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REGULATED CONVECTIVE COMPARTMENTAL DRYER FOR AGRO ALLIED PRODUCTS

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Abstract: **This innovation is a research and development project of National Engineering Design Development Institute (NEDDI), Nnewi. The purpose of the project is to design and fabricate a dryer for drying all manners of crops, pursuant to the institute's mandate. Existing conventional convective dryers which are mainly open sun drying, solar drying systems, wood and charcoal dryers and conventional electric dryers are attendant with lots of shortcomings from contamination in some cases to under or over drying because of the thermally uncontrolled process. Drying is a process of preservation and as such should be executed within a very short period. Sun and solar dryers fail in timely processing because of their dependency on availability of sun's energy. Wood and charcoal dryers are difficult to control. This leads to under and over drying of materials. Most available electric convective dryers do not have chamber capacity for commercial processing. The need for storage of agricultural produce to avoid waste and enhance the availability of food throughout the season and to ensure food security in the country is the key motive for this project. The equipment is robust and spacious with a thermostat to regulate the heating of the heat generator and the temperature of the drying air going into the drying chamber before reaching the products to be dried using an Atmega328P Microcontroller. The drying air temperature for each material is set at the scientifically recommended temperature for drying the particular produce.**

Keywords: **Drying, Preservation, Regulate, Temperature, Commercial, Quality.**

I. INTRODUCTION

Drying is the most common and fundamental method for post-harvest preservation of agricultural plants products because it allows for the quick conservation of the qualities of the plant material in an uncomplicated manner. Quality distinction was already made some 4000 years ago in ancient Egypt between medicinal plants dried in the sun and those dried in the shade (Müller and Heindl, 2006). The removal of moisture in the materials prevents growth and production of micro-organisms that can cause decay and minimizes most moisture-mediated deteriorative reactions. Drying results to a substantial reduction both in weight and volume, minimal packaging requirement, enhances storage, low transportation costs and also, enables storability of products under ambient temperatures (Akpinar et al., 2006; Demir et al., 2010). However, factors such as scale of production, availability of new technologies and quality standards must be considered for plant products drying in modern times. Natural drying, which is drying without auxiliary energy either in the field or in sheds, should only be considered for drying of small quantities. In cases of mass production, the use of technical drying applications is indispensable. For the preservation of active ingredients of medicinal plant materials and nutritious food stuffs, comparatively low drying temperatures are recommended and, as a result, the drying duration is comparably long.

Drying requires heat to evaporate moisture from the material and a flow of air to carry away the evaporated moisture. There are two basic mechanisms involved in the drying process; the migration of the moisture from the interior of the individual material to the surface, and the evaporation of the moisture from the surface to the surrounding air. The rate of drying is determined by the moisture content and the temperature of the material, and the relative humidity and the velocity of the air

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in contact with the material. The moisture content falls rapidly at first but as the material loses moisture the rate of drying slows. In general the drying rate decreases with moisture content, increases with increase in air temperature or decrease with increase in air humidity. At very low air flows increasing the velocity causes faster drying but at greater velocities the effects is minimal indicating that moisture diffusion within the grain is the controlling mechanism. Müller and Heindl, (2006) reports that currently, energy demand of drying represents a significant cost factor, especially with the increased price of fossil fuels. This is largely due to the high moisture content of the flowers, leaves or roots to be dried. For example, drying plant material with a moisture content of 80% will require 4 kg of water removal in order to obtain 1 kg of dried material with a storable moisture content of 11%. Additionally, specific heat requirement, such as 10,000 kJ per kg water removed in the drying of herbal drugs, is twofold in comparison with grain drying. From that, a heating-oil requirement of about 1 l per kg drug arises and with additional purification losses, heating-oil requirement can still be doubled. Thus, energy requirements of drying are considerable and represent a major expense in the drying procedure, which is already the greatest cost in the processing of medicinal plants and foods. Moreover, drying performance takes authoritative influence on the quality of the product and, therefore, on its value. Optimal combination of dryer design, operational method, energy use and quality maintenance of the product requires crucial managerial decisions.

