TECHNICAL REPORT ON THE CONSTRUCTION OF AN ELECTRIC-POWERED CABINET DRYER AT CSIR-FOOD RESEARCH INSTITUTE

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DECEMBER 2018

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CHAPTER ONE

1.0 THEORY OF DRYING OF FOOD PRODUCTS

1.1 Introduction

According to the Food and Agriculture Organization (FAO), food production needs to increase by 70 % in order to meet the food demand of a world population of about 9 billion by 2050. Trends such as change in lifestyle as well as dietary patterns in developing and developed countries coupled with the effects of climate change continue to put pressure on the Earth's resources (World Economic Forum, 2009; FAO/OECD, 2011). This brings to bear the major issue scientists and industry players face in feeding the growing human population while grappling with the impact of climate change, efficient land and water use.

The Food and Agriculture Organization estimates that one third of food produced globally for human consumption is lost or wasted along the supply chain. Losses are even higher in Africa, thus, have a negative effect on food security, nutrition and economic stability.

Reduction in these losses would increase the amount of food available for human consumption and enhance global food security: a growing concern with rising food prices due to growing consumer demand, increasing demand for biofuel and other industrial uses and increased weather variability (Mundial, 2008; Trostle, 2010). A reduction in food losses also improves food security by increasing the real income for all the consumers (World Bank, 2011).

The term "Postharvest Loss (PHL)" refers to measurable quantitative and qualitative food loss in the postharvest system. This system comprises interconnected activities from the time of harvest through crop processing, marketing and food preparation, to the final decision by the consumer to eat or discard the food (Kiaya, 2014-ACF International). Kader (2002) also explains PHL in a similar way as the degradation in both quantity and quality of a food production from harvest to consumption. Quality losses include those that affect the nutrient or caloric composition, the acceptability and the edibility of a given product.

The postharvest drying of agricultural products is of great economic and industrial importance in the food sector. Drying decreases moisture levels in agricultural produce to appreciable levels in order to reduce the activities of microbes and food deterioration causing organisms. In addition to preservation and extension of shelf life, drying may also be carried out to achieve a particular physical form such as high quality cassava and plantain flour for the production of 'fufu' flour.

1.2 Drying Theory

During drying, there are two major periods; constant rate and falling rate. In constant rate period, there is a lot of 'free' or 'unbound water' available on the surface of food product which is readily evaporated by the drying process. In this period, there are no solid materials existing or being a part of the free water and so the rate of evaporation is dependent on the quantity of free water available which in turn is dependent on the biological nature of the food product. Methakhup (2003) reiterates the sound scientific theory that in this stage of drying, the rate-controlling step is the diffusion of the water vapor across the air-moisture interface surrounding the food product. This period continues until water which is readily available on the surface is no longer available at the surface of the food material because water from the interior of the product no longer moves to the surface.

The point separating the constant and falling rate periods is the critical moisture content. At this point, there is virtually no movement of water from the interior of the product to the surface.

From this point we move to the falling rate period which is initially characterized by complete dryness on the surface of food product. After this initial dryness, the evaporation front moves further into the product towards the center where water now exists. The water moves from the center of the product to its surface through diffusion. Due to the presence of barriers in the form of food material and travel distance of vapor, the falling rate period takes a longer time compared to the constant rate. At this period, more heat energy is also required to move water vapour to the surface of product. The principles of heat transfer come to play during this period and can be useful in determining the drying efficiency.

The drying rate in the falling rate period is controlled by diffusion of moisture from the inside of the food product to the surface and then mass transfer from the surface to the environment. During this stage some of the bound water is removed (Methakhup, 2003).

During the falling rate period, after some quantity of water has been removed, the moisture concentration reduces partly due to the fact that most of the moisture in the food product has already been removed and hence the rate of movement of bound water from the center of the product to the surface also decreases. The period immediately following the falling rate period is described as the 'slowing down period' in some circles. The free water, which migrated from the inside to the outside of the product to be transformed into water vapor, has completely disappeared. Only bound water is left in the product tightly 'attached' to it. Water no longer evaporates at the surface of the product but inside it causing the evaporation front to progress towards the heart of the product. Consequently, the drying rate decreases to the point where drying occurs no more; this is where the rate of moisture removal from product is equivalent to the saturated values of the prevailing ambient conditions such as air temperature and relative humidity.

