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# DESIGN AND CONSTRUCTION OF A MULTI-PURPOSE DRYER FOR PRESERVATION

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## ABSTRACT
*With the subsequent increase of food growing especiallyin rural areas, there is an accompanying need for preservation method. This has led to a substantial increase in the number of driers, yet expensive for local farmers to acquire.This paper condensed and comprehensive work done with the aim of reducing the cost of drying and also for practical demonstration of some of the theoretical knowledge acquired. It was discovered that the drier is efficient since the heat leakage was found to be very low.*

*Keywords Drier efficiency, microbiological growth, heat leakage, coefficient of thermal conductivity and convection heat transfer.*

## INTRODUCTION
Drying is one of the oldest methods of preserving food. Societies practiced the drying of meat, fish, fruits and vegetables in the sun before recorded history. Today, the drying process is still important as a method of preservation of agricultural foods (Earle, 2004). Apart from the agricultural products, many industrial products including chemicals and pharmaceuticals are dried for various purposes like safe storage, easy handling, value addition, further processing and quality improvement (Chavda and kualmar, 2009).
Drying is used to remove water from foods for two reasons; to prevent (or inhibit) micro organisms and hence preserve the food and to reduce the weight and bulk for cheaper transport and storage. When carried out correctly, the nutritional quality, flavor and texture of dehydrated foods are maintained though often slightly less than that of the fresh food (Practical Action, n.d). However, if drying is carried out incorrectly there is

a greater loss of nutritional value and food qualities, more seriously, a risk of microbial spoilage and possibly even food poisoning.

Nigeria produces wide varieties of food and agricultural commodities, but a greater percentage of these food items perish in our market system or at homes due to deterioration in transit and poor preservation methods. According to food and Agricultural organization(FAO), out of the 10 million tones of cereal grains and legumes produced in Nigeria 1.5 to 2 million tones are lost due to poor post harvest handling. It is estimated also that between 30 to 50% of the yam and cassava tubers produced are lost at post-harvest level annually (Oni and Obiakor, 2002). Fruits and vegetables also, are categorized as highly perishable crops and today, prices and availability of these crops are quite erratic due to inadequate processing equipment and seasonality.

The challenge for us is to come up with appropriate low cost drying technology that will carter for the needs to process, dry, preserve and store many of our tropical root crops such as yam, cassava, potatoes, ginger, cocoyam; Cereals crops such as maize, rice, sorghum, millet, soya bean, etc; oil crops such as oil palm fruits, groundnuts, sunflower; fruits and vegetables, such as tomatoes, mangoes, plantains, oranges. Conducting an adaptive and innovative design and research will help reduce post-harvest losses, increase the stability of food supply and product availability and make up during off-season or scarcity or drought.

Moreover, dried foods are good sources of quick energy and wholesome nutrition, since the only thing lost during preservation is moisture. For instance meat, jerky dried nut and seeds are good source of protein for a snack or a meal. Therefore, dried foods are an easy food option for busy executives, hungry backpackers, active woman and children, all of whom can benefit from the ease of use and nutritional content of dried foods.

Drying, or dehydration, is a food preservation technique which relies upon reducing the moisture content of a food to a level where microbial growth is inhibited or where the rate of an adverse chemical reaction is minimized. The minimum moisture content for the activity of bacteria, fungi or moulds is relatively clear cut, with a rapid increase in the rate of growth above the minimum. However, the rate of a chemical reaction is likely to decrease much more slowly with reduced moisture content. Drying requires the removal of water from a food solid or food solution by vaporization and therefore requires thermal energy; this is often supplied in the form of steam or hot air. Consequently drying is both a heat transfer and a mass transfer operation. Other than as a preservation process, drying is used because of the need to provide better physical properties, to make material handling easier.

The removal of water from fruit and vegetable tissue may damage the structure of the food; the rate of drying and the temperature to which food is exposed are both important in determining the quality of the dried product. The ability of micro-organisms to grow is reduced as water activity is reduced. In general, bacteria require a greater water activity or moisture content for growth than do fungi. However, there is a range of water activity for growth of all micro-organisms and this range is widest at the optimum growth temperature for a given bacterium, yeast or mould. Also, yeasts and moulds tend to grow over a wider range of water activity than do bacteria.

