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Design and Fabrication of NCAM Developed Multi-Crop Dryer

By

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Abstract

NCAM developed multi-crop dryer is an electrical powered cross ventilated cabinet dryer it is a viable technology that is capable of drying any form of farm produces or foods. It allow the drying to take place at a desired or required temperature and airflow rate, the foods or farm produces is dried in hygienic way without losing the nutrient as well retain the original color, It's a single phase machine which makes it suitable for industrial, domestic, office and for research activities. The construction material was locally sourced and the fabrication was carried out at NCAM fabrication workshop, the components parts are readily available in the market these makes the NCAM developed multi-crop dryer has a conical shape and also allow selection of desired temperature and airflow rate.

Keyword: Design, fabrication, performance evaluation, multi-crop dryer, Airflow rate.

1.0 Introduction

Drying has been one of the age long practices to preserve farm produce that cannot be stored for long. This is because the moisture content in the produce encourages the activities of microorganisms thus the produce deteriorates within a short period. This however, if not mitigated, would bring about economic loss. NCAM Developed Dryer is an electrically powered dryer. This dryer is primarily for drying farm produce or foods indoors by removing moisture and to allow safe storage.

An effective approach to dehydrate and preserve the perishable goods such as fruits, and vegetables is dying at a required temperature (low temperature) to preserve the food in its natural texture (Esper and Muhlbauer, 1998) the slow drying can be easily carried out by open sun drying with a longer period to reach required storage moisture. The rain, dust, insects, pollution and contamination from environment always have adversely affect the quality of the products which will make the dried product not to be acceptable in the international market (Ivanona & Andonov, 2001 and Anonymous, 2007) thus drying with required temperature and air flow rate not just shorten the drying period but also dried the product to a storage moisture level, maintain the color, meet the hygienic standard and retain the original nutrient, natural texture and color of the farm products or foods,

Drying is the process of removing moisture from a product while preserving the quality. Growth of micro-organisms can be prevented by removing moisture from foods. The process of moisture remover required a large amount of energy. For this reason, drying is considered to be one of the most energy intensive unit operations in agricultural and food processing industries (Timothy et al., 2011).

Drying takes away the moisture or liquid from a food by bringing this moisture into a gaseous state. In most drying operations, water is the liquid evaporated and air is the normally employed purge gas. In general, the main goal of drying is to reduce the moisture content of food to a certain limit, which results in quality enhancement, and ease of handling and further processing, consumption or storage (Sokhansanj and Jayas 1995).

Farm produce drying is one of the oldest methods of preserving food for later use and most diverse of engineering operations. It can either be an alternative to canning or freezing, or compliment these methods. Drying food is simple, safe and easy to learn with modern food dryer. Fruits, grains, tubers, vegetables; can be dried year round at home. More than four hundred types of dryer reported from literature and more than one hundred types are commonly available (Syahrul et al., 2002)

Drying is a very important process in food processing as dried products store and preserve much better than fresh products. There is scarcity of knowledge on conceptual design, analysis and optimization of dryers for food.

Abur*et al* (2014), reported that one of the most reliable ways of checking post-harvest losses especially in developing countries is through the use of well-designed drying systems

Vegetables and fruits during the on-seasons can be purchased at affordable prices in bulk and can be preserved for their off-season use

Drying summarily is the removal of moisture and the food becomes smaller and lighter in weight until the moisture content of product get to storage moisture level

NCAM developed dryer is an electrical powered cross ventilated cabinet dryer that is capable of drying any form of farm produces or foods. It's a single phase machine which makes it suitable to use not only in company or factory but also at homes and offices. It's also suitable for research activities. The construction material was locally sourced and the spare parts are readily available in the market these makes the NCAM developed dryer different from the existing dryer

2.0 Objectives

i. To develop a suitable and affordable dyer for effective drying of farm produce at a required temperature and airflow rate level that will maintain original nutrient, natural texture, color and taste in an hygienic way; and

ii. To incorporate a simple electrical control system that would maintain steady drying temperature and airflow rate.

3.0 Materials and Methods

3.1 Machine description

The machine can be divided into two segments namely: mechanical part and electrical part.

i) Mechanical Part

Mechanical parts are drying cabinet, stand, chimney and trays

Drying cabinet is made up of 2 mm mild steel metal plate and lagged with a fiber glass. The cabinet is 640 mm height, 620 mm width, 1340 mm length with a chimney made up of galvanized rod of 100mmϕ, 140 mm height. The drying cabinet is seated on a stand/platform made up of 2mm angle iron that is detachable from the cabinet. The height and length of the cabinet and the stand is 1220 mm and 1340mm respectively. 2 numbers of 3inches were used to hold the door and 2.5 mild steel bolt were also used for the locking of the door.

