# DESIGN AND FABRICATION OF ELECTRIC PLANTAIN CHIPS DRYER

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2004/18410EA

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA,

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# DESIGN AND FABRICATION OF ELECTRIC PLANTAIN CHIPS DRYER

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## DECLARATION

ereby declare that this project is a record of a research work that was undertaken and written me. It has not been presented before for any degree or diploma or certificate at any University Institution. Information derived from personal communications, published and unpublished rks of others were duly referenced in the text.

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## CERTIFICATION

This project entitled "Design and Fabrication of Electric Plantain Chips Dryer" by Onogure Ogagaoghene, meets the regulations governing the award of the degree of Bachelor of Engineering (B.ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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# DEDICATION

To my beloved parents Mr. and Mrs. Lagos Onogure.

## ACKNOWLEDGEMENTS

With depth of appreciation I legislate my profound gratitude to my loving and caring creator Jehovah in catering for my needs during when the project was done.

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## ABSTRACT

The design, fabrication and testing of a plantain chips dryer was carried out. The dryer was designed using electric heating filament rated as 2000W of electric power at 220V and a centrifugal fan consisting of an electric motor rated 120W with an axial fan blade that blows atmospheric air at ambient temperature over hot electric heating filament. The temperature of the air is raised as it flows through the heating filament and is fed into the drying chamber of the dryer, a process that results in moisture removal from the plantain chips due to simultaneous heat and mass transfer. The loading capacity of the dryer is 1.065kg of plantain chips and the volume of the drying cabinet is 0.05655m$^3$. The drying temperature is 72 $^0$C and a fan speed of 800-1000rpm depending on the voltage supplied. A time of 60mins was taken to achieve drying with a suitable moisture content of 19% and a drying efficiency of 71%. it was recommended that the optimization of dryer design using electricity as power source should be emphasized, the heat loss through the exhaust of the dryer can be useful by recirculation to increase the drying efficiency and time and the capacity of the dryer can be increased by altering the machine dimension including better baffle system for uniform drying.

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## CHAPTER ONE

### 1.0 INTRODUCTION

### 1.1 BACKGROUND OF THE STUDY

Drying is one of the oldest methods of food preservation. Dry plantain chips can be stored or can be processed into flour. In agriculture, however, drying is mainly for the purpose of preservation. Early Chinese dried eggs, the Swiss dried vegetables and the Africans served surplus corn, beam and meat by drying.(Hughes and Wallenberg, 1994). In food preservation methods, drying foods has received the most widespread and enthusiastic publicity recent years. Methods used for drying food have become mechanized over time. Initially, salting and drying in the sun, on an open room or on the stove tops were accepted methods. It was not until 1795 that the first dehydrator was introduced in France for the purpose of drying fruits and vegetables.(Bochm, 1993). When foods are dried, the growth of micro organisms is retarded and the spoilage is reduced. The basis of preservation of agricultural products by drying is the fact that micro organisms and enzymes need a certain amount of moisture to grow. Any moisture content below that value is critical to them. Moisture content of products reduced to 3.4% (db) is recommended for most vegetable and fruits under storage (Hall et al., 1986). Apart from preservation,dried foods are compact so that less storage space is needed. However, through improved commercial processes there are increasing numbers of dried food in the market.

### 1.2 STATEMENT OF THE PROBLEM

Medical sciences have particularly supported the consumption of staple foods and flours made from plantain because it tends to be firmer and lower in sugar contents when compared to other alternative sources. This has since then increased the need to dry plantain chips for various purposes. However, the traditional ways of spreading plantain chips under sun is not too hygienic and can pose danger to consumer's health.

During rainy season when sun is not reliable, the consequence of lack of drying facility is physical and qualitative loss of commodity. In this case, the following problems are encountered:

- It cannot be subjected to further processing such as grinding
- Mould and off-flavours develop if the drying is too slow or when there is no sun at all.

The effects of the following problems are:

- It makes the form utility to be scarce in the market thereby increasing the price of the products.
- It reduces the level of production.
- It reduces the income of the farmer because product with mould does not attract high price.
- It causes the farmer's resources to be wasted from planting to harvesting.

## 1.3 OBJECTIVES OF THE STUDY

The objectives of the study include:

(1) To design an electrical plantain chips dryer

(2) To fabricate and test the dryer.

## 1.4 JUSTIFICATION OF THE STUDY

Plantain is a seasonal crop that needs to be stored for future use. With little or no sun, ripe plantain deteriorate rapidly with the development of mould. As a result, the design and fabrication of a plantain chip dryer will facilitate and enhance efficient drying of plantain chips at the shortest time.

The machine intends to improve the hygienic condition under which plantain chips is dried. It will also add to numerous contributions of modern technology to agriculture especially in the aspect of food processing and ease of usage.

## 1.5 SCOPE OF THE STUDY

The work is the design and fabrication of plantain chip dryer using electricity as power source.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 GENERAL

Plantains (*musa paradisiaca)* are a staple food in the tropical regions of the world with a neutral flavour and texture when it in unripe. Native to the Indo-Malesian, Asian and Australian tropics; plantain is now found throughout the tropics and subtropics. It grows well at elevation of 0-920m or more depending on latitude, mean annual temperature of 26-36$^0$C and annual rainfall of 2000mm or higher for commercial production. Plantain is grown in a wide range of soil, preferably well drained. They are capable of yielding up to 40,000Kg of fruits per hectare annually in commercial orchards (Wikipedia, 2004). Plantain is world second most important fruit crops after oil palms. Plantain is grown in 52 countries with world with world production of 33 million metric tones(FAO,2004)

Plantain chips are obtained by removing the skin and the unripe fruits is then sliced (1 or 3mm thickness). Plantain chips are prepared for consumption by a variety of ways often simply by boiling, roasting or frying and may be eaten raw if ripe. Frying plantain chips in vegetable oil/palm oil are the most common practices in West Africa. Although one of the most important product prepared in this area's from plantain chip is its dried form which is grounded into flour.

Currently, plantains are of less importance than banana in terms of world trade in the genus but in West and Central Africa, about 70 million people were estimated to derive more than one third of their food energy requirement from plantains(Robinson,1996; swennen and Ortiz,1997).

Optimum storage temperature for plantain is 13-14 $^0$C. At this temperature, storage life of mature ripe fruit is 1-2 weeks. Average moisture content of plantain is 65% and has a drying temperature is 70 $^0$C. (PNT Johnson, 1998).

## 2.2 TYPES OF DRYERS

### 2.2.1 Pneumatic Dryer

In a pneumatic dryer, the solid food particles are conveyed rapidly in an air stream, the velocity and turbulence of the stream maintaining the particle in suspension. Heated air accomplished the drying and in some cases the material is passed through a classifier where the dried material is separated. The dry material passes out as product and the moist remainder is re-circulated for further drying.

### 2.2.2 Tray Dryer

The food is spread out on the tray quite thinly where the drying takes place. Heating may be an air current sweeping across the trays by conduction from heated trays or heated shelves on which the trays lies, or by radiation from heated surfaces most tray dryers are heated by air which also removes the vapour (Earle, 1992).

### 2.2.3 Rotary Dryer

The food stuff is contained in a horizontal inclined cylinder through which it travels, being heated either by air flow through the cylinder or by the conduction of heat from the cylinder walls. In some cases, the cylinder rotates and in other the cylinder is stationary and a paddle or screw rotates within the cylinder conveying the material through (Earle, 1992).

### 2.2.4 Spray Dryer

In spray dryer, liquid or fine solid materials in a sherry is sprayed in the form of a firm dispersion into a current of heated air. Drying occurs very rapidly, so that this process is very useful for materials which are damaged by exposure to heat for any appreciated length of time. The dryer body is large so that the particles can settle as they dry without touching the walls on which they might otherwise stick.