## DESIGN METHODOLOGY

### Preamble

The design of the agricultural soil tilling machine includes amongst other things the analysis of the major components parts using the relevant mathematical equations for the calculations and selecting of the appropriate materials for durability and functionality. The main components of the machine are; the drying chamber, casing, lagging, the heater, and the hot water tank.

### Material Selection

| COMPONENTS | MATERIALS | PROPERTIES |
|---|---|---|
| **Drying chamber** | Low carbon steel | i. Contains up to about 0.25% carbon<br>ii. Cheap and possesses good formality and weldability.<br>iii. Can be cold worked<br>iv. Very suitable for machine element where high strength is not required |
| **Casing** | Low carbon steel | Same as above |
| **Hot water tank** | Low carbon steel | Same as above |

| | | |
|---|---|---|
| **Lagging** | Saw dust | Cheap and possesses poor conductor of heat |
| **Heater** | Copper | High conductivity |

Table 1. Selection of materials

In summary, the factors considered for the selections of the materials used for this work include;

i. Availability of material and cost of material,
ii. Mechanical properties of the materials,
iii. Cost of the machine should be affordable.

The multi-purpose dryer was designed in form of a furnace base extraction mechanism. It was fabricated by $800mm \times 400mm \times 1060mm$ flat iron sheet, ¼ mild steel rod, ½ inches copper pipe, ¾ inches pipe for water inlet and steam outlet, and wire gauze. The entire body of the dryer was lagged to eliminate heat loss to the environment.

The focus was to dry food products between 45-70°C and still retains its nutritional and market value. In order to achieve this, the drying chamber was designed uniquely.

**PART DESIGN:**

i. Vent design
ii. Copper pipes design
iii. Tray design
iv. Breather pipe design
v. Dome design
vi. Blower
vii. Drying chamber
viii. Casing
ix. Water tank design an

**BLOWER DESIGN**

Designing for air flows by forced convection. The blower is machined having the shape of an aerofoil, smaller diameter and length.

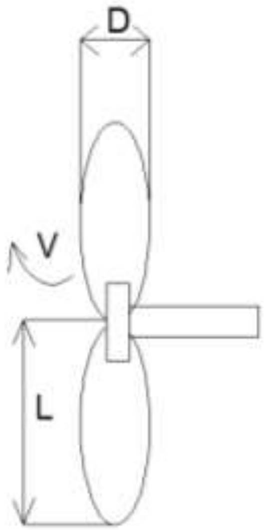



Fig 2.3.1 A TWO BLADE FAN

Length=100$mm$

Diameter=300$mm$

We assume Velocity=2.5 $^{m}/_{s}$

Cross sectional area of casing A = $\frac{\pi d^2}{4}$

D = diameter of casing = 0.3m

$$A = \frac{\pi \times 0.3^2}{4}$$

$$= 0.07m^2$$

Air flow rate $Q_1$ = area× $velocity$

$$=0.07m^2 \times 2.5\ ^{m}/_{s}$$

$$=0.177m^3/s$$

Power Required of the Blower.

The power required to drive the blower is given by

$$W=\frac{h\rho_a gQ}{\eta_m} \quad \text{............................................} (1)$$

Where

h= pressure rise across blower

$\rho_a$= density of air at 60°C = 1.047Kg/m$^3$ (from steam table)

$g$ = acceleration due to gravity = 9.81m/s$^2$

$Q$ = volume flow rate of air in blower = 0.177m$^3$/s

$\eta_m =$ mechanical efficiency of blower 0.90 (assumed)

h = $V^2/2g$ where V is the velocity of air = 2.5m/s

$= 0.318mH_2O$

$$\therefore \; W = \frac{0.318 \times 1.047 \times 9.81 \times 0.177}{0.90} = 0.642kw$$

$=0.861hp$

## VENT DESIGN

In general, more air flow is desired in the early stages of drying to remove free water or water around cells and on the surface. Reducing the vent area will increase the temperature and decrease the humidity of the entry air and the air flow. A square vent of size ($25mm \times 25mm$)

Area, $A= L^2$

$= (0.025m)^2$

Moist air flow rate $Q_1 = AV$……………………………(2)

Where V is the air velocity =2.5m/s

$Q_1 = (0.025m)^2 \times 2.5m/s$

$= 1.5625 \times 10^3 m^3/s$

## DESIGN OF COPPER PIPES

To minimize possibility of surface moisture removal more rapidly than interior moisture can migrate to the surface. The surface can harden and retard the further loss of moisture. As a result the copper pipes are designed to be smaller in diameter so the dryer can start off at low temperature and high humidity and thus avoid this problem.