Tray: The tray is made up of 4 mm thick aluminum material and is perforated to allow easy penetration of hot air into the dying produce with the dimension of 640 mm by 1340 mm, 3 numbers of trays were been used. The trays accommodate the product to be dried

ii) Electrical Part

The electrical parts consist of the blower, heat chamber, frequency inverter, temperature controller, solid state relay, thermocouple, wires and cable

Blower: The blower is a single phase 230 v, 50 Hz, 1440 rpm with 2 axial fans.

Heating Chamber: Heating chamber comprise of 2 numbers of electrical heating element of 1800 w, 230v each was connected to solid state relay.

Frequency Drive Inverter: Frequency drive inverter regulates the air flow from the blower in a fine way such that it allows one to set the air flow rate to the required drying air flow rate of a particular food or farm produce an anemometer was used to calibrate the frequency inverter to ascertain the air flow rate at a particular frequency. The frequency inverter ranges between 0Hz to 65 Hz, the higher the frequency the higher the air flow rate. It also has a display where it shows the set frequency with a nub that can increase and decrease the frequency as well have some buttons includes: run stop/reset among others.

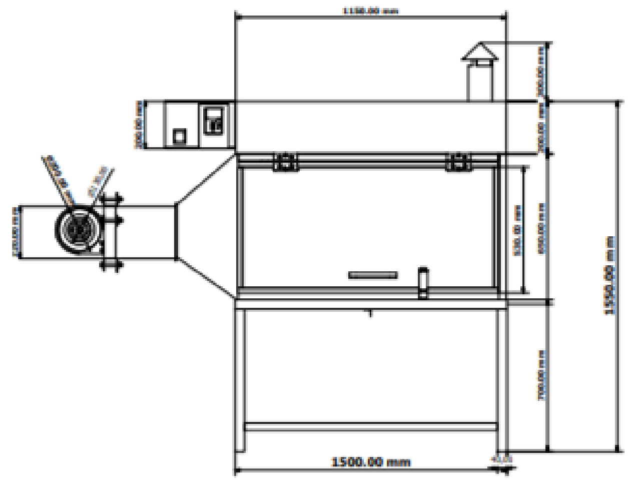
Temperature Controller: A PID temperature controller with an input power supply of 230v Alternating Current (AC) and an output of 24v Direct Current (DC) was connected to the solid state relay, the thermocouple was also connected to the temperature controller. It has a visual display where the present value and set value can be seen with a set buttons to set the required drying temperature.

Solid State Relay (SSR): Solid state relay of input 32 VDC, output VAC, 40amphere is to make and break the supply to the heating element it open the circuit and also close the circuit when needed. It got it direct current supply from temperature controller and supply alternating current to the electrical element.

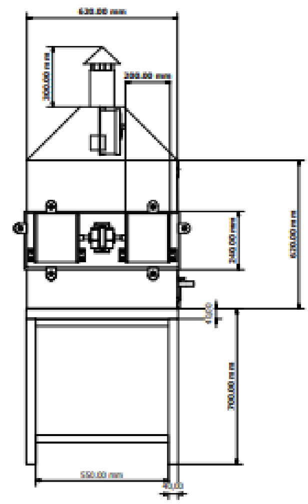
Thermocouple: Thermocouple is a sensor that is sensing the temperature in the cabinet and communicating the temperature controller to display the present reading. The sensor probe is placed inside the cabinet and it's connected to the temperature controller.

Wire: A Heat resistance wire of 6mm is used to connect the heating element. A flexible wire of 2 mm is used to connect the blower to the frequency inverter, the solid state relay to the temperature controller as well as the loop of temperature controller

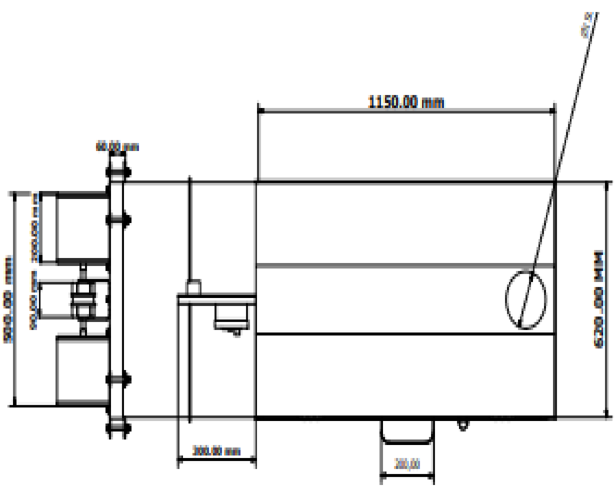
A 3 core 10 mm cable is use to connect the machine to the single-phase power supply.