### 2.2.5 Belt Dryer

The food is spread as a thin layer on a horizontal mesh or solid belt and air passes through or over the material. In most cases the belt is moving through while in some designs the belt is stationery and the material is transported by scrappers (Earle, 1992).

## 2.3 METHOD OF DRYING PLANTAIN CHIPS

There are basically two methods of drying – sun drying and artificial drying.

**Sun Drying**

In sun drying, the plantain chips are spread on mats, tray or on concrete in the sun. The chips are usually turned to ensure uniformity of drying and many need to be covered when there is rain. Sun drying is used in countries where harvesting occurs in a dry period such as West Africa or the West Indies. With adequate sunshine and little rainfall, sun drying may take about one week, but if the weather is dull or rainy it will take a longer time (Lee, 1996).

**Artificial Drying**

It is aimed at removing excess moisture from the plantain chip in a short rime as possible. This is done by subjecting the chips to a stream of hot air. Artificial drying may be resorted to in countries where there is a lack of pronounced dry periods, after harvesting such as Brazil and south East Asia and sometimes in West Africa. Artificially dried plantain chips can be of poor quality if the drying conditions are not controlled such as rapid drying (Lee, 1996).

The simplest form of artificial dryers are conventional dryers which consists of a simple fire in a plenum chamber and a permeable drying platform. Air inlets are provided in order to allow the convection currents to flow without allowing smoke to taint the chips. These dryers are easy to construct and have been used in Klesterin Samoa, Cameroon, brazil and the Solomon inlands.

Other artificial dryers are platform dryers using heat exchangers, where the hot air is kept separate from the products which pass to the atmosphere or direct fired heaters, where the product of combustion mix with the hot air and are blown through the chips. These dryers can use oil or solid fuels as a source of power (Cuntia, 1991). The addition of a fan forces the hot air through the chips and creates a force draught dryer.

Another type of dryer uses conduction. Drying platform bilt of slate or cement is heated at one end by a fire or heat source. Heat distribution is not uniform with this type of dryer. Other technique has been used in association with the above example to overcome the problem of turning plantain chips in the dryer.

### 2.3.1 Artificial (Mechanical) Dryers

These are fired to increase the air temperature, and reduce the relative humidity (RH) and fans to increase air spread. They give close control over the drying condition and hence produce high quality products. They operate independently of the weather and have how labour costs. However, they are more expensive to buy and operate than other types of dryers In some application, where consistent product quality is essential, it is necessary to use mechanical dryers.

### 2.3.2 Basic Principles of Tray Dryers

The dryer consists of cabinet containing trays which is connected to a source of air heated by gas, diesel or biomass such as rice husk. The air temperature is basically controlled by a thermostat which is normally set at between 50 and $700^{0}$C. The air enters the bottom of the chamber below the trays and then rises, through the trays of food being dried and exits from an opening at the top of the chamber. In the intermediate technology system, the trays are designed to force the air to follow a longer zigzag route which increases the air/food contact time. This system reduces back pressure which means that cheaper and smaller fans can be used.

### 2.3.3 Basic Types of Tray Dryers

There are (3) three basic types of tray dryers; batch cabinet, semi-continuous cabinet and cross flow cabinet.

(a) **Batch Cabinet:** These are the simplest and cheapest to construct. The cabinet is a simple large modern box filled with internal runners to support the trays of food being processed. The trays are loaded in the chambers, the doors closed and heated air is blown through the stack of trays until the entire product is dried. As the hot enters below the bottom tray, this tray will dry first. The last tray to dry is the one at the top of the chambers.

The advantages of this system are:

- Simplicity and low cost
- Low labour costs, simply load and then unload.

The disadvantages of this system are:

- A tendency to over dry the lower trays
- Low efficiency in terms of fuel consumption, in the later stages of drying when most of the trays are dry.

(b) **Semi-continuous Cabinet:** These are developed to overcome some of the disadvantages of batch system. In semi-continuous cabinet a lifting mechanism allows all of the trays except the bottom tray to be lifted. It is thus possible to remove the lowest tray as soon as the product is dried. The mechanism then allows all the trays to be lowered. This leaves a space at the top of the stack to load a tray of fresh materials

Two types of lifting mechanism are available both of which activate four moveable fingers that lifts the second tray upwards. One design is operated by a handle which is pulled downwards. The other design has been found more suitable for use by women and here the lifting mechanism is a car screw jack which on winding up lifts the four fingers.

The advantages of this system are:

- Over drying is avoided
- Product quality is higher.

(c) **Cross Flow Chambers Cabinet:** Although intermediate technology development group has not, as yet, developed this system it is considered worth mentioning in this work. In this chamber the air is blown, through a series of louvers, directly across the trays and then re-circulated over the heater. In the early stages of drying, when a lot of water is being removed, a high proportion of the air is vented to an exit and replaced by fresh air. As drying proceeds, the proportion of vented air is reduced. At the end of the drying cycle, no air is vented. This system overcomes the problems associated with batch and semi-continuous cabinet in that:

- Labour costs are low as it works like a batch dryer.
- All the trays dry at the same rate.
- Fuel efficiency is maximum.

Cross flow systems are however, technically more complex and require automatic humidity sensor to control the percentage of air vented into the cycle.

## 2.4 THEORY OF DRYING

Drying is the removal of moisture from agricultural produce to a predetermined level. It is a thermo-physical and physio-chemical operation by which the excess moisture from a product is removed. It is an important unit operation in post harvest treatment/handling of crops. It is carried out basically for two reasons.

- To inhibit the activity of micro organisms and hence preserve the food and
- To reduce the weight and bulk of food for cheaper transport and storage.

When drying is carried out correctly, the nutritional quality, colour and texture are slightly less than fresh foods but for most people, this has only minor nutritional significance as dried foods form one component in the diet. However, if drying is carried out incorrectly there is a greater loss of nutritional and eating quality and more seriously a risk of microbial spoilage and possibly even food poisoning, (IT DG's Technical Briefs, 1999).

### 2.4.1 Heat Exchanger

A heat exchanger is a unit which draws in cold air and heats it as it passes through the unit into the drying section. In a sense, cold air is exchanged for heated air. The unit has a heating filament for heating the air and a fan to move the air. There are generally two types of heat exchangers, the direct and indirect The direct type draws the air past the heating filament and blows heated air directly through the product to be dried. In the indirect type, the heated air flows around air tubes and pass out through a vent. The hot air blown into the products to be dried is drawn through the tubes.

### 2.4.2 Heat Transfer in Drying

The rate of drying is generally by the rate at which energy can be transferred generally to the water or to the ice in order to provide the latent heats. Although under some circumstances the rate of mass transfer removal of the water can be limiting all three of these mechanisms by which heat is transferred though conduction, radiation and convection may enter into drying. The relative important of the mechanism varies from one drying process to another and very often one mode of heat transfer predominates to such an extent that it governs the overall process (Earle, 1992).

As an example in air drying the rate of latent heat transfer is given by

$q = h_s (t_a - t_s)$ (J/s)

q = rate of heat transfer j/s

$h_s$= surface heat transfer coefficient $Jm^{-2}s^{-10}c^{-1}$

A = area through which heat flow is taking place, $m^2$

$t_a$ = the air temperature $^0C$

$t_s$ = temperature of the surface which is drying $^0C$

### 2.4.3 Heat Requirement for Vaporization

The quality of energy required per kilogram of water called the latent heat of vaporization it is from a liquid or latent heat of sublimation if it is from solid. (Earle 1992). Heat energy required for one kilogram of material is calculated as the heat required for raising the temperature to vaporizing temperature plus the latent heat to remove water (Earle, 1992)

$Hy = Hr + Hi$

And $Hr = (Tv - Tm)E$

Where Tm = temperature of material

Tv = vaporization temperature

E = specific heat capacity of the material $Kj/Kg/^0C$

The process of drying is the removAL of some quantity of water from the material to be dried in drying the amount of dry matter does not change if $M_1$ and $M_2$ are weight of the material before and after drying, $Q_1$ and $Q_2$ are the contents before and after drying them.