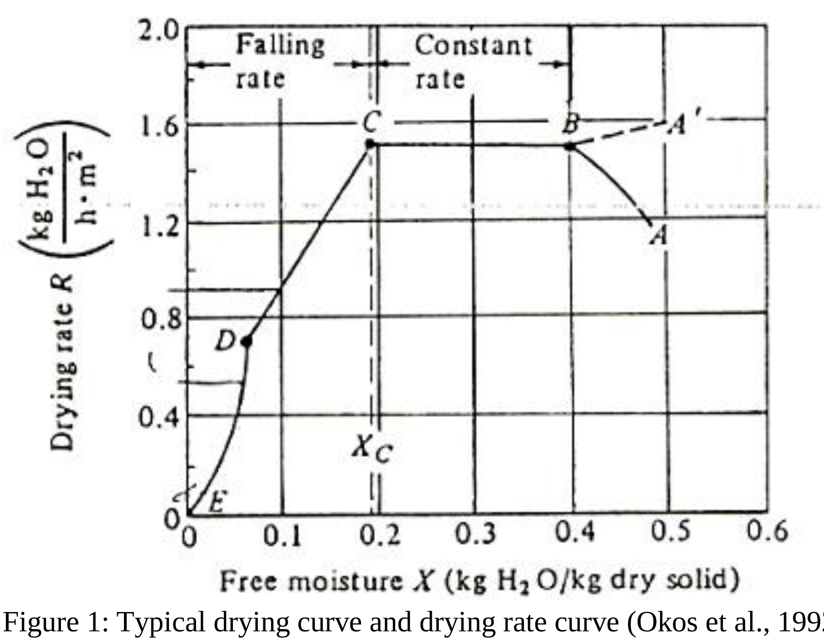

Figure 1: Typical drying curve and drying rate curve (Okos et al., 1992)

From the drying rate curve by Okos et al. (1992), drying begins at point A. The rate of drying is high due to the presence of a lot of free water already on the surface of product but short lived and quickly reaches the constant rate (B-C) which draws on water just below the surface of product. This goes on for some time until such a time when there is no more water on the surface or just below the surface. Hence the heat energy being supplied for drying must cause bound water found deep inside the product to diffuse to the surface for evaporation to occur; this is the falling rate period (C-D). The slowing down period is best described by D-E.

The factors influencing drying time and quality of dried food products can be attributed to the following;

- Initial moisture content
- Drying temperature
- Ambient temperature
- Relative humidity
- Air flow rate
- Quantity/Weight of products
- Thickness and sizes of slices

Table 1: Composition of some common food products

Food stuff %	% water	% protein	% lipids	% carbohydrate	% minerals
Fresh vegetables	93	1	0.3	4.6	0.6
Tomato	89	2.4	0.2	8.4	0.5
Fresh fruit	87	1	0.2	9.8	-
Orange	81	0.4	0.1	17.5	-
Mango	75	1.4	0.5	20	-
Banana	52	4	2.6	42	-
Beef. Mutton	60	17	200	0.5	1.3
Pork	55	16	25	0.5	1.2
Horse	75	21	2	1	1
Chicken	70	21	8	-	1.4
Lean fish (hake)	80	17	2*	-	1.6
Fatty fish (tuna)	60	26	13	-	-1.6

Source: Alais, C., Linden, G. ‘biochimie alimentaire’. Ed. Masson (1991)

CHAPTER TWO

2.0 DRYING METHODS AND DRYER TYPES

Drying is a method of removing moisture from food products in order to obtain safe moisture content at which food products can be safely stored over long periods without attack by microorganisms (Garg and Prakash, 1997). Drying involves both heat and mass transfer (Nayak et al., 2012).

2.1 Types of drying processes

There are three basic types of drying processes which include atmospheric drying made up of batch (kiln, tower, and cabinet dryers), continuous (tunnel, belt, belt-trough, fluidized bed, explosion puff, foam-mat, spray, drum and microwave) and sub-atmospheric dehydration (vacuum shelf/belt/drum and freeze dryers).

2.2 Factors for selection of a particular dryer or drying method

The choice of a particular dryer or a drying method for drying food products is determined by

- form of raw material and its properties;
- desired physical forms and characteristics of the dried product at the end of drying
- operating cost.

2.3 Drying methods

Various types of drying methods are available for drying different kinds of food products. Among these types of drying methods include open sun drying and solar drying.

2.3.1 Open sun drying

Open sun drying of food products is the most widespread method of food preservation in many African countries due to solar irradiance being very high for most of the year. By using solar energy the working principle of open sun drying is simple. The solar energy of shorter wavelength falls on the uneven crop surface. Depending upon the colour of crops some part of this energy is absorbed by the surface and the remaining is reflected back. The radiation which is absorbed by the crop is converted into thermal energy and the temperature of crop start to increase. Due to this the long wavelength radiation from the surface of crop is lost to ambient air through moist air (Sahu et al., 2016).

Also there is convective heat loss in addition to long wavelength radiation loss because of the wind blowing through moist air over the crop surface. In the form of evaporative losses, evaporation of moisture takes place and the crop is dried. Further, in the interior of the product a part of thermal energy absorbed is conducted. Due to this, there is a rise in temperature inside the crop and also water vapour forms and then start to diffuse towards the crop surface and finally thermal energy in the crop is lost (Sahu et al., 2016). The moisture removal is rapid in the initial stages as the excess moisture is on the product surface.

2.3.2 Solar drying

Solar drying is a continuous process where moisture content, air and product temperature, and the humidity of air all change simultaneously along with the two basic inputs to the system: the solar insolation and the ambient temperature. The drying rate is affected by ambient climatic conditions. These include temperature, relative humidity, available solar insolation, wind velocity, frequency and duration of rain-showers during the drying period.

