (for testing connections): it is an electronic measuring instrument that combines several functions (voltage, current, resistance testing). It was used to check electrical circuits, test battery voltage, or ensure proper connections in the solar-powered system

7. Pliers: It is a hand tool with gripping jaws, sometimes with cutting edges.it was used for holding objects firmly, bending wires, or cutting small materials.

8. Measuring Tape: It is a flexible ruler used to measure distances or dimensions. It is used to take accurate measurements of components during fabrication or assembly.

9. File (for finishing edges):It is a hand tool with a roughened surface used for smoothing or shaping metal.It is used to smoothen sharp edges after cutting or welding metal parts.

10. Paintbrush/Spray Gun: it is a tool used to apply paint or protective coatings. It is used for finishing touches to protect metal surfaces from rust and improve aesthetics.

11. Soldering Iron (for electronic parts): It is a hand tool that heats up to melt solder (a metal alloy) for joining electronic components. It is used in assembling or repairing the electronic parts of your project like sensors, circuits, or connections.

Plate 3.1a:Electric Arc Weldingplate 3.1b: Grinding

Plate 3.1c: Thong plate 3.1d Electrodes

Small GrinderHammer

3.11Design Layout

The experimental design for this study was structured using a two factor factorial design to evaluate the effect of the drying parameters on the drying rate and drying efficiency of cocoa seeds. The factors and responses are presented as follows:

i. Mass of Sample (g)

ii. Air flow rate (m^3/s)

2. Experimental Responses (Dependent Variables)

Two performance indicators were monitored during the drying process:

i. Drying Rate (kg/h): measured as the rate at which moisture was removed from the cocoa seeds.

ii. Drying efficiency (%): calculated as the ratio of useful energy utilized for moisture removal to the total energy supplied.

3. Experimental Runs

A total of 13 experimental runs were carrid out as presented in Table 3.1. The runs were randomized to minimize the experimental bias and ensure the independence of observations. The experimental matrix includes various combinations of the two factors and their respective

levels.

Table 3.1shows the experimental design matrix with the factors and responses for the cocoa seed drying process

		Factor 1	Factor 2	Response 1	Response 2
Std	Run	A:Mass of Sample	B:Air Flow Rate	Drying Rate	Drying Efficiency
		g		Kg/h	%
3	1	1000	0.6		
9	2	2000	0.5		
12	3	2000	0.5		
7	4	2000	0.4		
4	5	3000	0.6		
2	6	3000	0.4		
13	7	2000	0.5		
1	8	1000	0.4		
11	9	2000	0.5		
5	10	1000	0.5		
10	11	2000	0.5		

6	1 2	3000	0.5		
8	1 3	2000	0.6		