To ensure clean and good quality products, several researchers have recommended solar convection drying to sun drying. However, the irregular effects and weather dependency of solar dryers have been the major challenge to the effective use of the solar energy (Komolafe and Waheed, 2018). Direct exposure to sunlight reduces the quality (color and vitamin content) of some fruits and vegetables. Convective dryers as shown Plate 1and 2 were constructed to house the products to be dried while protecting them from direct sunlight which can damage the qualities of products. A heat collector was built to gather heat from solar and redirect the heat into the drying chambers using the thermodynamics principles. The heat generated can reach up to 80^{o} C when the clouds are clear. Such systems are usually effective within the period of sun rise and sunset of the particular region. In other words, effective drying activities are only carried out when there are available sunrays hot enough, only in the day time, and within the period of 8:00 am to 5:00 pm. This system cannot be deployed for large production and would diminish the nutritional contents of products with low tolerance to heat.

Plate 3 depicts a convectional hybrid system incorporating alternative means (biomass fuel) for heating the air to be used for drying produce. This system enables the dryer to be operated during cloudy periods, as well as at night. But it does not have a regulating system that controls the heating period and temperature produced so as to remain within the safe temperature requirements for the particular type of product being processed. Also, particles such as the ashes, charcoals and tar become a challenge as they tend to affect physical appearance and as well as the chemical composition of the products. As a result a large amount of nutrients of the products may be lost due to contaminants. Plate 4 shows an improved hybrid solar dryer which reduces product contamination. But the system requires a high capital whereby ceramic materials are used as insulator. It also requires large space for small amounts of material to achieve quality drying within a short period. As such, it cannot be employed for commercial production. The hopper carrying the bio-fuel must be refilled periodically for the dryer to work 24 hours a day. Also, human efforts must be employed which can result to waste due to human errors on fuel refill and temperature control. The aim of drying which is to achieve economical and healthy storage and preservation cannot be attained employing these conventional convective dryers.

Plate 1: Solar Dryer with Two Solar Concentrating Panels *(Stiling et al., 2012)*

Plate 2: Solar Convection Dryer (Schiavone *et al.*, 2013)

Plate 3: Solar-Biomass Hybrid Cabinet Dryer (IAE/UPLB, 2002)

Plate 4: Solar-Biomass Convective Dryer (Tibebu, 2015)

This study has contrived a robust electrical convective dryer to remove dependency on uncertain weather and limited fuels while ensuring timely processing of materials. The innovation employs electrical heating element to generate heat; whereas a blower forces air to pass through the heating elements so as to heat the drying air and to equally distribute the drying air in the drying chamber. With the ability to select a specific temperature for drying a particular product, checkmates temperature levels not to exceed the selected temperature and operates all round the clock with little or no supervision. Using this equipment for drying operations produces healthy products in large quantity, safe for storage and safe for human consumption within a stipulated time frame.

II. AIM AND OBJECTIVE

The is to aim of this study is to develop a commercial dryer with temperature regulating apparatus that would ensure quick production of quality products in large quantities and at specified temperatures. The objectives are:

i. To design a temperature regulated electrically fired convective dryer.

ii. To fabricate the machine.

iii. To carry out performance evaluation of the equipment using fruits, cereals and tubers.

III. METHODOLOGY

The project focuses on engineering design and fabrication of the dryer with the accompanying facilities (drying chamber, tray-trucks, heating chamber, air distribution system, power system and control system). The engineering design includes process design, mechanical design and automation and control systems design. The steps are

i. Conduct research on different ways of food preservation, their merits and their demerits.

ii. Conduct Research on the types of food crops, their drying temperatures and other necessary parameters.

iii. Design and develop a dryer based on the function target of quality quick drying in commercial quantities.

iv. Testing and evaluation of the dryer.

IV. EQUIPMENT DESCRIPTION

The Automatic Convective Dryer mainly comprises of namely: the Atmega328P Microcontroller, Heat Sensors, Blower Motor, Heating Elements and Control Panel. Fresh air is sucked into the system by the Blower Assembly immediately when Blower Motor is actuated. The suction is a continuous process all through the drying period till the moisture content of the materials reaches the designed percentage. Fresh air constitutes about 20% of the total air going into the blower to be heated,

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moving simultaneously and mixed with the lower temperature air in the drying chamber, which constitutes the remaining 80%. This circulation system reuses the unused drying air, and optimizes the energy required for raising the fresh air temperature to the desired degree. As shown in Figure 1, heated recycling air is mixed with the fresh air and passes through the Suction Channel.