2.4 Classification of solar dryers

Solar dryers can be classified into two major groups, namely passive solar-energy drying systems (conventionally termed natural-circulation solar drying systems) and active solar-energy drying systems (most types of which are often termed hybrid solar dryers). Three distinct sub-classes of either the active or passive solar drying systems can be grouped into direct-type solar dryers, indirect-type solar dryers and hybrid solar dryers. The working principle of these dryers mainly depends upon the method of solar-energy collection and its conversion to useful thermal energy for drying (Ramteke et al., 2016).

2.5 Types of Dryers

Dryer designs take into consideration the type of material to be dried, the methods of heat transfer and the heating medium. Dryers can therefore be classified according to the physical state of the material (solid or liquid), the method of heat transfer (direct or indirect) and the heating medium (air, steam, hot water etc.). Each category can further be classified as batch or continuous type. Also as a general rule, production rates of 5000 kg/day are best handled using batch dryers and capacities of over 5000 kg/day handled in a continuous dryer (Joshi and Mahajani, 1996).

2.5.1 Tray Dryer

This is practically a batch cabinet dryer with a drying chamber comprising a number of trays. In this type of dryer, gas, steam or electrically heated air may be used as a drying medium. The air is passed by means of a fan over a radiator, tubes or fins and then through the trays. A part of the air is discharged and the other part reheated and recirculated to continue drying. For vacuum tray dryers, the framework with the covering must be strong enough to withstand external pressure of about 1 kg/cm2. All joint must be air-tight. In some cases, trays are mounted on trolleys and may be pulled out of the cabinet for loading and unloading (Joshi and Mahajani, 1996).

Figure 2: Simple tray dryer and trolleys

2.5.2 Continuous Band Dryer

In some cases, the material may be placed or attached directly to a conveyor belt. A fan placed above the heater pulls the air through the heater and circulates it through the wet material. Recirculation and reheating is usually automatically controlled (Joshi and Mahajani, 1996).

2.5.3 Rotary Dryer

This consists of a long cylindrical shell mounted horizontally with a slight slope. The shell may be stationary or revolving. If it is stationary, an agitator revolves within the shell at a slow speed. The rate of feed, speed of rotation or agitation, the volume of heated air or gases and their temperatures, are so regulated that the material is completely dried before it is discharged at the lower end. Wet material is fed continuously through a hopper at the upper end and a vibrating feeder or screw regulates the flow of material. The dry material which drops in a hopper at the lower end may be removed continuously by a bucket elevator. Retention time of material in the dryer will be determined by several factors such as slope, length and speed of rotation of dryer shell (Joshi and Mahajani, 1996).

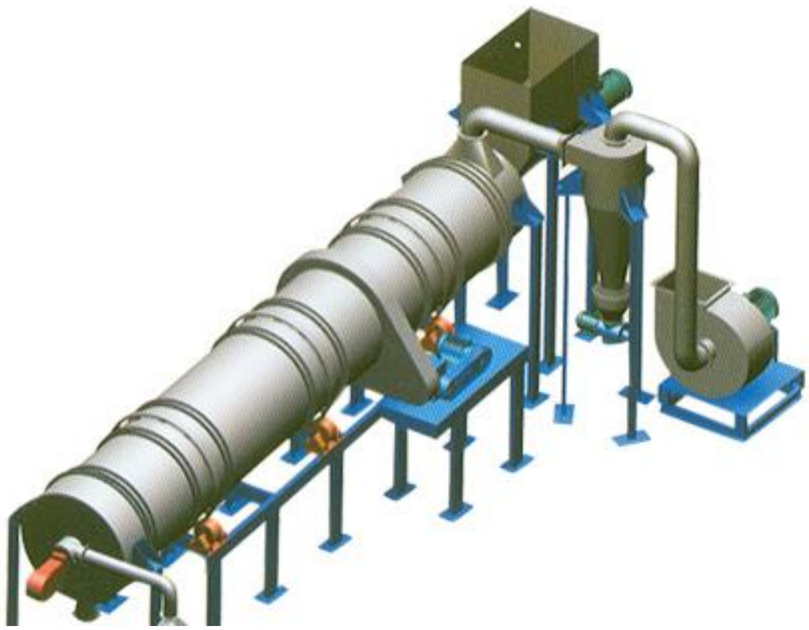

Figure 3: Rotary Dryer

2.5.4 Drum Dryer

They come as single drum, double drum and twin drum. The feedstock is continuously fed to the effective drying surface of the drums and the dried product is removed by a scraper knife. The twin-drum dryer consists of 2 single drums with a common drive, 2 separate feed arrangements and 2 scraper knife assemblies. The direction of rotation of drum is almost invariably downwards towards the nip between the cylinders. Pasty materials are fed by rollers from the top whiles viscous materials are fed at the nip between drums. Common materials used for the construction of the drum include stainless steel, cast iron and chromium plated steel. The surface of the drum is hard and smooth and heated internally by steam and therefore has to withstand internal pressure. Steam is supplied from an attached boiler through piping connections. Drums are rotated at speeds between 3 to 20 rpm. As the drum rotates, a film of about 1-3 mm thickness forms which is scraped by doctor knives. For materials which are extremely abrasive, the knives are tipped with abrasion resistant metal. Where corrosion is likely to occur, knives may be of suitable plastic material or toughened glass. The drum is rotated by a gear and pinion. The pinion is driven through a belt or chain or through a reduction gear from a motor. A variable speed drive can be available to help adjust the drum speed (Joshi and Mahajani, 1996).