$M_1(1-Q_1) = M_2 (1-Q_2)$ dry matter balance

The amount of water to be removed is calculated as

$Mw = M_1 - M_2$

But $M_2$ from 2.3

$M_2 = M_2 (1-Q1)/ (1-Q2)$

$Mw = M_1 (1-1-Q_1) / (1-Q_2)$

$Mw = M_1 (1-Q_2-1)/ (1-Q_2)$

In air drying, as dry air passes through the drying chamber, increasing the moisture content of air from the initial value of $X_1$ to $X_2$ the amount air needed to remove water Mw is given as

$Mw = Mv (X_2 - X_1)$

$Mv = Mw/X_2 - X_1$

Mv = amount of air

$= M_1 (1-1-Q_2) / (X_2 - X_1)$

This is assuming that the rate of drying is constant. If the amount of air given by the blower equals Qv, then time needed for the drying is calculated as:

$T = Mv/Qv \times V$

Where:

Qv = the amount of air given by the ventilator

V = specific weight of air ($Kg/m^3$)

### 2.4.4 Mass Transfer in Drying

Heat energy is transferred under the driving force provided by a temperature difference. The rate of transfer is proportional to the potential temperature difference and to the properties of the transferred system characterized by the heat transfer coefficient Uche, 1998. In the same way, mass is transferred under the driving force provided by a partial pressure or concentration difference and the rate is proportional to the potential. Pressure or concentration difference to the properties of the transfer system characterized by the mass transfer coefficient.

Writing these symbolically analogies to $q = UA\Delta t$

We have $dW/dQ = KgA\Delta y$ 2.12

Where W is the mass being transferred in Kg/s. A is the area through which the transfer is taking place, KgA is the mass transfer coefficient in $Kgm^{-2}s^{-1}$ and $\Delta y$ is the humidity difference in Kg/Kg.

The application of the formula above is not straight forward because the movement of moisture changes as drying proceeds. Initially, the mass moisture is transferred from the surface of the material and later to an increasing extent, from deeper within the food to the surface and then to the air.So the first stage is to determine the relationship between the moist surface and the ambient air and then to consider the diffusion through the food. In studying the surface/air relationships, it is necessary to consider mass and heat transfer simultaneously.

Rate of mass transfer CMc = Kg (Hs - Ha) (Kg/s) 1.13

Where Kg = mass transfer coefficient ($Kgm^{-2}s^{-1}$)

A = area through which heat flow takes place M2

Hs = humidity at the surface

Ha = humidity of air

The air for drying is usually heated and is also the heat transfer medium. Therefore, the need to consider the relationship between air and the moisture content is necessary.

### 2.4.5 Psychometrics

The capacity of air for moisture removal depends on its humidity and its temperature. The study of relationship between air and its associated water is called psychometrics. And the relationships between temperature wet bulb and dry bulb, humidity absolute relative and other properties of air water vapour mixtures are presented in a psychometric chart which allows for a given pressure the condition during the drying of a food to be followed (Earle, 1992). Humidity is the measure of the water content of the air. The absolute humidity is the mass of the water vapour per unit mass of dry air and the unit is therefore Kg/Kg.

### 2.4.6 The Psychometric Chart

A plot of dry bulb temperature of air water mixture and its water vapour pressure made under a particular pressure normally at atmosphere gives a psychrometric chart. The two main axes are temperature dry bulb and humidity (Earle, 1992). For example when air at sate point A moves to a new condition B, it is to have undergone a state process the amount of energy absorbed by the air when being heated from state point A to B may be calculated as the difference in enthalpy (hs - ha) between points A and B.

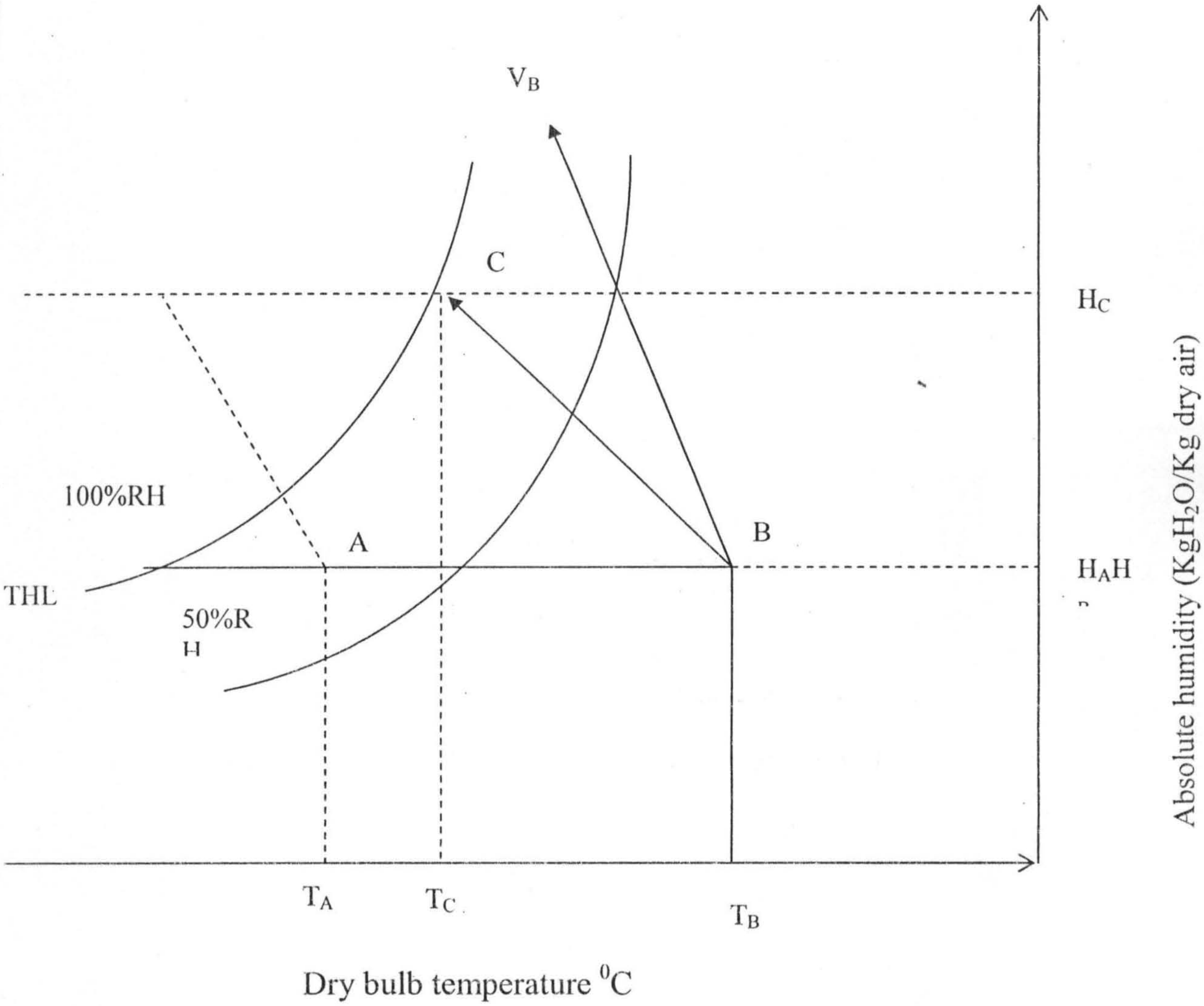



**Fig. 2.0** the psychometric chart showing state points and process of air in a dryer.

Dryers with heated air, particularly during the constant rate period is a constant wet bulb process and may be described by the path B to C on the psychometrics charts. The energy to evaporate the moisture from the food stuff is supplied by the passing air, which decrease in temperature from Tb to Tc during this dehydration process, the wet bulb temperature is almost constant and normally does not vary more than $1.1^0C$.