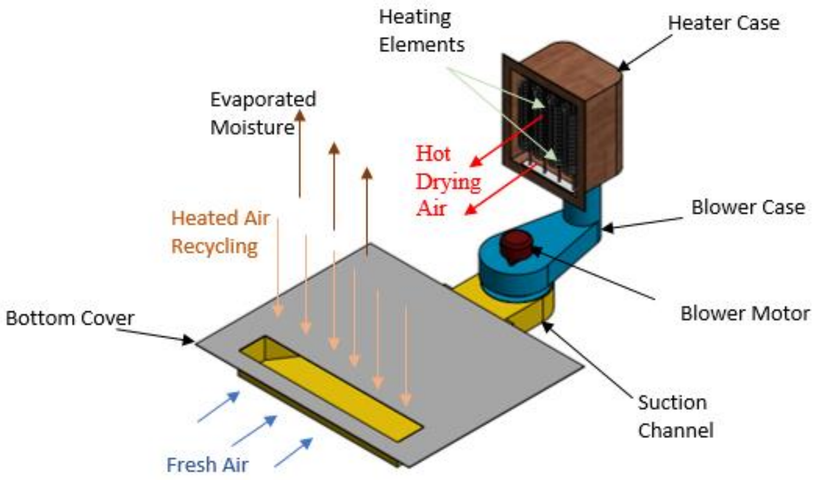

Figure 1. Heat Enhancement and Circulation System.

The air mixture is then forced into the Heater Case by the Blower so as to be heated, equally distributed and directed to the Drying Trays through the openings on the Back Cover. A heat sensor is placed at one opening of the Back Cover to directly measure the exact temperature of the drying air going into the drying chamber before heat exchange begins. Another heat sensor is placed at the exhaust channel of the dryer to measure the rate of heat leaving the system. These readings are utilized by the Atmega328P Microcontroller to compute when to switch on the Heating Element, likewise on when to turn it off. The Atmega328P Microcontroller is controlled at the Control Panel. The Control Panel houses the control buttons that enables the selection of different temperatures as desired and when to turn the system off as and when due thereby conserves energy. The Heating Element is powered by a 220 volts power supply. As drying air continuously moves with high velocity on the surface of the materials to be dried, moisture present in the materials tends to increase in temperature and leaves the surface of the materials being dried. As the evaporated moisture moves up the chamber seeking an escape route it is replaced by the fresh air coming into the system. This process runs continuously to achieve drying. Figure 2, 3 and 4 are respectively the Isometric, orthographic and exploded views of the Regulated Convective Compartmental Dryer.