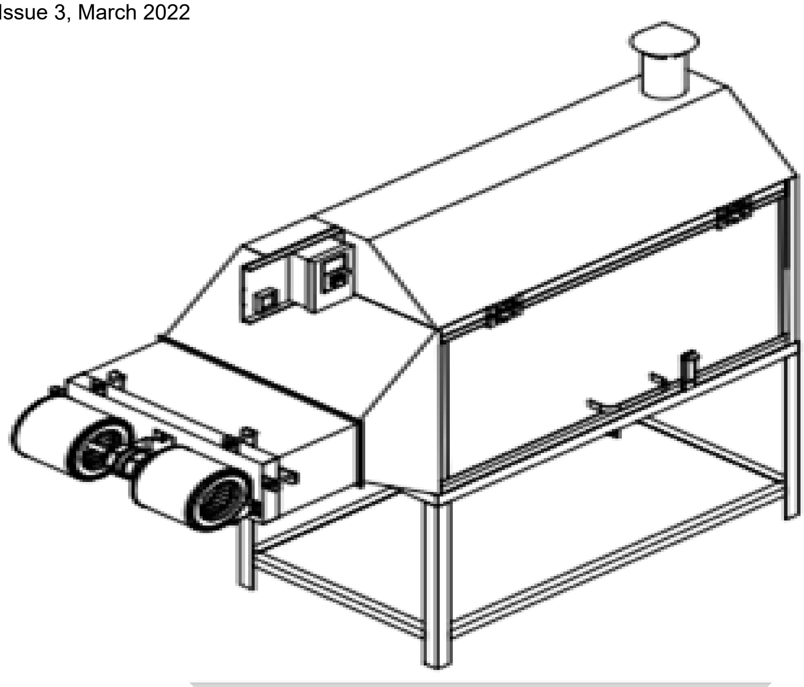
Front View



End View



Plan view



Isometric view

Pictorial view

4.0 Working Principle of the Dryer

The dryer dry the farm produce and foods so as to allow preservation of the farm produce and foods, after weighing the product and taking the moisture content to determine the moisture content before drying , the product to be dried will be placed on the trays the temperature and the air flow rate will be set to the drying requirement of the product to be dried, there will be offloading at a period interval to weigh the product till the product dried and the moisture got to a storage moisture level.

The dryer is being powered by a single phase 230v, from the power supply to the contactor which serve as a protection and switch for the dryer the contactor will supply the electricity to the dryer; the supply goes direct to the electric motor frequency drive that power the blower, the nob on the electric motor frequency drive increase and decrease the air flow rate of the blower, the temperature controller got the supply from the contactor which sense the temperature of the drying cabinet through the thermocouple that is connected with temperature controller, the temperature controller also connect to the input of the solid state relay to cut off the supply to heating element to maintain the set temperature.

5.0 Design Consideration

While designing the NCAM multi-purpose dryer, some factors were taken into consideration such as ambient temperature, relative humidity, initial moisture content of fresh products and final moisture content considered safe for dried products. Other considerations included ease of loading fresh products into and removing dried products out of the drying chamber; heat distribution in the cabinet,

5.1 Design Calculations

i) Design for mass of moisture to be removed from the products

The mass of moisture to be removed from the products is calculated from the relationship given by Ichsani and Dyah (2002) as:

$$m_{\mathcal{W}} = m_i \frac{(\mathcal{M}_0 - \mathcal{M}_f)}{(100 - \mathcal{M}_f)} \qquad (1)$$

Where:

m_w is mass of moisture to be removed in kg
m_i is initial mass of products in kg
m_o is initial moisture contents of products in % (wet basis).
m_f is final moisture contents of products in % (wet basis).

ii) Design for quantity of air needed for drying the products

The quantity of air needed for drying can be calculated from the basic energy balance equation for drying process (Ichsani and Dyah, 2002) as:

$$m_a C_{pa} (\mathrm{T}_b - \mathrm{T}_c) = m_w L \qquad (2)$$

Where;

m_a is mass of drying air in kg
C_{pa} is specific heat capacity of air at constant pressure in J/kg
T_b is initial temperature of drying air in degrees Celsius
T_c is final temperature of drying air in degrees Celsius
L = latent heat of evaporation of free water from the product in J/kg.