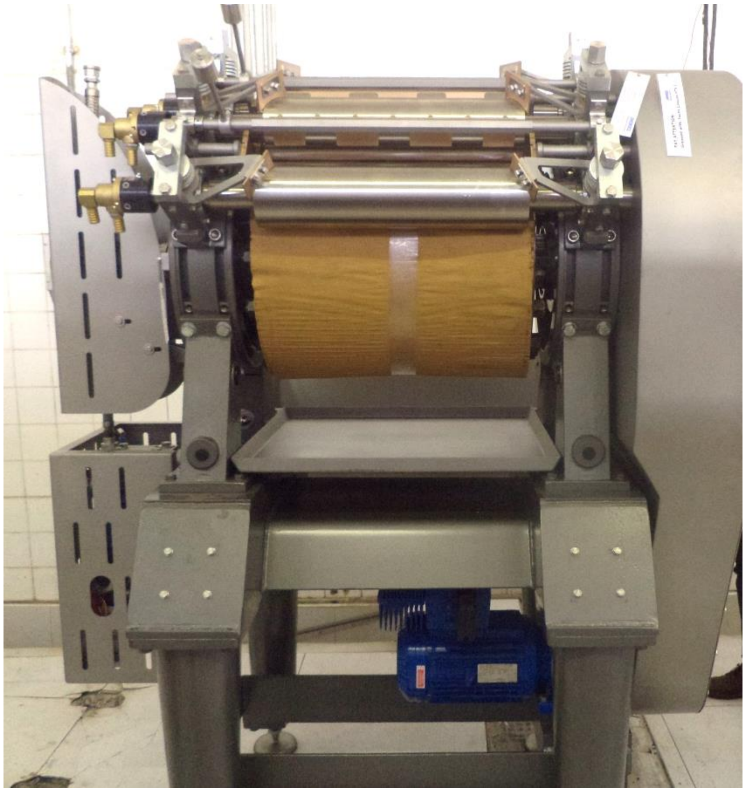

Figure 4: Drum Dryer Assembly

2.5.5 Gas cabinet dryer

This is basically a cabinet dyer that utilizes LPG as energy source for drying. The base of the dryer is made of burnt bricks and the upper part made of redwood lined with aluminium foil so as to be able to withstand the internal heat from the LPG burner. Racks are provided for spreading of sliced food products.

Operation begins with checking the gas pipes for leakages, followed by an initial pre-heating to a temperature 60-80 °C for roughly 15 minutes, before the sliced fruits are loaded. Temperature regulation is done by setting the gas burners to desired intensity and monitoring the temperature readings on the dial thermometers. Once the samples have been loaded, the LPG regulator is adjusted until the desired temperature is attained in the drying chamber.

Figure 5: Gas Cabinet Dryer

2.5.6 Bin dryer

The bin dryers in Ghana are the shallow-layer batch bin dryers which are in the form of a rectangular tray with a perforated/lined base made of stacked aluminum bars overlapping on top of the other with a 2 mm gap in between for hot air to flow through. The bin itself is inclined at an angle of 5 to 10 degrees reducing the drudgery involved in loading and offloading of final dried products through the product outlet. The likely energy sources for the heat exchanger are diesel or liquefied petroleum gas (LPG). To avoid contamination, mild steel constructed heat exchangers are used to transfer heat into the dryer. An electric operated motor is used to suck fresh air through the heat exchanger and blow the warmed air into the bin dryer. Warmed air is blown into the plenum chamber beneath the bin dryer and then up through the perforated base through to the cassava products to be dried.

Figure 6: Bin Dryer

2.5.7 Flash dryer

A typical flash-drying process consists of a modified pneumatic conveyor in which the

wet solids are introduced into a pipe through which they are transported in a high velocity

hot gas stream. Wet material is dispersed into a stream of heated/gas which conveys it through a drying duct. The heated air/gas velocity must be greater than the free fall velocity of the largest particle to be dried (Borde and Levy, 2006). Using the heat from the airstream, the material dries as it is conveyed.

Thermal contact time between the conveying air and the solids is usually very short and therefore flash dryers are most suitable for removal of external moisture (surface moisture) and are less suitable for the removal of internal moisture (Borde and Levy, 2006). Product is separated using cyclones, and/or bag filters. Typically, cyclones are followed by scrubbers or bag filters for final cleaning of the exhaust gases to meet current emission requirements.

Figure 7: Flash Dryer

CHAPTER THREE

3.0 FABRICATION OF ELECTRIC CABINET DRYER

3.1 Introduction

There has been an increase in the number of small and medium scale agro-food enterprises within the country in recent times. Programs such as "Planting for Food and Jobs" has also rekindled the interest in such ventures and the CSIR-FRI being a one-stop-shop for all kinds of food product processing, testing and marketing has recorded an immense increase in the number of inquiries and consultancies.

Drying comes to play in food processing whenever flour production is mentioned. The electric cabinet dryer is one such equipment that has received much inquiries culminating in the preparation of this report.

