Development of an Arduino-Controlled Convective Heat Dryer

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Abstract- Drying, though an old method of preservation is gaining momentum contemporarily as means of preserving agricultural products. In this study, an Arduino-controlled convective heat dryer was designed, fabricated and tested using Dioscorea dumetorum (Trifoliate Yam). The stages of preparation of the yam were done as to be used commercially with a dimension of 50mm by 30mm by 5mm. The drying time for the second and the last temperatures of 65^0C and 70^0C are 110mins and 80mins respectively. Temperature was inversely proportional to drying time. Moisture movement from inner to outer surface was rapid as well. The whole drying occurred almost at falling rate period. The work has also shown that any agricultural product can be dried and controlled, provided the temperature of drying is specified, the heat and the power required to drive out moisture present in the product to the desired weight is controlled using Arduino.

Keywords: *Dryer, Arduino, Dioscorea dumetorum, moisture removal, convective heating.*

1. Introduction

Drying is one of the ancient physical method of food preservation and other products of organic origin. Its essential purpose is to minimize the moisture content of materials, predominately it is use for preserving food materials like fruits, vegetables, and other products with high degree of moisture (> 80%), as well as others which are considered to be highly perishable (Moses, Alagusundaram, and Tiwari 2014). It involves several approaches, which is a function of both the available means and the predominant atmospheric conditions of a particular geographical location. In some tropical countries, sun drying constitutes an economical and reliable means of preserving agricultural products. According to (Hashim, Daniel, and Rahaman 2014), sun drying involves spreading of wet material under the sun on desirable flat surfaces, hanging wet material on buildings or drying in bundles placed in stalks. Although open-air sun drying remains a cheap processing technique, its limitations include the control of the drying process and parameters, fluctuating weather conditions, big space need, pest invasion, combining with dust and other external particles. In view to minimize high level of post-harvest losses and the challenges of sun drying, other means of dehydration such as solar drying, microwave drying, freeze drying, and others evolved. More than 85% of commercial dryers use convective heat transfer process with either hot air or combustion gases as the working fluid (Moses, Alagusundaram, and Tiwari 2014) stated that drying is an energy demanding preservative process, hence, it usually accounts for approximately 12-20% of energy used during processing process, (Schlünder 2007).

The main characteristics of this method of preservation is the reduction in the moisture activities in the material thus lowering the product volume, restraining the production of micro-organisms, and minimizing deterioration reactions, thus increasing the product shelf life, efficiency of storage and packaging. Drying is widely used to reduce bulk handling and to guarantee food security during the off-season. The use of dryers can minimize waste of agricultural products and produce better quality of dried product when compared to the local means of drying such as sun or shade drying, this was observed by (E. Doymaz 2014) after investigating the outcome of pretreatment using citric acidic mixture with drying temperatures of 40^0C, 50^0C, 60^0C and 70^0C on mushroom slices. It was shown that temperature and pretreatment have reasonable influence on moisture extraction from mushroom. However, drying process sometimes result in the quality reduction of dried products because of high drying temperature as well as the required drying duration. Heat sensitive bio-active constituents for instance the Overall Phenolic Content (OPC), vitamin C constituent of fruits may be reduced during drying (Edziri et al. 2011). Despite this challenge, dried foods are gaining momentum especially with the growing resistance to the chemical preservation of foods and also for the growing demand for a wider variety of dried foods providing considerable convenience to the consumers. The importance of sustaining the standard measures of the dried agricultural products with considerable retention of bioactive constituents after drying process is discussed in (Xia 2013). Generally, different drying means will generate varied quality of dried products. For instance, fluidized bed is a short time drying method but it is capable of producing better quality of mushrooms as compared to microwave drying. Vacuum drying is another good substitute because it could help retain the quality of fruits although it requires a longer drying time when compared to microwave drying. Hence drying using Microwave produced a degree of undesirable result with short drying duration than the earlier mentioned methods (Chin, S. K., Siew, E. S. and Soon 2015). Higher values of moisture content and temperature for a give product results in a lower value of heat of vaporization. (Ekechukwu and Norton 1999) presented the changes of the latent heat of vaporization for some grains with their corresponding water present and temperature change during drying.