Material type= copper

Thickness= 1.5mm

Length of pipe=1m

Heat capacity=400J/KgK

## TRAY DESSIGN

A compartment of four trays (wire gauze) made up of copper with high thermal conductivity trays.

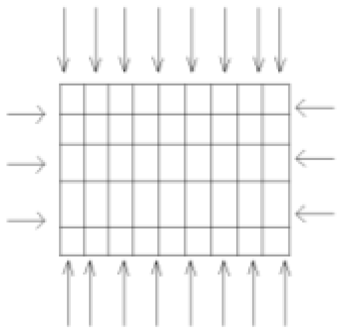


Fig 2.3.2 Perforated Tray

Size of tray
Breadth =400mm
Length=375mm
Area =LB
Heat transfer Q = $\frac{KA}{L}(T_f - T_i)$……………………………(3)
Where k = thermal conductivity of tray made of copper =385W/mK
$T_f$ = Final temperature of copper tray in the drying chamber= 65°C
$T_i$ = Ambient temperature= 25°C

$$Q = \frac{385\text{W/mK}\times0.4\text{m}\times0.375\text{m}(65-25)°\text{C}}{0.375m}$$
$$= 6{,}160\text{J}$$

## DRYING CHAMBER

The temperature obtainable in the drying chamber will be affected by several factors: Lagging, efficiency, vent area, and ambient temperature. The drying chamber was constructed with flat mild steel of (800mm×400mm×760mm). The chamber consists of four perforated trays to allow the passage of air flow and out of the drying chamber for effective drying of food samples placed inside the chamber.

## DESIGN OF BREATHER PIPE

Designed along with the water inlet pipe, and is fitted in the heating chamber to prevent pressure build up leading to boiler explosion.

$$\text{Diameter of pipe} = {}^{3}/_{4}\ inches = 19.05\text{mm}$$

Length of pipe= 120cm=1200mm

$$\text{Area} = A = \pi \times \frac{D^2}{4}$$

$$A = \pi \times \frac{19.05^2}{4}$$

$$= 285.022\text{mm}^2$$

Flow rate of steam leaving the breather pipe $Q_2$= AV

Energy supplied by the heater = Heat gained by water in the tank

$$I^2Rt = M_wC_w\Delta t \text{……………………………..(4)}$$

$$t = \frac{MwCw\Delta t}{I^2R}$$

$$p = I^2R = 2000\text{W}$$

$$C_w = 4200\text{J/KgK}$$

$$M_w = \boldsymbol{\rho}_w V_w$$

$$\boldsymbol{\rho}_w = 1000\text{Kg/m}^3$$

$V_w$=LBH (Volume of water tank)

Length= 500mm

Breadth=400mm

Height= 250mm

$$V_w = 500\text{mm} \times 400\text{mm} \times 250\text{mm}$$

$$= 5.0 \times 10^7 mm^3$$

$$V_w = 0.05\text{m}^3$$

$$m_w = \boldsymbol{\rho}_w V_w \text{…………………………… (5)}$$

$$= 1000\text{Kg/m}^3 \times 0.05\text{m}^3$$

$$= 50\text{Kg}$$

$$t = \frac{mwCw\Delta t}{I^2R}$$

$$= \frac{50\text{Kg} \times 4200\text{J/KgK} \times 100\text{k}}{2000W}$$

$$= 10500\text{secs}$$

$$t = 2.9167\text{hrs}$$

$$m_{steam} = \boldsymbol{\rho}_{steam} \times \text{Vol}_{\text{ pipe}}$$

$$\boldsymbol{\rho}_{steam} = \frac{1}{V_g}$$

Where $V_g = the\ specific\ volume\ of\ steam\ in\ breather\ pipe$

$V_g$ = 1.673m³/kg at 100°C ( from steam table)

$$\boldsymbol{\rho}_{steam} = \frac{1}{1.673\text{m3/kg}}$$

$$\boldsymbol{\rho}_{steam} = 0.5977\text{Kg/m}^3$$

## DOME DESIGN

The dome is designed hemi-spherically, in order to distribute the warm air uniformly throughout the drying chamber.