#### 2.4.7 Drying Periods

Food drying process is divided into the following periods.

##### 2.4.7.1 Constant Rate Drying Period

In the constant rate period, drying takes place from the surface of the food similar to evaporation from a free water surface the rate of removal of water can then be related to the rate of heat transfer, if there is no change in the temperature of the food and therefore all heat energy transferred to it must result in evaporation of water. The rate of the water is also the rate of mass transfer from the solid to the ambient air.

##### 2.4.7.2 Critical Moisture Content

The change from constant drying rate to a slower rate occurs at different moisture contents for different foods. However, for most food the change from constant drying occurs at a moisture content in equilibrium with air of 58-65% relative humidity occurs, it is known as critical moisture content (Earle, 1992).

##### 2.4.7.3 Falling Rate Drying Period

When the moisture is bond internally in the grounds of the food and must move to the surface for removal in this case drying is characterized by the falling rate period, during this period, drying depends partly upon the rate of moisture diffusion from within to the surface of the food. In other words, as drying proceeds, the moisture content falls and the access of water from the interior of the food to the surface affects the rate and decreases it (Earle, 1992).

#### 2.4.8 Factor Affecting the Rate of Drying

The main factor which affects the rate of drying of food stuff are:

- The physical and chemical properties of the food stuff shape, size, composition, moisture content.
- The geometric arrangement of the product or food stuff in relation to the heat transfer

surface or medium (e.g. tray loading)

- The physical property of the drying environment air temperature, humidity, velocity.
- The characteristics of the drying equipment heat transfer efficiency. (Ojha and Michael 2006).

it is generally observed that many food products undergoes an initial rapid, constant rate drying periods followed by a slower, decreasing drying rate period, sometimes a two different rates. During the constant rate period, moisture evaporates from the surface at a rate dependent on the drying conditions but then after critical moisture content has been reached; the moisture evaporation must diffuse from within the food.

### 2.4.9 Calculation of Drying Times

Drying rates are determined experimentally or predicted from theory which can be used to

calculate drying times so that drying equipment and operation can be designed. In most cases, the drying rates vary through out the dryer with time as drying proceeds and with the changing moisture content of the food stuff such that the situation is assume that the temperature and relative humidity of the drying air are constant.

In the case of constant rate period the time needed to remove the quality of water will reduce the food material to the critical moisture content Xc that correspond to the end of the constant rate period and below which the drying rate falls can be calculated by dividing the quality by the rate

so $\theta = w(x_b - x_f)/({}^{dw}/_{d\theta})\ constant$ 2.14

where $({}^{dw}/_{d\theta})\ constant = \text{kg}kgA(y_s' - y_a)$

And Xo is the initial moisture content and $X_f$ is the final moisture content = $X_c$ in this case both on a dry bases, W is the amount of dry material in the food and (dW/dθ) constant is the constant drying rate.

Where the drying rate is reduced by a factor f, then this is incorporated to give:

So $\theta = W (X_b - X_f) / (dw/d\theta)$ constant 2.15

Where $(dw/d\theta)$ constant $= Kg^1A(ys - yl)$

And f therefore, expresses the rate of the actual drying rate to the maximum

drying rate corresponding to the free surface moisture situation.

**2.4.10 Drying Efficiency**

This is a means of accessing the thermodynamics of drying and it is useful for two reasons.

It enables a comparison to be made between the performances of two or more dryers.

It provides a means of assessing how a good dryer is operating under certain conditions.

There are different ways of estimating the efficiency of drying. One is by comparing the efficiency of the dryer. This considers the rate of heat that could be theoretically required to supply the latent heat of vaporization of the water has been dried ff to the actual heat used in the dryer.

Dryer efficiency = Ht/Ha

Where

Ht = theoretical heat required

Ha = actual heat used in the dryer it can be calculated in the amount of heat

given by the air when used as the drying medium

$Ha = M (T_1 - T_2)$

Where:

M = specific heat of air in $Kg/Kg/^0C$

$T_1$ = initial temperature

$T_2$ = temperature of air after cooling (Uche, 1998).

However, there are three groups of factors affecting the drying efficiency.

- Those related to the environment, in particular ambient air condition

- Those specific to the crop
- Those specific to the design and operation of the dryer.

### 2.5 NUTRITIONAL VALUE OF PLANTAIN

Plantains have a high carbohydrate content (31g|100g) and low fat content(0.4g|100g). they are good sources of vitamins and minerals, particularly iron(24mg|100g), potassium(9.5mg|kg), calcium(715mg|kg), vitamin A, ascorbic acid, thiamine, riboflavin and niacin. The sodium content (351mg|kg) is low in dietary terms, hence recommended for low sodium diets (Stover and Simnonds,1987; Welford et al.)

# CHAPTER THREE

## 3.0 MACHINE DESIGN AND CALCULATIONS

The electric plantain chips dryer is a device that works by the action of a centrifugal fan blowing atmospheric air at ambient temperature over hot electric heating filaments, the temperature of the air is raised as it flows through the heating filament. This hot air is then channeled to the drying chamber or cabinet of the dryer where it vaporizes the moisture content of the plantain chips, the vapor that results is then channeled out of the cabinet through the exhaust on the cabinet. This process is defined as a process of moisture removal due to simultaneous heat and mass transfer.

## 3.1 MACHINE COMPONENTS DESCRIPTION

The plantain chips drier is made up of the following component parts

### 3.1.1 Drying Cabinet

The drying cabinet is made of up aluminum sheet of 0.3mm thickness rolled into two concentric cylinders with a lagging space of 20mm and a door at the ends. The cabinet serves as the chamber within which the drying trays containing the plantain chips to be dried are placed, it sits horizontally and also houses the other components of the dryer within it.

### 3.1.2 Electric Heating Filament

The electric heating filament is made of nickel and chromium; it converts electric energy to heat energy. It is rated 2000watts of electric power at 220volts, the filament heats up when electric current flows through it thereby generating the required drying heat.

### 3.1.3 Centrifugal Fan

The centrifugal fan consists of an electric motor and an axial fan blade. The motor converts electric energy to rotary mechanical motion to supply the system with the required air directed through the heating filament into the drying cabinet.

### 3.1.4 Drying Trays

The drying trays are rectangular plates made of aluminum sheets, plantain chips are spread on them and placed in the drying cabinet for drying

### 3.1.5 Power Input Cable

The power cable transmits electrical energy from the mains power supply to the fan and filaments.

## 3.2 MODE OF OPERATION

When the trays are filled to capacity with the plantain chips and the drying chamber is closed, the dryer is then turned ON. The dryer was has an electric heating filament rated as 2000W of electric power at 220V and a centrifugal fan consisting of an electric motor rated 120W with an axial fan blade that blows atmospheric air at ambient temperature over hot electric heating filament. The temperature of the air is raised as it flows through the heating filament and is fed into the drying chamber of the dryer, a process that results in moisture removal from the plantain chips due to simultaneous heat and mass transfer. After 60mins of drying, the chips are removed and redy for either storage or further processing. The dryer is then turned OFF. The trays should be cleaned properly to prevent accumulation of dirt.

## 3.3 DESIGN CONSIDERATION FOR MATERIAL SELECTION

The following factors were considered wile fabricating the electric plantain chips dryer:

(1) Availability of material.

(2) Type of material to be used.

(3) Durability of the material.

(4) Cost of the material.