In the recent years, dryers whether for use in homes or in industries have replaced the traditional method of drying agricultural products because with them drying conditions are controlled for example temperature, moisture content, the drying time, etc. Thus the final product quality is improved. However, drying should be carried out as economically as possible. A Survey carried out on post-harvest food losses in many Agro-based towns and rural areas in Nigeria showed that approximately 20 – 30% of all grain crops, 30 – 50 % of tuber and root crop as well as a higher percentage of fruits and vegetables are wasted with a great amount observed during storage (Omolola, Jideani, and Kapila 2015). The assumption is that most of these products were lost as a result of inadequate preservation techniques. Considering the prevailing inconsistency in food supply throughout the world, cost- effective and hygienic means of preservation is needful to guarantee food security. Numerous means of food and moist material preservation had been recorded in literature with drying reported to be one of the oldest method (Mustayen, Mekhilef, and Saidur 2014). Drying is a process in which moisture is removed from a wet material by applying suitable energy source mostly in the form of heat. The mechanism of drying is an intricate phenomenon consisting convective transport of heat and mass within the material of interest. Drying is useful in chemical, agricultural, biotechnology, pharmaceutical, pulp and paper, mineral processing, and wood processing industries. The aims of drying are to increase the period of storage, to reduce packaging requirements and to minimize the transportation weight (I. Doymaz 2005). Any designed dryer at a stipulated time is expected to remove moisture from any product to be dried, produce desired product quality, with facilities that satisfy and/or promote environmental sustainability and safety, of durable size and cost effective.

Heat transfer during drying takes place either by one or combination of any two or these three major ways, which are conduction (solids), convection (liquids and gases), and radiation (Kumar, Sarkar, and Sharma 2012; Sacilik, Keskin, and Elicin 2006). Heat transfer method for a particular application depends on the type of system and the required conditions; heat usually moves from a location of higher thermal potential to a location of lower thermal potential.

2. Types of Drying

Different types of drying exist in literature, which had been studied by different researchers. The following are some of the types of drying processes seen in literature.

Sun Drying

Open-air sun drying is a traditional means of preserving agricultural products and other essential materials. Although this mode of drying is not usually appropriate for large- scale preservation due to the inability to regulate the drying process properly, elongation of drying time, weather variations, contamination, large space requirement and labour demand. However, the high sugar and acidic value of fruits make them good for drying under the sun whereas vegetables and meats are not good for drying in the sun because in vegetable's sugar and acid is small making them to prone spoilage. Meats have high protein making them prone to microbial attacks when heat and humidity are not maintained. In sun drying, hot, dry, breezy days with an average temperature of 30^0C are required with elevated temperatures being better. Also, humidity ratio less than 60% is preferable in sun drying (Ahmed et al. 2013). Usually, these ideal conditions are not always available and the cool night air may condense, adding more moisture to the material, thus increasing the moisture content consequently decreasing the rate of drying.

Solar Drying

Recent efforts to harness energy from solar radiation led to the concept of solar drying, which has several benefits over sun drying, these have been clearly stated by many authors. Compared to other basic uses of solar energy, solar dryers are in consistent struggle for acceptance and famous among large scale makers of dried materials, particularly in the nations that are still developing. The consequence of this poor dependence are complex and varied, hence it is a function of numerous factors for example, solar radiations required to provide sufficient energy for drying can only be available during the daytime (Sacilik, Keskin, and Elicin 2006). This makes it impossible for large-scale agricultural product dryers to process the products consistently with reliability. It is important to build a hybrid dryer with an appropriate form of back-up heating. Although the sun is the primary energy source in both sun and solar drying, but in this case its radiations, which occurs basically in the visible spectrum to which, the atmosphere is transparent to is utilized.