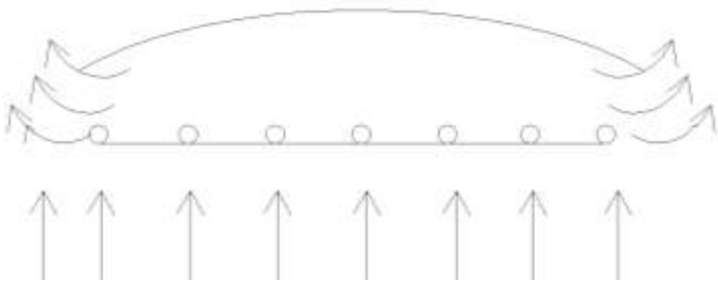


Fig 2.3.3 Hemispherical Dome

## MANUFACTURING SPECIFICATION

| | |
|---|---|
| DRYER TYPE: | Tray dryer |
| SIZE: | 80cm x 106cm x 40cm |
| COPPER TUBE: | ¾ inch |
| MATERIAL USED: | Mild steel |
| HEATING COIL: | 2000W |
| COIL USED: | Copper coil |
| TRAY SIZE: | 50cm x 40cm x 25cm |

## WORKING DRAWINGS

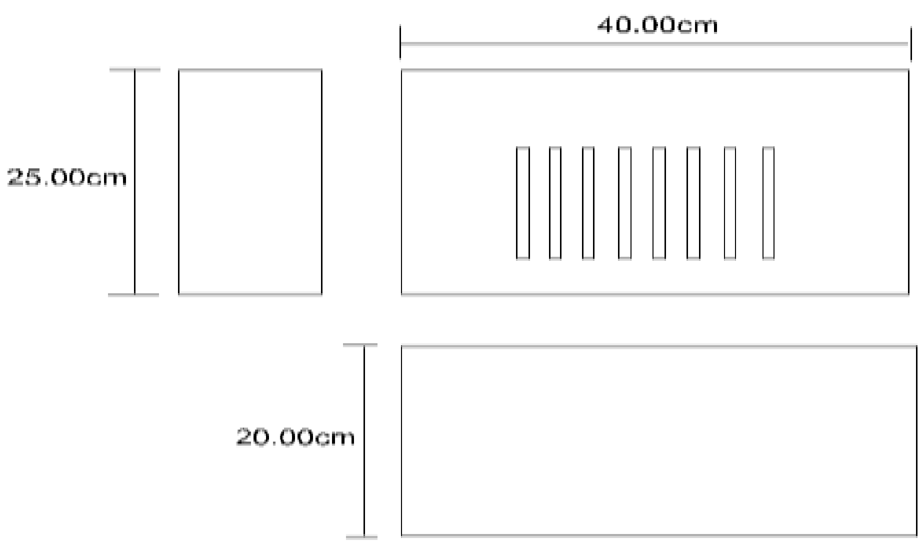



Fig 2.5 Fan chamber (Material: Mild steel)

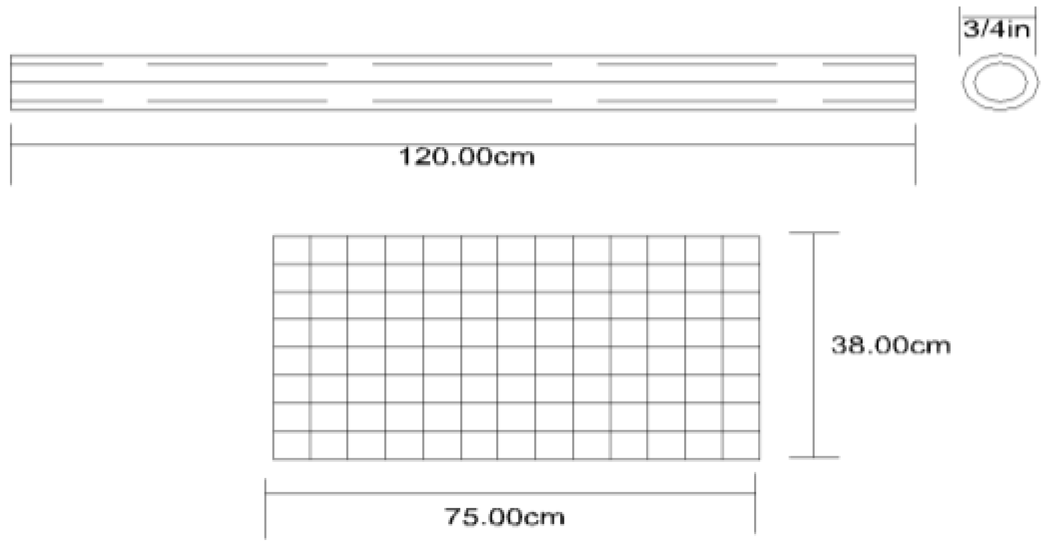



Fig 2.6 Pipe and wire gauze (Material: copper and Aluminium)