The materials for the development of the dryer are

### 3.3.1 Aluminum Sheet

This is used for the casing of the dryer and gauge 18mm is used for the design. Aluminum is used because it is a good conductor of heat, it does not rust and is also light.

### 3.3.2 Wire Gauze

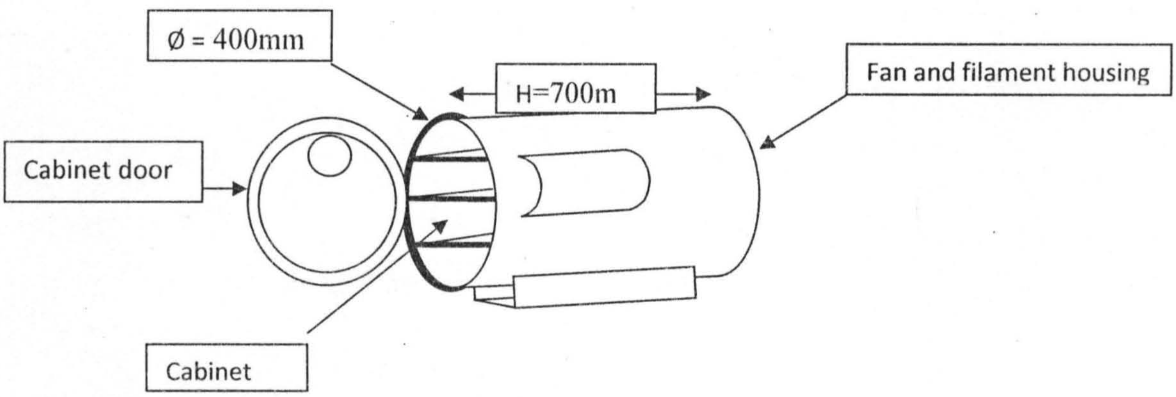
This material is used to construct the floor of the tray. Wire gauze of 1.7mm is used for the design. Wire gauze are used to allow easy flow of air throughout the drying chamber

## 3.4 DESIGN CALCULATIONS

### 3.4.0 Drying Analysis

Pneumatic drying is generally described by the equations of convective heat transfer. The total energy input is necessary for: water evaporation, heating up the dry material and heat losses by radiation. The energy balance shows appropriate relations between the total provided energy, utilized energy, and heat losses in the drying process.

### 3.4.1 Volume of drying cabinet (Vc)




$$V_c = \frac{\pi \times d^2 H}{4} = \frac{\pi \times 0.4^2 \times 0.45}{4} = 0.05655m^3$$

### 3.4.2 Area of Drying Trays

The middle tray is of dimension 380mm/400mm

The upper and lower trays measure 320mm/400mm each

$A = l \times b$

Total area of drying tray = $(0.38 \times 0.40) + 2(0.32 \times 0.40) = 0.408m^2$

### 3.4.3 Mass of Plantain Chips $m_p$

Mass of plantain in dryer is given by

$m_p = \rho_p \times V_p$

$V_p$ =volume of chips=?

$\rho_p$=density of plantain = 870 kg/m$^3$

$V_p = A \times t_p$

A=area of drying tray = 0.408m$^2$

$t_p$=plantain chips thickness = 0.003m

$V_p = 0.408 \times 0.003 = 0.001224m^3$

$m_p = 870 \times 0.001224 = 1.065kg$

This value represents the loading capacity of the dryer.

### 3.4.4 Total Drying Energy

The total energy required for drying a given quantity of food items can be estimated using the basic energy balance equation for the evaporation of water

$Q_{Total} = Q_{Evap} + Q_{Mater}$

Where,

$Q_{Total}$ = Total heat supplied (kJ/s)

$Q_{Evap}$= Heat for water evaporation

$Q_{Mater}$= Heat for heating of drying material (plantain)

### 3.4.5 Heat Requirement For Water Evaporation ($L_W$)

The total energy required for drying a given quantity of food items can be estimated using the basic energy balance equation for the evaporation of water (Youcef-Ali, *et al.* 2001; Bolaji 2005):

$$m_w L_w = m_a C_p (T_1 - T_2)$$

where:

$m_w$ = mass of water evaporated from the food item (kg);

$m_a$ = mass of drying air (kg);

$T_1$ and $T_2$ = initial and final temperatures of the drying air respectively = 300 and 337 (K);

$C_p$ = Specific heat at constant pressure =1.005 ($kJkg^{-1}K^{-1}$).

$$m_w = \frac{m_p (M_p - M_e)}{100 - M_e}$$

Where

$m_p$ = initial mass of the food item1.065 (kg);

$M_e$ = equilibrium moisture content (% dry basis);

$M_i$ = initial moisture content (% dry basis).

The plantain averages about 65% moisture content

The target moisture content is 12%

$$m_w = \frac{1.065(65 - 12)}{100 - 12} = 0.64kg$$

$$L_w = \frac{m_a \times 1.005 \times 37}{0.64}$$

Density =mass/volume

$m_a$=1.164×0.05655= 0.0658kg/s

$$L_w = \frac{37.714 \times 1.005 \times 37}{0.64} = 2191.22kJ$$

During drying, water at the surface of the substance evaporates and water in the inner part migrates to the surface to get evaporated. The ease of this migration depends on the porosity of the substance and the surface area available. Other factors that may enhance quick drying of food items are: high temperature, high wind speed and low relative humidity. In drying items like fish, meat, yam chips, plantain chips etc., excessive heating must also be avoided, as it spoils the texture and quality of the item.

### 3.4.6 Heat of Dried Chips

$$Q_{Mater} = c \times m_p (\theta_2 - \theta_1)$$

Where,

$c$ = specific heat capacity of the material 0.64(kJ/KgK)

$m_p$ = quantity of moist material before drying1.065 (kg)

$\theta_1$, $\theta_2$= temperature of the material before and after drying27 and 64 ($^oC$)

$$Q_{Mater} = 0.64 \times 1.065 \times 37 = 25.23kJ$$

### 3.4.7 Drying Air Volume

The quantity of drying air $m^3/s$ is given by

$$V = \frac{Q}{Cp(t_1 - t_2)}$$

Q= heating coil energy =2kJ

*Cp*= specific heat capacity of air1.005 (kJ/KgK)

$t_1$ = Air temperature at the inlet of the dryer 27 ($^oC$)

$t_2$= Air temperature at the out of the dryer 64($^oC$)

$$V = \frac{2}{1.005 \times 37} = 0.054m^3/s$$

Mass of drying air within drying time of 60mins.(3600sec) is given by

$m_a = \rho \times V \times T = 1.164 \times 0.054 \times 3600 = 226.28kg$

Total drying energy is given by

$$Q_{Total} = Q_{Evap} + Q_{Mater}$$

$$Q_{Total} = 2191.22 + 25.23 = 2216.45kJ$$

Total energy required by the plantain chips dryer in sixty minutes drying time is 2216.45kJ

### 3.4.8 Fan Energy Consumption

The selected electric fan motor is rated 120 watt =0.12kw

Fan energy $= power \times Time = 0.12 \times 3600 = 432kJ$

## 3.5 FABRICATION PROCEDURE

### 3.5.1 Machine and Tools Used

The following machine and tools were used during the course of fabricating the machine. They are the drilling machine, shear cutting machine, bending machine, riveting gum, handsaw, table vice, hammer, panel saw, riveting pin and marking out tools.

### 3.5.2 Fabrication Stage

(a) The aluminum sheet iwas cut into size using a shear cutting machine. The required dimensions were then marked out with a scriber on the already cut out sheet. The sheet is then folded into a cylindrical shape and held together with a riveting gum and a riveting pin.

(b) A bending machine was used when producing the frame of the trays. Screws were used to hold the horizontally laid rods in the drying chamber that supported the trays.