3.2 Technical Specifications

The cabinet dryer consists of the following functions;

- Dryer body/cabinet heavily insulated with glass wool
- 16 electric heating coils (8 aside) of 2 kW each
- 40 aluminium trays (20 aside)
- A control panel that consists of a temperature-timer automated system
- 2 electric motors of 2 HP each
- Average air flow rate = 200 m3/h
- 2 fans connected to the motors creating a convective current within the dryer cabinet
- The dimensions of the dryer are L x B x H = 2.0 m x 2.0 m x 1.8 m
- The rotating action of the 2 fans set up a convective current within the drying chamber which circulates the warm air heated by the electric coils. Drying occurs through this continuous action
- Products to be dried are placed on perforated aluminium trays (1.8 m x 1.4 m) and loaded inside the dryer

3.3 Construction Materials and Tools

The total project cost was estimated at GH 12, 888.67. Below is the breakdown of the materials used for phase I and phase II of the project.

Table 1: Material List for Phase I

No.	Item	Quantity
1	1.5 mm Mild Steel Sheet	17
2	2.0 mm Mild Steel Sheet	8
3	2 x 2 ” Angle Iron	4
4	1 x 1 ” Angle Iron	20
5	2 ” Square Pipe	8
6	2 ” Flat Bar	3
7	Steel Wool	6 bags
8	Filler	2 gallons
9	Electrode	4 packs
10	Cutting Disc	4 pcs
11	Antirust paint	3 gallons

Spraying of all metallic components with anti-rust paint was carried out after purchase of items. In addition, measured body parts were precisely cutting from materials and welded together to form the skeleton of the Cabinet dryer.

Table 2: Material List for Phase II

No.	Item	Quantity
1	2.0 mm Stainless Steel Sheet	½
2	30 mm Stainless Steel Shaft	5 ft length
3	19 mm bolts & nuts	15 pairs
4	Oil Paint	2 gallons
5	Silver paint	2 gallons
6	Thinner	4 gallons
7	Door hinges	4 pairs
8	2.5 mm Aluminium mesh	1 sheet
9	Heating Coils	16 pcs
10	Control Panel+2HP motors	4 pcs
11	Polishing Brushes	4 pcs
12	Grinding Disc	4 pcs

Phase II works included the power system, heating system and electrical control system of the dryer.

The tools and equipment used in the construction of the dryer are as follows:

1. Drilling machine and drill bits (HSS, 1/8 ”)
2. Grinding machine
3. Riveting machine
4. Sheet Cutter
5. Sheet metal bending machine
6. Paint brush
7. Metal hammer

8. Spraying machine
9. Power hacksaw
10. Measuring tape
11. Vernier caliper
12. Outside and inside calipers

3.4 Description and Operation of Some Selected Tools used in the Electric Dryer Fabrication

3.4.1 Drilling Machine

Drilling is one of the most common and useful processes in both metal work and woodwork activities. The following instructions should be applied when using the hand drill:

Figure 8: Hand drilling machine (Bosch Brand)

Step 1: Measure the location of hole on the piece of material and mark its exact position.

Step 2: Select the appropriate drill bit sizes. Trying to cut a 3/8 inch diameter hole with a 3/8 inch drill bit may not be the best; start with a small diameter and work your way up

Step 3: Use a center punch to make a small dent on the surface of the material. This helps prevent the drill from wandering when it makes first contact with the metal surface.

Step 4: Align and clamp the material in place. As the drill pierces through to the opposite side of the material, it can grab and spin the whole workpiece. At this point, the entire tool bit can be ripped out of your hands. Thus, the importance of using clamps.

Step 5: Put on safety goggles and ear protection before operating the drill. Firstly ensure drill is spinning in the right direction (clockwise) and speed. Plunge the spinning drill into the material. The drill should cut without applying tremendous amount of force along its axis. In the case where the drill does not appear to cut through the material, ensure the flutes are not clogged. When working on metals, cutting fluid (oil or water) may be helpful. It helps lubricate the sliding contact between the drill and workpiece, flushes chips away from the interface and cools the drill.

Step 6: In the situation where holes are not to your satisfaction try a deburring tool to smoothen around the edges of the hole.

Step 7: Finally clean up by sweeping up any mess, wipe off any cutting fluid and put all tools away.

3.4.2 Angle Grinding Machine

Angle grinders can be considered as handy, versatile and powerful electric powered machines. They come with detachable grinding wheels that can be used for a variety of works including cutting tiles, cleaning tools, sharpening mower blades and grinding dry mortar. The factors influencing choice of grinder include the following; the type of work at hand, the type of material requiring grinding and finishing required. Consideration should also be given to wheel adjustments. The following simple instructions should be applied when using the angle grinder:

Figure 9: Angle Grinding Machine (Makita Brand)

Step 1: Grinder Selection

In selecting a suitable grinder, note that pneumatic type grinders are less powerful and rugged but easier to maneuver and are more suitable for works that occupy smaller areas and tight fitting spaces. Electric grinders are more suitable for works that cover large surface areas.

Step 2: Disc Selection

Sanding discs and polishing discs are used for finishing and aesthetics. Cutting discs on the other hand are used for cutting tiles, masonry steel, metal work pipes, angles and thick plates. Grinding discs are used for grinding metal and stone. Never use a cutting disc for grinding purpose and vice versa.