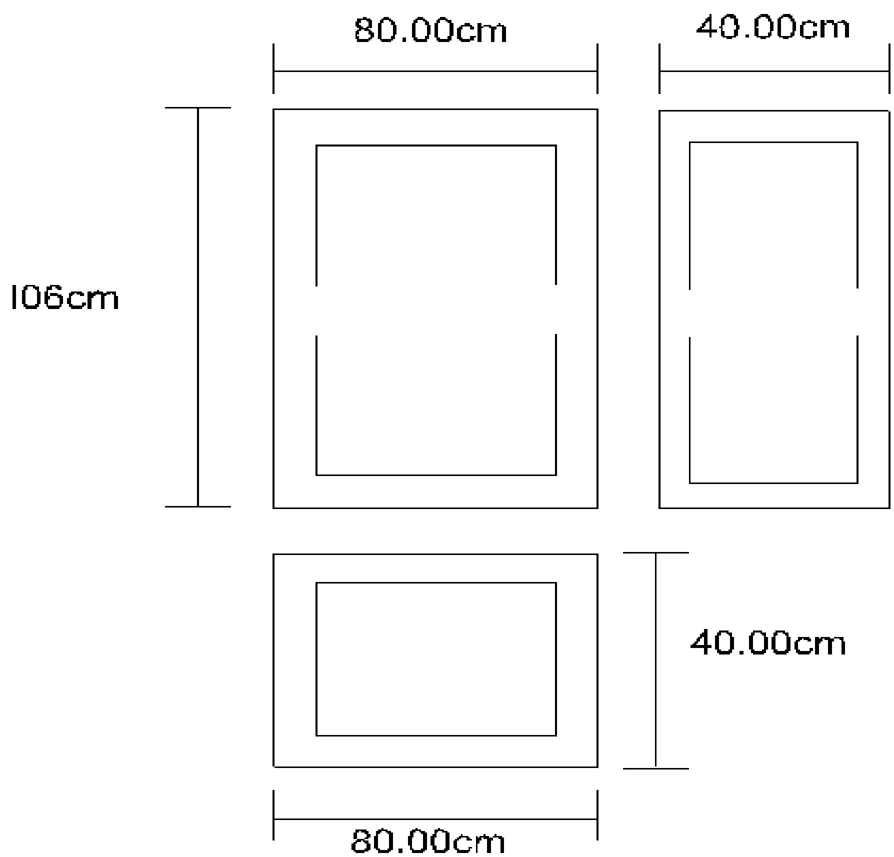



Fig 2.7 Dryer Body Casing (Material: Mild Steel)

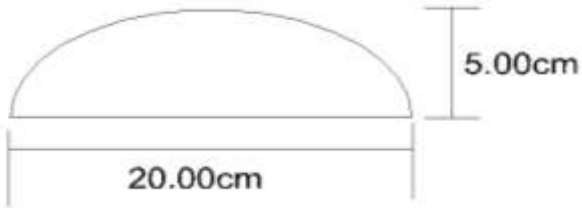



Fig 2.8 Hemispherical Dome (Material: Mild Steel)