Freeze Drying

Freeze drying is called lyophilisation or cryodesiccation. It is a drying process usually used to keep agricultural products or to make the product safer and lighter for the convenience of transportation. It`s operating principle centers on material freezing and then lowering the surrounding pressure to make sure the frozen moisture in the product sublimated directly from the solid phase to the gas phase.

Oven Drying

If factors such as heat low humidity, and airflow are combined, they the oven function as a dehydrator. An oven is occasionally used for drying of fruits chips from banana and for preserving excess products like celery or mushrooms. The usefulness of the oven especially for cooking makes it unsatisfactory to preserve much garden products. It is slower than other dehydrators reason being that it does not have a built-in blower required for air circulation even though some convective oven has a fan. It takes about double of the time required for a dehydrator to dry food (Akpinar 2005). Thus, the efficiency of an oven is lower than that for a dehydrator, therefore its energy intake is higher. Its moving potential is the variation in the osmotic pressure of concentrations on the sides of the semi-permeable cell surfaces. The movement of water and other less molecular weight matters in the osmotic dehydration from the tissue is accompanied by opposed current diffusion of osmo-active matters (Yadav, Yadav, and Jatain 2012). Owning to this fact, osmotic dehydration as compared with the prevalent drying processes recognized for its elusive movement of water, substances are dissolved in the cell sap and osmo-active matters.

3. Applications of Drying

Drying as a useful tool for product dehydration finds use in food industry according to Donatello and Cheeseman (Donatello and Cheeseman 2013). Drying can be applied in the following ways.

Drying of Agricultural Products

This involves removal of moisture in agricultural products in other to reduce the development of microorganisms that would cause the deterioration and reduce many of the moisture facilitated degradation reactions (Sobukola, Dairo, and Odunewu 2008). The first phase (in which the drying rate increases) is short and goes with the rise in temperature of the product till equilibrium is attained. The product takes as much heat from the air as it needed to initiate the vaporization of the water. The drying rate increases, because the exchange of moisture between the product and the air is efficient as the product is heated. The second phase, with a constant drying rate, applies to the water evaporation on the surface of product. The water coming from the inside of the product renews it. During this phase, the drying velocity is constant as long as the characteristics of the air and its velocity going over the product are constant. The third phase involves decrease in the drying rate, which may cause shrinkage of the product; also evaporation of bound water takes place. The free water, which migrated from the inside to the outside of the product to be transformed into water vapour, has completely disappeared by the end of second phase. Moreover, the drying rate decreases as one approach the end of the operation. Some of the agricultural products that can be dry and preserve are yam, cassava, potatoes, garlic and tomatoes to mention but a few, though all virtually all agricultural produce required drying for preservation (Driscollb and Buckleb 1996). Trifoliate Yam (Dioscorea dumetorum) is one of the most-growing, important staple tuber crops, cultivated especially Nigeria. It is an annual or perennial tuber-producing crop with more than six hundred species. However, only little are planted for consumption. A study conducted on it proved that it is a good substitute to wheat flour at 20-70% level. It was also shown that the addition of trifoliate yam flour into wheat flour enhanced the moisture, crude fiber, ash and fat content of dried noodles (Akinoso, Kk, and Oo 2016).

Drying of other Biological Product

Due to the organic origin of some biological materials, there is a possibility of mold development, hence they require moderate drying. This is typified in timber processing, although reduction of wood weight and volume is also important. Similarly, water removal from sewage sludge, a by-product from the process occurring in waste-water treatment plants (WTP) can be attained by drying (Donatello and Cheeseman 2013). Also, drying is needed as a process step if the excreta-based substance is meant to be incinerated. Incineration of sewage sludge needs that the solids content be raised to closely 33% for the sludge to be autothermic (Furness, Hoggett, and Judd 2002).

4. Research originality

To the best of our knowledge and in the literature review conducted, no work has been done whatsoever on convective heat dryer incorporating Arduino program to monitor/control the drying temperatures and using plywood in the fabrication. This work is also necessary to preserve the quality of the dried agricultural product with optimal retention of bioactive constituents during drying to minimize product degradation and to retain product quality after drying.