Step 3: Read carefully manufacturer's instructions and guidelines before operating the grinder.

Step 4: Clamp the work firmly to a stable surface and ensure the grinding disc guard is properly secured.

Step 5: Hold the grinder with a firm grip and against the bulk or body of the work rather than the edge of it.

Step 6: Move the grinder across the body of the work in the direction of the handle to avoid the grinder kicking back and the blade slipping, which may ruin the work or cause injury.

Precaution: Always wear eye and ear protection and gloves when using the angle grinder. Point the grinder away from the human body always.

3.4.3 Power Hacksaw

Figure 10: Power Hacksaw

The following instructions should be adhered to when using the angle grinder:

Step 1: Select a hacksaw blade of appropriate length and pitch for the material to be cut.

Step 2: Fix the hacksaw blade with the teeth pointing downwards towards the motor end of the machine.

Step 3: Check the alignment of the vice and hacksaw blade and mount the workpiece in the vice.

Step 4: Cut using strong steady strokes directed away from the workman. Use the entire length of the blade in each cutting stroke.

Step 5: Wipe the saw clean after use.

3.5 Fabrication Process of the Dryer

The first phase of the project includes the precise joining/fabrication of body parts of the dryer. The second phase includes the installation of the electrical system, heating system, control system, finishing polish and final testing of the dryer.

Construction of the Cabinet began with the following activities:

- Spraying of all metallic materials with anti-rust paint.
- Joining and welding of cabinet frame.
- Fabrication of dryer floor.
- Addition of insulation material (steel wool) to dryer floor.
- Fabrication of dryer roof.

Figure 11: Construction of dryer base

Figure 12: Insulation of dryer base

Figure 13: Close-up of the insulation

Glass wool or any material with a good thermal insulation property is sandwiched between two galvanize sheets to form a module. Both the dryer and roof are made from these modules. Square pipes are placed at equal distances within the module to avoid sagging and alternatively provide strength during mounting of fans and exhaust pipes.

The next set of activities includes the following:

- The molding and installation of the fan duct threshold.
- The complete fabrication of the inside of the drying chamber.
- Final filling of holes and patches.

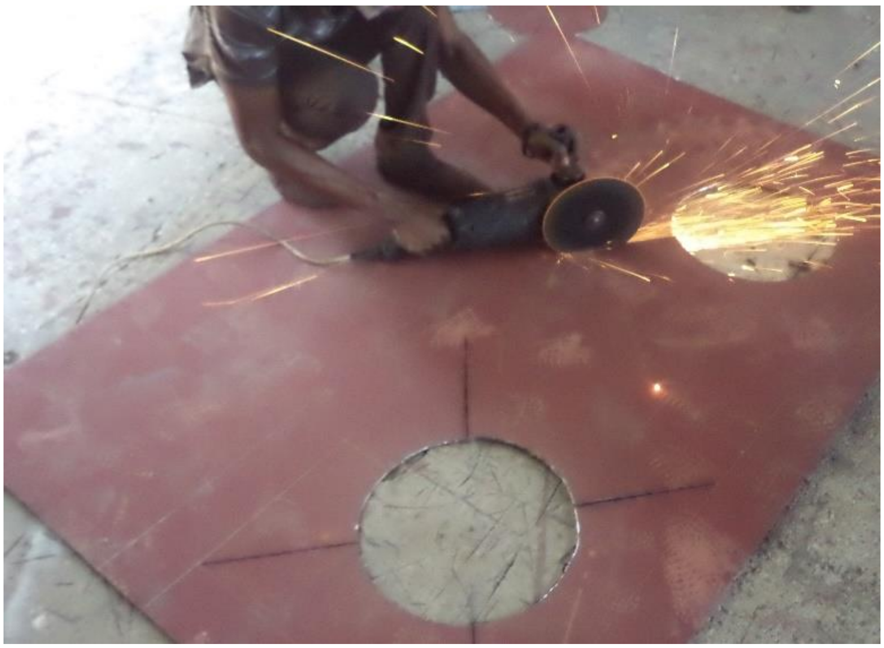

Figure 14: Cutting of Fan duct threshold

Figure 15: Molding of Fan duct threshold

Figure 16: Installation of left inner plates

Figure 17: Installation of right Inner plate

Figure 18: Front view of drying chamber

Figure 19: Installation of fan duct threshold

The following were the activities carried out after the purchase of items for phase II:

- Installation of dryer outer plates.
- Installation of tray panels and buffers.
- Installation of heating coils attachment point.
- Further painting of exposed metal with anti-rust paint.
- Further application of fillers to provide a smooth finish.

Figure 20: Installation of dryer buffers

Figure 21: Further application of anti-rust paint to exposed metal parts

After construction of the dryer body, tray panels and buffers were installed and given finishing touches through the execution of the following activities:

- Fabrication of dryer door frame.
- Filling of frame with insulator.
- Sealing door frame with metal plates.
- Installation of door hinge onto dryer door.
- Installation of door onto dryer.
- Spraying dryer with anti-rust paint.