(c)The wire gauze were cut with shera cutting machine to make the floor of the trays and to fit into the cylindrical chamber for partition between the drying chamber and the component housing. This is then followed by assembling of the component parts that function together to achieved drying.

## 3.4 EXPERIMENTAL PROCEDURE

The plantain is peeled and sliced into chips of uniform thickness of 3mm using a slicing machine. They were then spread inside the trays before drying. The trays are of three sets with a loading capacity of 1.065kgof plantain chips/ the heating filament and the centrifugal fan were then put on to start the drying. The plantain chips were weighed before and after drying. The system was put off after 60minutes of drying before weighing the dried chips.

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSION

Sample of sliced plantain ships of 3mm thickness was used for the performance test of the dryer. The chips are weighed and spread on the trays. The weight of dried chips was then recorded after 60mins.

## 4.1 RESULT OF PERFORMANCE TESTS

Thickness of plantain chips before drying =3mm

Time taken to achieve drying = 60mins

Initial weight of plantain chips = 0.5899kg

Final weight of plantain chips = 0.3175kg

## 4.2 CALCULATION AND RESULT

To determine moisture content of plantain chips after 60mins of drying, the following expression is used.

Where $M_c = \frac{W_1 - w_2}{W_1} \times 100\%$

Mc = moisture content on a percent basis

$W_1$ = initial weight

$W_2$ = final weight

Therefore

$W_1$ = 0.5899kg

$W_2$ = 0.3175kg

Mc =( 0.5899 – 0.3175) / 0.5899 X 100 % = 46%

This means that 46% of moisture was removed from the plantain chips after drying for 60minutes. If this value is compared to the theoretical moisture content of 65%, the moisture content left in plantain chips after drying is 19%.

## 4.3 DRYING EFFICIENCY

This can be determined using

$$\eta = \frac{\text{Moisture content removed}}{\text{theoretical moisture content}} \times 100\%$$

$$\eta = \frac{46\%}{65\%} \times 100\% = 71\%$$

## 4.4 DISCUSSION OF RESULT

The electrical plantain chip dryer is faster than sun drying and other traditional methods and can be suited for different sessions for the drying of plantain chips at short time. The moisture from the chip is 46% which when compared to the theoretical moisture content of 65%, !9% moisture content is left which is safe moisture content for either storage of the chips or grounding into flour.

A drying efficiency of 71% is reasonable and can be improved upon to achieved maximum drying and at a short time. The plantain chips however produce retain their value,texture, aroma and quality.

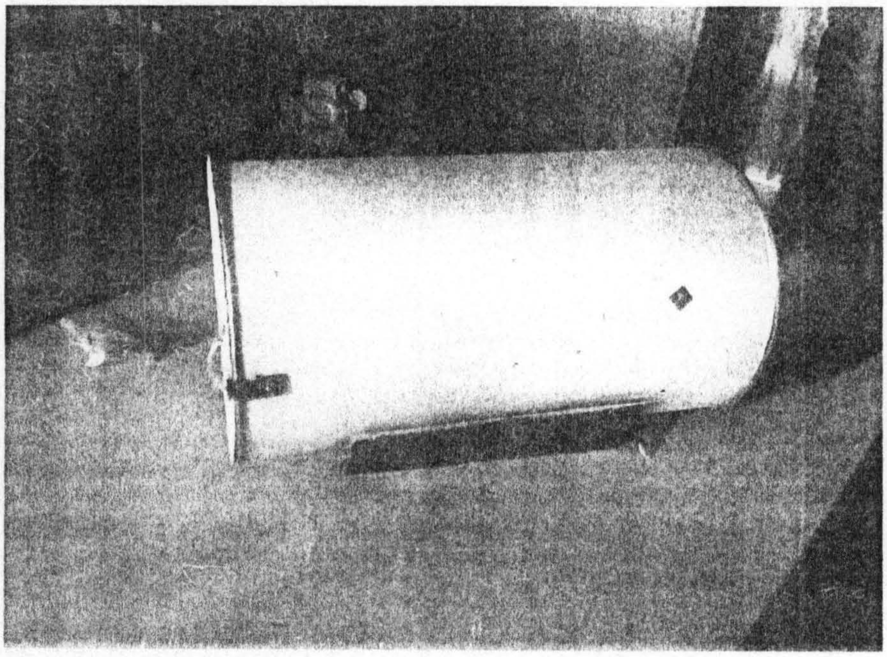


**Plate 1** Electric plantain chips dryer from side view

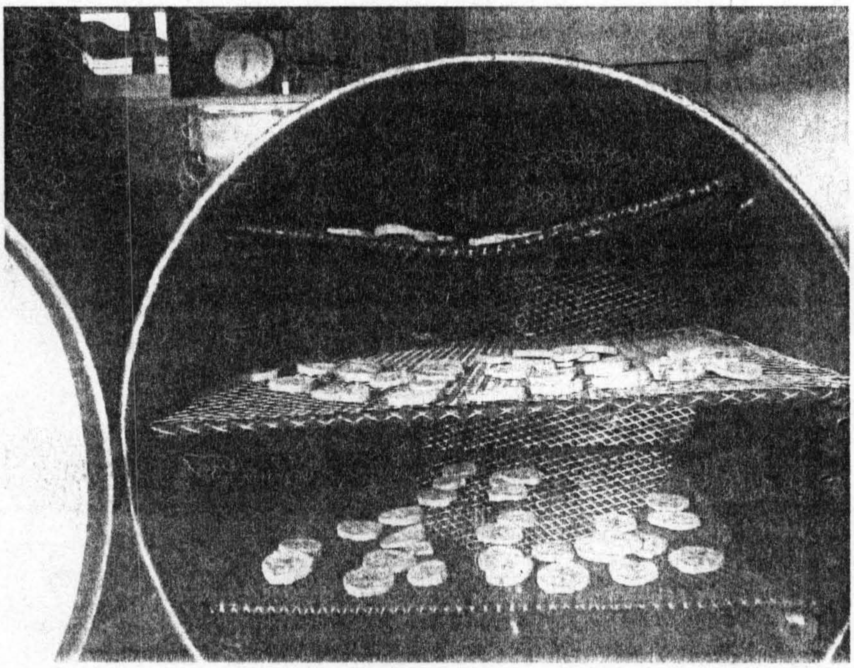


**Plate 2:** A view of dried plantain chips

## 4.5 COST ANALYSIS

Cost analysis is the total cost of fabricating the plantain chip dryer as shown in table 4.5. The cost can be divided into three parts

- Material cost
- Labour cost
- Overhead cost

### 4.5.1 Material Costing

**Table 4.1** Bill of Material, Quantity and Costing.

| S/No | Material | Quantity | Cost (□) | Amount(□) |
|---|---|---|---|---|
| 1 | Aluminum sheet | 1 Sheet | 3000 | 3000 |
| 2 | Mild steel sheet | 1pc | 600 | 600 |
| 3 | Electric motor | 1 | 1500 | 1500 |
| 4 | Fan blade | 1 | 700 | 700 |
| 5 | Heating filament | 1 | 1000 | 1000 |
| 6 | Galvanized steel sheet | 1pc | 500 | 500 |
| 7 | Plug and cables | 2 | 200 | 200 |
| 8 | Hinges | 2 | 20 | 40 |
| 9 | Metal rod | 1 | 50 | 50 |
| 10 | Handle | 1 | 30 | 30 |
| 11 | Spray paint | 1 | 500 | 500 |
| | Total | | | 8120 |

**Material cost = □ 8120**

### 4.5.2 Labour Cost

The project labor cost is determined as 20% of the total material cost:

Labor cost = $\frac{20}{100} \times 8120$ = □1624

### 4.5.3 Overhead Cost

This is 10% of total material used. It is expressed as

Overhead cost = $\frac{10}{100} \times 8120$ = □812

**Total cost**

The total cost of fabrication = Material cost + Labor cost + Overhead cost

= 8120 + 1624 + 812 = □10,556

CHAPTER FIVE

# 5.0 CONCLUSION AND RECOMMENDATIONS

## 5.1 CONCLUSION

An electrically powered dryer with a loading capacity of 1.065kg of plantain chips was designed, fabricated and tested. After the machine had been tested and the result recorded, the following conclusions were made.