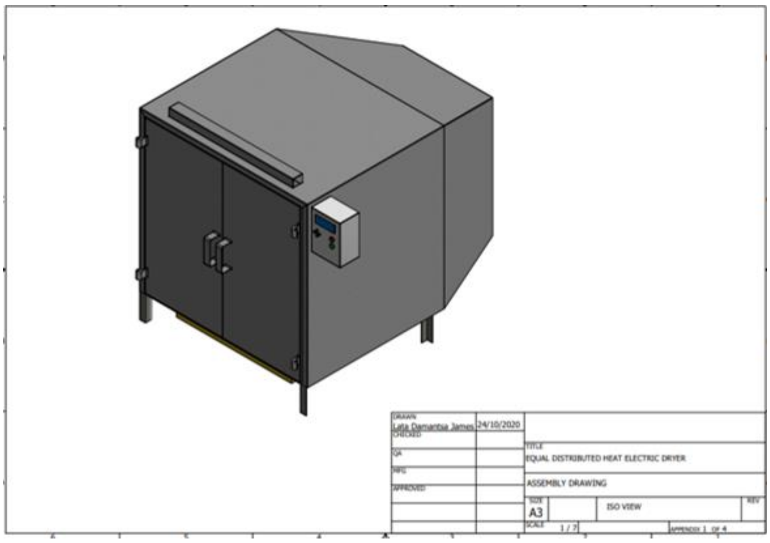

Figure 2. Isometric View of the Regulated Convective Compartmental Dryer

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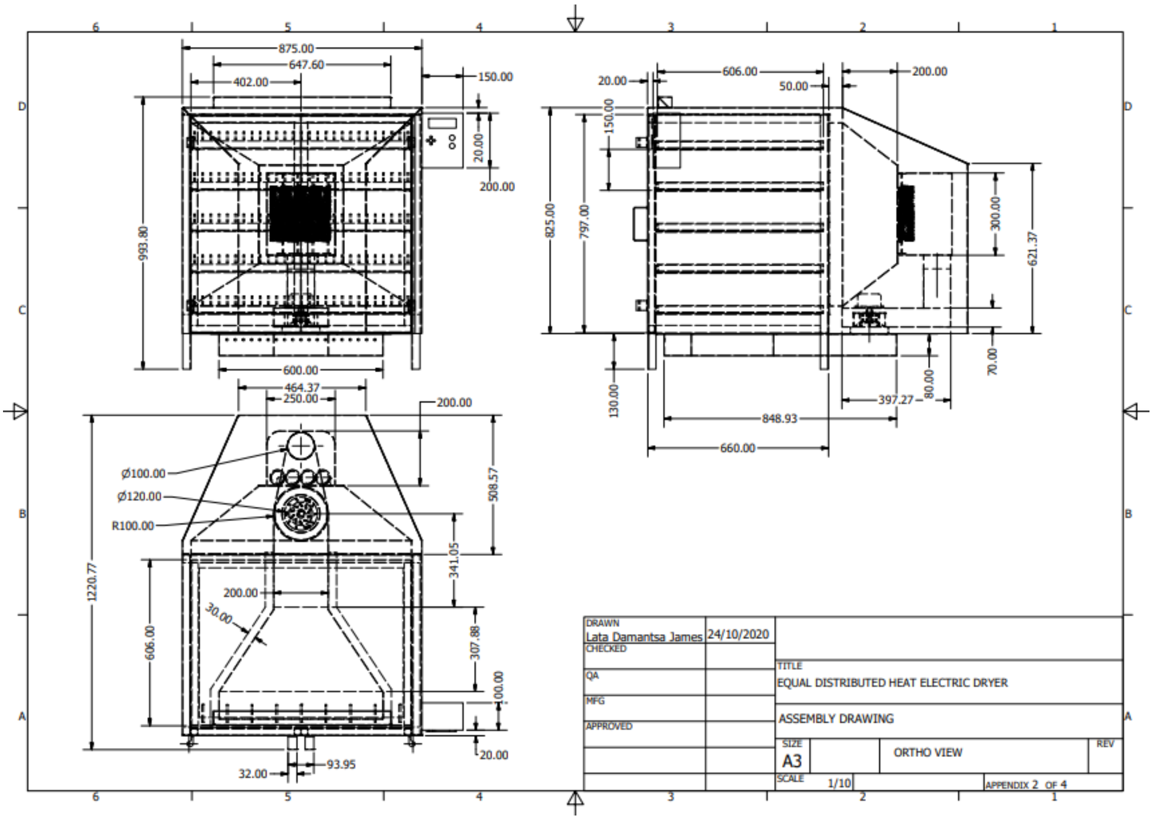