Figure 22: Front view of dryer with doors installed

3.5.1 Installation of electrical/electronic system

Activities in this section include the wiring of Control panel and troubleshooting of control panel.

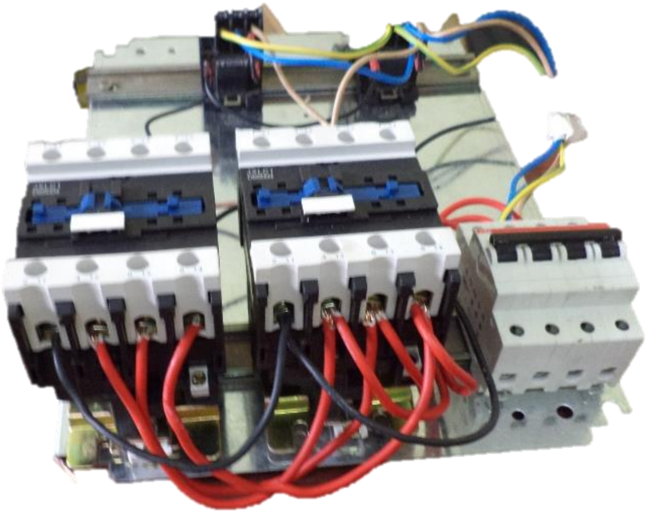

Figure 23: Wiring of control board

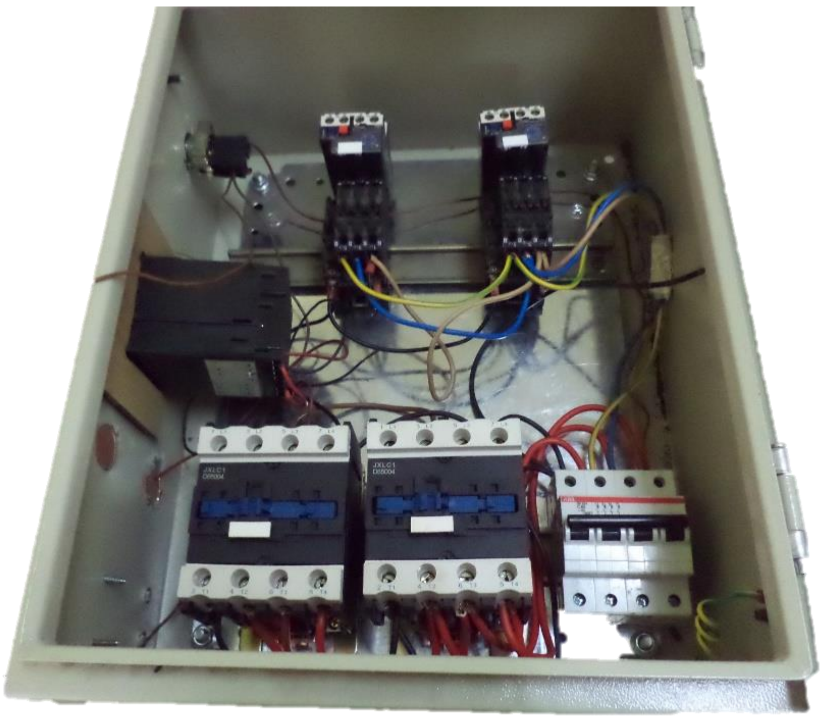

Figure 24: Applying final finishes to control board

With the aim of completing all electrical and power related works, the team undertook the following activities initially;

1. Construction of tray holders.
2. Construction of motor attachments and drilling of motor shaft holes.
3. Construction of motor fans.
4. Machining of motor shaft.
5. Drilling of heating coil attachments.

Figure 25: Construction of Motor Fans

Figure 26: Construction of Tray holders

Figure 27: Construction of Tray holders

Figure 28: Installation of heating coils

Figure 29: Installation of tray holders inside Dryer

Figure 30: Installation of coil guards and spraying of inner Dryer chamber

Figure 31: Complete installation of heating coils

Figure 32: Sprayed painted dryer allowed to dry for about 3 day

Figure 33: Mounting of Electric Motor

Figure 34: Fabrication completed

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APPENDICES

Appendix 1 - Power Consumption of Dryer

The main power consumption comes from the 2 Electric motors and 16 heating coils.

Each motor consumes a power of 1.5 kW.

Each heating element consumes power of 1.8 kW.

Assuming power losses through electric cables is negligible,

Total power consumption of 16 heating elements

Hheating elements = 16 x 1.8 kW = 28.8 kW

Total power consumption of 2 electric motors;

H Electric Motor = 2 x 1.5 = 3 kW

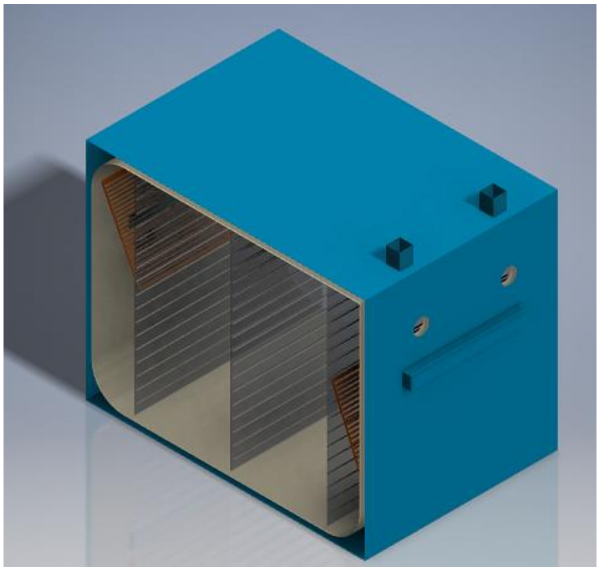
Total power consumption of dryer will be;