**(1) Drying Rate:** The electric plantain chip dryer is faster irrespective of the drying season when compared to the local method such as sun drying that can take days or weeks.

**(2) Final Moisture Content:** The moisture content of the plantain chips was reduced to after 60mins of drying which is a safe moisture content for storage and other purposes.

**(3) Ergonomics:** The dryer is safe for usage and maximum attention may not be required while drying since burning of chips or users hand is very rare.

**(4) Product Quality:** Plantain chips dried with dryer are more hygienic, retained their texture

and quality

**(5) Cost** of the electric plantain chip dryer is relatively cheap due to simplicity of design.

Thus, the objective for carrying out the work was satisfied.

## 5.2 RECOMMENDATIONS

1. It is clear that the use of electrically powered dryer in drying food such as plantain and yam with a reasonable moisture content yields better result comparable to that obtained using convectional processes of sun drying. It reveal with further work in optimization of dryer design for specific food items, use of electrical energy will be better suited for drying

purposes and the duration of drying would be shortened.

2. The capacity of the machine can be increased by altering the machine dimensionS and using rotary tray and better baffle system for uniformity of drying, thereby commercializing it for farmers and establishments for effective storage of its commodity.

3. The heat losses through the exhaust of the dryer can be useful by recirculation to increase the drying efficiency and time.

4. To make the project a little lighter in weight, lagging material of lesser weight should be used.

5. The person drying for the convenient handling of the heated trays should wear gloves. This goes a long way in preventing hand burn.

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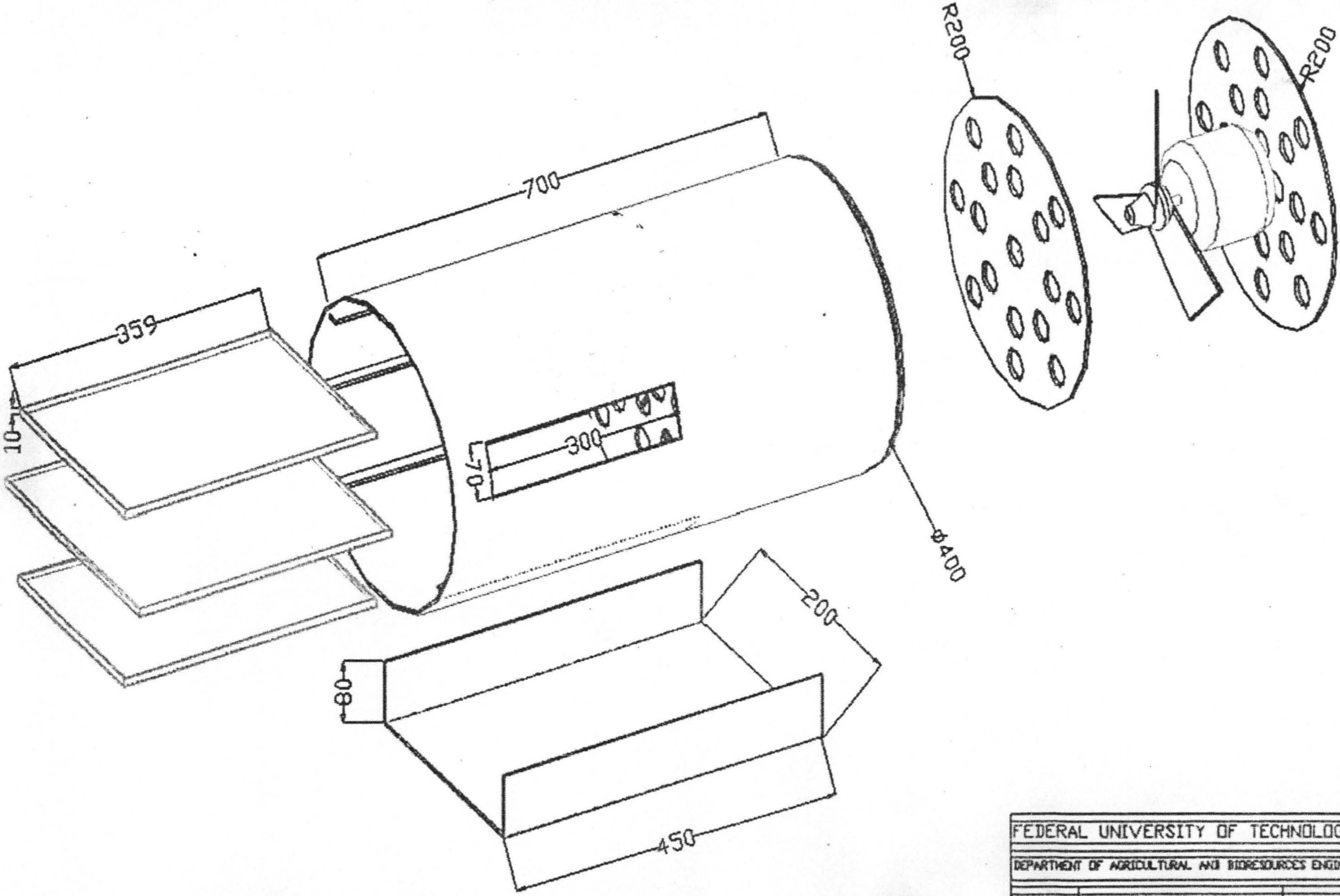


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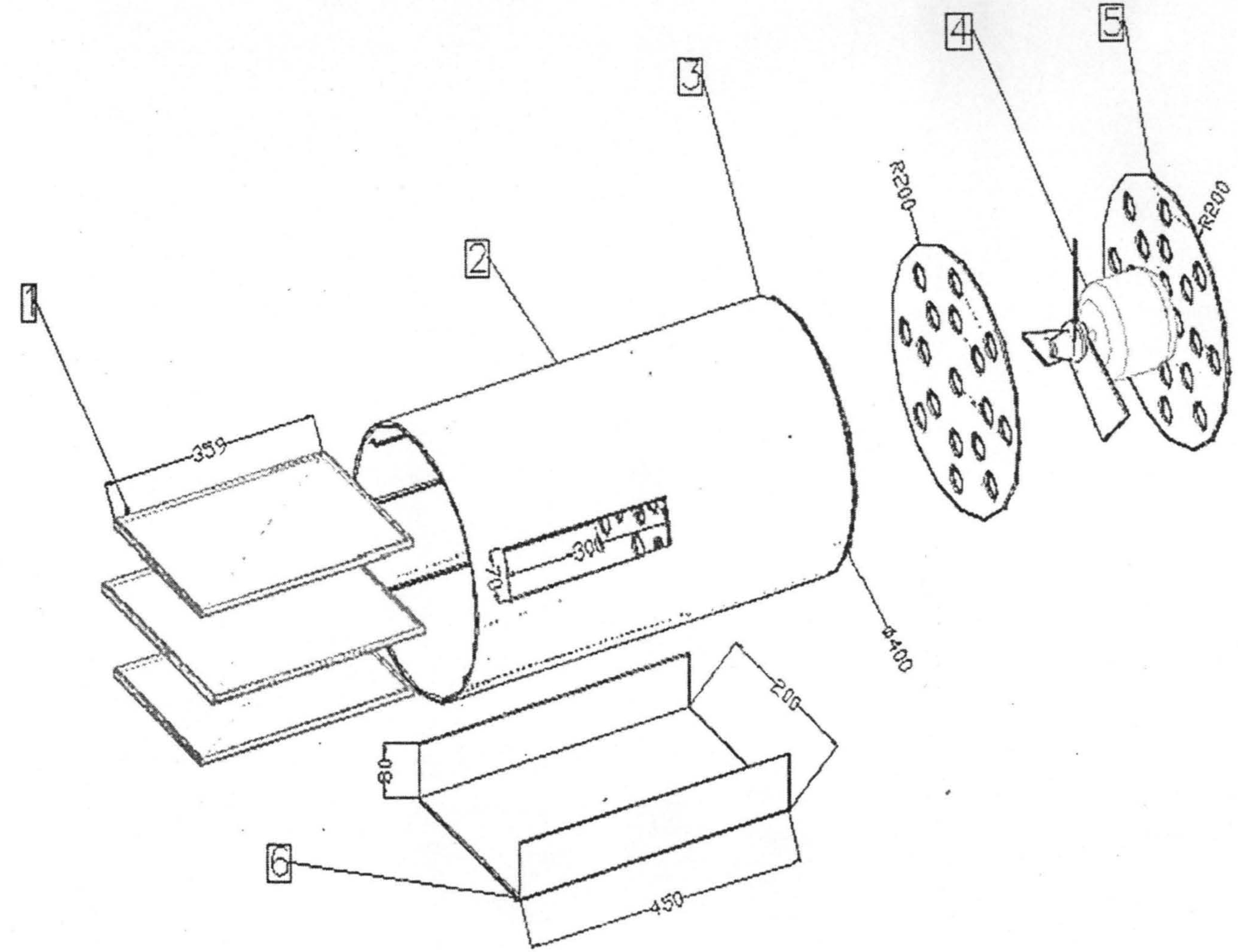
| DRAWN BY | ONOGURE OGAGAOGHENE | SIGNATURE | |