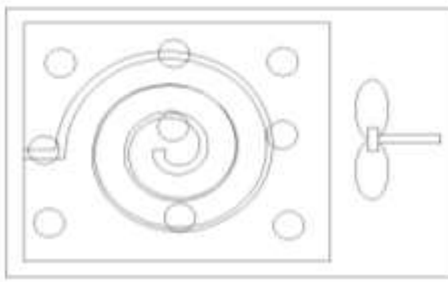
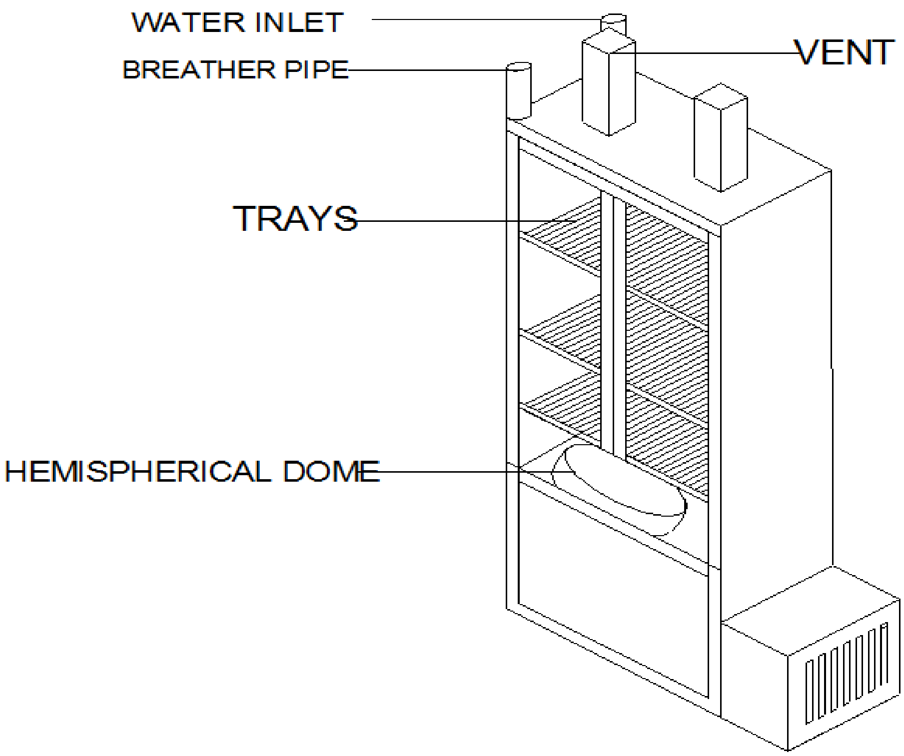
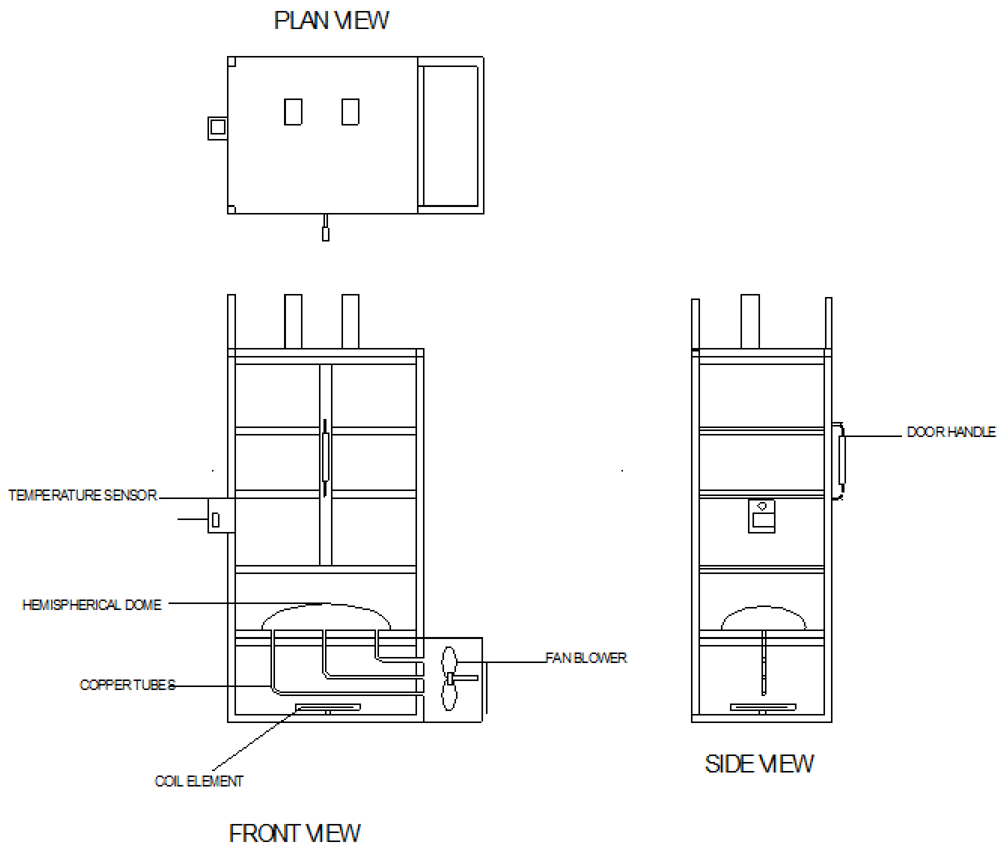