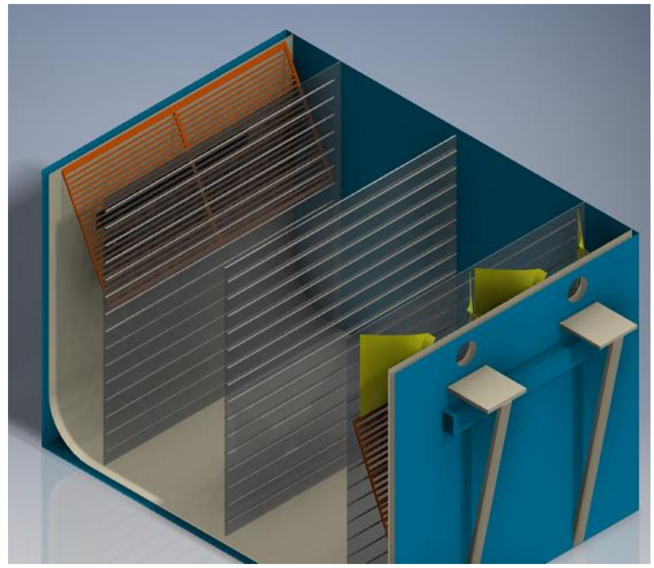
H total power = HElectric motor + Hheating elements

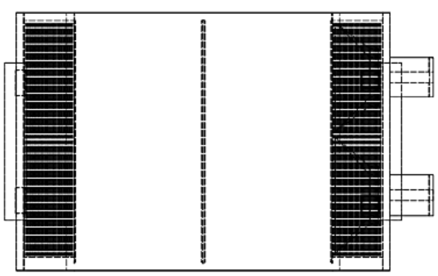
= 28.8 kW + 3 kW

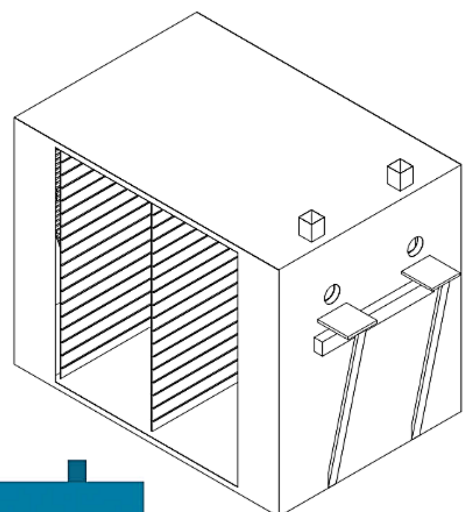
= 31.8 kW

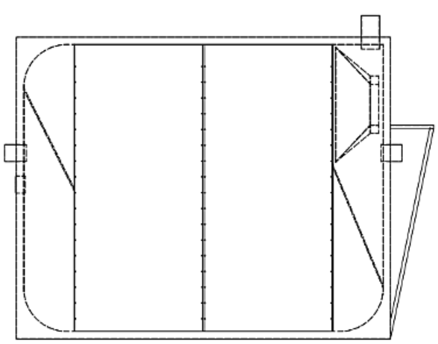
Appendix 2 - Dryer Schematics and 3D Elevations

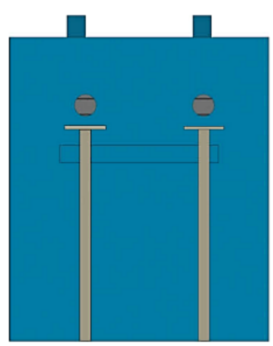












VIEW3

Appendix 3 - Operational and Maintenance Manual

Operational

i. Spread food products thinly in trays and place in the drying chamber.

ii. Set the correct drying temperature 50 to 60 degree Celsius (where necessary).

iii. Set the correct drying time (where necessary).

iv. Set the correct product final humidity (where necessary).

v. Start drying machine.

vi. Periodically check temperature, humidity and timer readings to ensure proper functioning of the dryer.

vii. Check product for thorough dryness when the dryer goes off.

viii. Allow the product to cool and remove the product from the dryer.

Routine and Periodic

i. Clean the dryer before and after use.

ii. Clean trolleys and trays after every use.

iii. Check electrical connections and make sure they are firm.

iv. Check and service electrical motors according to the manufacturer's recommendations.

v. When fans are belt driven, check belt tension and adjust where necessary.

vi. Check bolts securing fans and tighten if necessary at least once a week.

vii. Check the heating elements, temperature and moisture sensors for functionality and replace or calibrate the sensors if necessary