| Sym | Part description | Qty |
|---|---|---|
| 1 | tray | 3 |
| 2 | draying chamber | 1 |
| 3 | heating filament | 1 |
| 4 | centrifugal fan | 1 |
| 5 | perforated cover | 3 |
| 6 | supporting stand | 1 |




AN EXPLODED VIEW OF
A PLANTAIN DRYER

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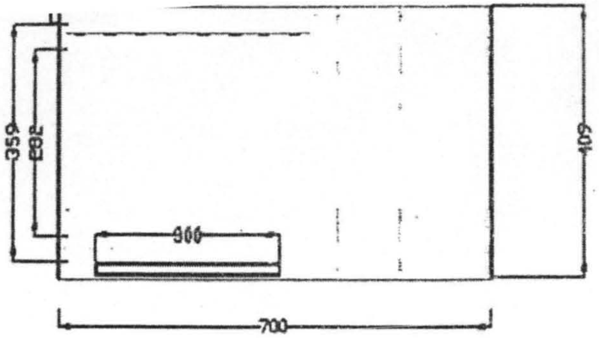
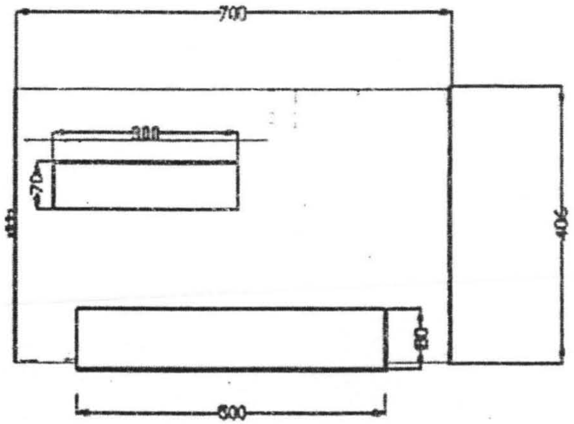
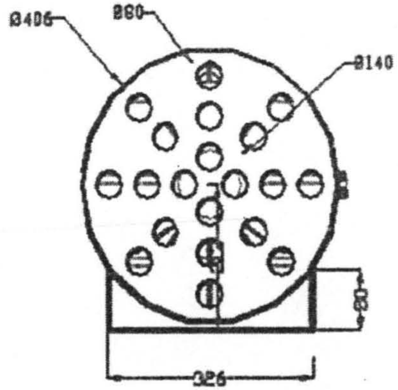
| SUPERVISED BY | ENGR. DR D. AGIDI | |
| TITLE | ASSEMBLY DRAWING OF PLANTAIN CHIPS DRYER | SCALE 1:1 |




LEFT VIEW




RIGHT VIEW




TOP VIEW

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| SUPERVISED BY | ENGR. DR O. AGIDI | |
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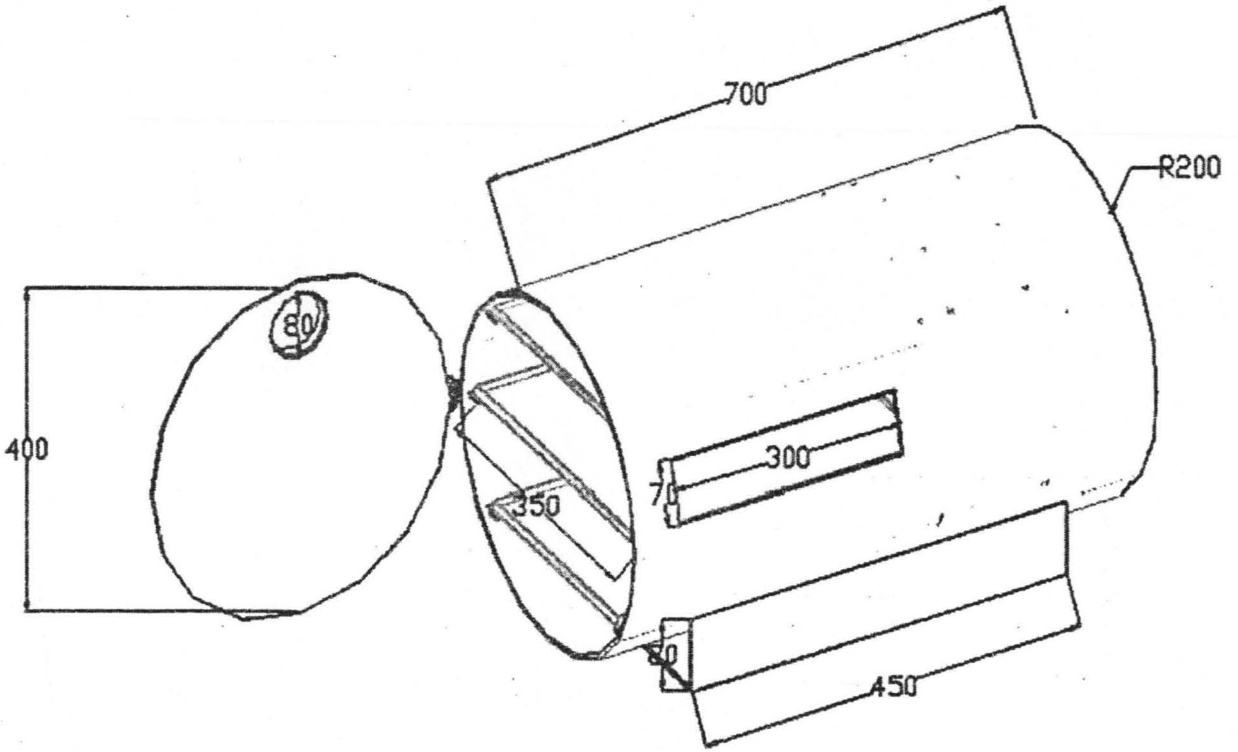
# ORTHOGRAPHIC VIEWS




ISOMETRIC VIEW OF THE ASSEMBLY

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