Fig 3.8.8: Fan Blower




## Isometric view




## Test and results

As a result of time constraint, the few food samples dried are pepper, okra and plantain. The different drying results obtained are as follows:

| Drying time (hr) | Sample mass (Kg) | Moisture content ratio | Drying rate (Kg/hr) | Temp (°C) |
|---|---|---|---|---|
| 0 | 1.20 | ----- | ----- | 64 |
| 1 | 1.15 | 0.9064 | 1.15 | 61 |
| 2 | 1.10 | 0.8142 | 0.55 | 57 |
| 4 | 0.90 | 0.7543 | 0.450 | 55 |
| 6 | 0.85 | 0.7183 | 0.2833 | 52 |
| 8 | 0.70 | 0.6045 | 0.175 | 52 |
| 10 | 0.65 | 0.5417 | 0.065 | 52 |
| 12 | 0.55 | 0.5209 | 0.04583 | 50 |
| 16 | 0.50 | 0.4837 | 0.03125 | 48 |

Table 3.1 Plantain Drying Results

| Drying time (hr) | Sample mass (Kg) | Moisture content ratio | Drying rate (Kg/hr) | Temp (°C) |
|---|---|---|---|---|
| 0 | 0.52 | 0.4912 | ----- | 44 |
| 1 | 0.41 | 0.4403 | 0.4100 | 42 |
| 2 | 0.35 | 0.4048 | 0.1750 | 39 |
| 4 | 0.28 | 0.3815 | 0.0700 | 38 |
| 6 | 0.25 | 0.3249 | 0.0417 | 36 |

Table 3.2 Pepper Drying Results

| Drying time (hr) | Sample mass (Kg) | Moisture content ratio | Drying rate (Kg/hr) | Temp (°C) |
|---|---|---|---|---|
| 0 | 1.5 | ----- | ----- | 65 |
| 1 | 1.2 | 0.9247 | 1.2 | 63 |
| 2 | 1.1 | 0.8542 | 0.55 | 61 |
| 4 | 0.95 | 0.7901 | 0.2375 | 58 |
| 6 | 0.8 | 0.7473 | 0.1333 | 56 |
| 8 | 0.75 | 0.6663 | 0.09375 | 55 |
| 10 | 0.675 | 0.5728 | 0.0675 | 52 |
| 12 | 0.62 | 0.5214 | 0.05167 | 51 |

Table 3.3 Okra Drying Results

## CONCLUSION

This project has established the need of a multipurpose dryer, that involves supplying heat to the moist material being dried and removing water from it. It is an operation that involves heat and mass transfer.

The multi-purpose dryer has been designed to meet the need of individuals either domestically, commercially or industrially by increasing the drying rate of a food sample which is the most important factor in any dryer and depends on the flow rate and temperature of water and air stream. In general, the greater the difference between the temperature of the water and the air, the more rapidly heat is transferred.

In consequence, with a view of drying time and product quality, drying air temperatures of 55.3-65.3˚C, air volumetric flow rate of 0.0177 $m^3/s$, air flow rate of 2.5m/s and relative humidity of 25% are determined as the parameters in which our multi-purpose dryer would operate so as to achieve desired results.

It is anticipated that the use of the multi-purpose dryer would reduce the inconveniences and losses encountered in the use of the traditional methods. Since the multi-purpose dryer is fabricated from locally available materials, it would be widely accepted by Nigerian farmers and as a result of the lack of complexity in the design, Nigerian farmers would find it easy to operate and maintain and can be developed by suggestions from local farmers.

## RECOMMENDATION

Our recommendation for this project is that the multi-purpose dryer can be applied industrially i.e. can meet industry needs, commercially i.e. capable of making profit if better managed by personnel and domestically i.e. capable of meeting family needs.

Further suggest that work on energy balance i.e. energy input and energy utilization in terms of KWhr be looked into with regards to operational cost of drying in on a large scale and also the rate at which heat is removed from drying chamber be looked at for effectiveness of drying process, so as to achieve objectives.

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