The mass of air required to remove moisture in the drying process is represented by Ichsani and Dyah (2010) as:

$$m_a = \frac{m_w}{(\Delta w_{cb} \times n)} \quad (3)$$

Where:

m_a is mass of air required to remove moisture from the product
m_w is quantity of moisture to be removed
Δw_{cb} is change in humidity ratio which is the moisture that can be removed by the heated air
η is the pickup factor.

iii) Design and selection of size and type of fan to convey the drying air

The fan size was determined by calculating the volumetric flow rate of the drying air which was given by Axtell (2002) as:

$$m_v = m_a \times v_s \quad (4)$$

Where:

m_v is volumetric flow rate of the drying air in m^3/s
m_a is mass of air required to remove moisture from the product
v_s is specific volume of the drying air in m3 kg-1.

iv) Design for energy required for drying

In order to determine the quantity of heat needed for the dryer, the quantity of heat energy required is calculated using the equation below according to Axtell (2002) as:

$$Q = m_{af}\,(h_2 - h_1) \quad (5)$$

Where:

Q is amount of heat energy in kJ/s

m_{af} is air mass flow rate in kg/s
h_1 is specific enthalpy of air at inlet in kJ/kg air; and
h_2 is specific enthalpy of air at the drying temperature in kJ/ kg air.

The drying rate was determined by using the equation below as:

$$R = \left(\frac{dM}{dt}\right) = \frac{m_i - m_f}{t} \qquad (6)$$

Where:

R is drying rate in g/h
dM is change in mass in g
dt is change in time in h
t is total time in h
m_i and m_f are the Initial and final mass of product respectively in g.

6.0 Results

The preliminary test result carried out after the fabrication of the multi-purpose dryer using two types of vegetables is as detailed below.

Table 1. Result of Preliminary Test

Vegetable	Drying Temp. (°C)	Drying airflow rate (M/S)	Drying Period (minute)	Initial Weight (g)	Weight At 1:00 hr (g)	Weight At 2:00 hr (g)	Weight At 2:40 hr (g)	Final Weight (g)	Initial Moisture (%)	Final Moisture (%)
Ugu leaf	60	1.1	160	200	110.9	55.0	42.1	42.1	83.23	5.07
Bitter leaf	60	1.1	160	200	110.3	66.4	37.7	37.7	79.38	5.28

It was found out that for Ugu leaf at initial moisture content of 83.23%, it was dried to a stable moisture content of 5.07% after a period of about 2 hours 40 minutes while bitter leaf, with initial moisture content of 79.38% was dried to a stable moisture content of 5.28% for a period of about 2 hours 40 minutes. It was also discovered that the vegetables did not change colour after drying to a stable moisture content.

Fresh Ugu Leaf

Dried Ugu Leaf

Fresh Bitter Leaf

Dried Bitter Leaf

The proximate analysis carried out is as reported in the table below.

Table 2. Proximate Analysis

Vegetable	Sample	Moisture (%)	Ash (%)	Fiber (%)	Fat (%)	Protein (%)	CHO (%)
Ugu leaf	Fresh	83.23	1.64	2.06	0.92	3.75	8.41
	Dried	5.07	18.26	13.08	6.43	21.45	35.71
Bitter leaf	Fresh	79.38	2.60	1.51	0.69	4.24	11.58
	Dried	5.28	14.02	4.54	2.39	25.07	48.70

Data is average of three replicates

Proximate analysis is based on the separation of food substances in to fractions in accordance with their nutritional values. The value fractions determined include Water/moisture, Ash, Crude fibre, crude fat, Crude protein and carbohydrate.

The proximate analysis was carried out according to the procedure of association of analytical chemist. Official method of analysis of AOAC International.19th Edition. Gaithersburg, MD, USA, Association of Analytical Communities; 2003.to determine the moisture content, crude protein, crude fat, ash, crude fibre and carbohydrate extract of the fresh and dry samples. The proximate analysis of the samples was repeated three times.

7.0 Recommendation

An extensive evaluation of the multi purse dryer should be carried out using other vegetables that have high moisture content and are susceptible to damage within a short period after harvest.

8.0 Conclusion

The NCAM Developed Multi-Crop dryer is a viable technology for drying crops. It is capable of drying any form of farm produce or foods, it is suitable for both domestic and industrial use.

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