Figure 3. Orthographic View of the Regulated Convective Compartmental Dryer

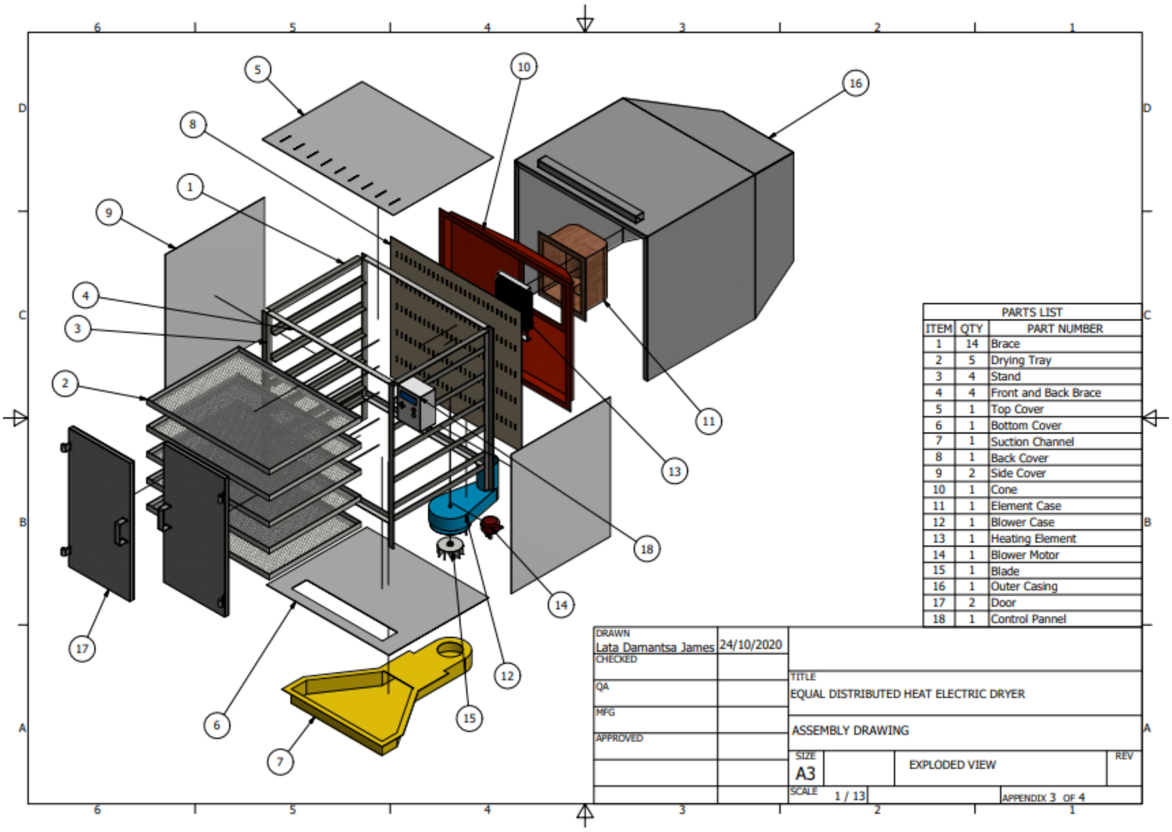

Figure 4. Exploded View of the Regulated Convective Compartmental Dryer

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V. RESULTS

Plate 5 is the picture of the Regulated Convective Compartmental Dryer. It was tested with yam, plantain and potatoes and performed optimally to about 85% of its design expectations. The dried yam, plantain and potatoes are depicted in Plate 6. The quality of the dried products namely: yam, potato and plantain of different thicknesses can be said to be good as the drying was even and without any form of coloration. Readings taken over time from Dryer Experiment for Yam Size 4mm at 60^{0}C, as the drying progressed are shown in Table 1.

Plate 5: Regulated Convective Compartmental Dryer.

Yam Plantain Potatoes

Plate 6: Dried yam, plantain and potatoes

Table 1: Readings from Dryer Experiment for Yam Size 4mm at 60ºC

TIME (mins)	0	30	60	90	120	150	165	180	190
Mass of tray + Yam (g) (M1)	3180.00	3003.00	2859.00	2752.00	2696.00	2629.00	2597.00	2575.00	2558.00
Mass of Yam (g) (M2)	1199.00	1022.00	878.00	771.00	715.00	648.00	616.00	594.00	577.00
Mass of water removed (g) (M3)		177.00	144.00	107.00	56.00	67.00	32.00	22.00	17.00
% water evpd (%)		14.76 (14.76)	14.09 (26.77)	12.19 (35.70)	7.26 (40.37)	9.37 (45.95)	4.94 (48.62)	3.57 (50.46)	2.86 (51.88)
MC (%)	51.88	43.54	34.28	25.16	19.30	10.96	6.33	2.86	
Drying rate (g/min)		5.90	4.80	3.57	1.87	2.23	1.07	0.73	0.57

VI. CONCLUSION

A robust Convective Compartmental Dryer with temperature regulating apparatus that ensures quick production of quality products in large quantities and at specified temperatures was designed and fabricated at National Engineering Design Development Institute (NEDDI), Nnewi. Performance evaluation of the equipment using yam, plantain and potatoes showed efficient operation within expected time. It is expected to also process fruits and cereals efficiently.

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