5. Methodology

Although, the entire selection process and design of a dryer for a particular purpose is influenced by the motive of obtaining a favourable product quality as well as economical process. But considering several commercial dryers in use most dried products (i.e. vegetables and cereals) are made with convective hot air dryers because it is economical and simple. Even though there are other water or liquid extraction processes in existence such as supercritical removal of liquid from gels, centrifugation, filtration, settling, etc. With these processes, water is extracted by mechanical processes, although a significant quantity of liquid is present in the solid material. Four heating bulbs rated 200W each were used in the drying given total power of 800W. The drying was commenced after several electrical connections with the Arduino program for temperature variations of 60^0C, 65^0C and 70^0C. The Dioscorea dumetorum at initial weight of 0.3Kg was dried to a final weight of 0.11Kg for each of drying temperatures. The weight decrease at every 10minutes was observed. Results showed that for the first drying temperature, the drying time was 140mins. In this research, Arduino software was incorporated into the design to control and regulate the temperature of the dryer. The script was written to work with the hardware part to ensure that the temperature control is achieved. The product design is shown in Fig. 1 while the final prototype of the design is shown in Fig. 2.

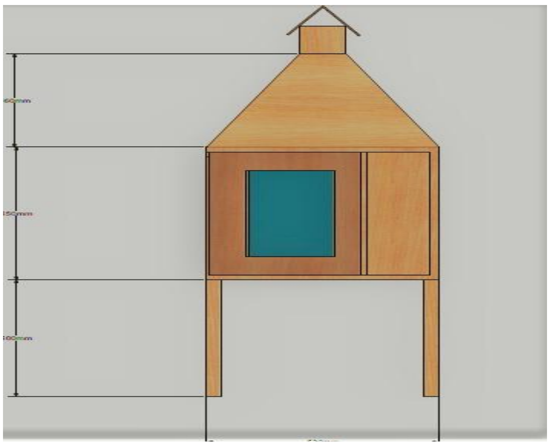


Figure 1: The Schematic diagram of the dryer

Analysis of Convective Hot Air Dryer

The above subject matter requires a comprehensive review of heat and mass transfer, thermodynamics and other relative transport theories for analyzing the system.

During the analysis, it was assumed that the drying chamber is perfectly insulated, the heat loss through the vent is negligible, the temperature change between the air at exit and inlet is assumed to be constant and air is assumed to be isotropic.

The energy balance equation in a convective hot air drying process can be mathematically written as:

$$M_w L_v = M_a C_{p.a}(T_i - T_f) \quad (1)$$

Where M_w is the mass of moisture removed from the product and taken by the drying air of mass M_a; T_i and T_f are the initial and final temperatures of the convective heat transfer air respectively, $Lv = 2260KJkg^{-1}$ is the latent heat of vaporization of the water, $C_{p,a}$ is the specific heat capacity of air. Therefore, if all the necessary conditions are satisfied with perfect insulation assumed, the heating power of the Tungsten filament must be equal to the thermodynamic heat supplied during the process. Thus

$$I^2Rt = M_a C_{p.a}(T_i - T_f) \qquad (2)$$

From the above equation, the only variable that can be varied during the drying process is the temperature difference, which is influenced by the drying time. Hence, the efficiency of the dryer can be estimated using the Mathematical relation;

$$\eta_{Dr} \frac{M_w L_v}{P_{in}\, t} \qquad (3)$$

where η_d is the Dryer efficiency, t is the drying time, M_w is the mass of water removed,

L_{vap} is the latent heat of vapourization and P_{in} is the power input.

6. Design Considerations

Dryer Sizing

In the determination of the size of the dryer, one must put into consideration that the specified volume of the dryer must be greater than the volume of items to be dried and the air required for air-circulation and head transportation within the chamber. Assuming the mass capacity of the dryer to be 2.5 Kg of Trifoliate Yam (Dioscorea dumetorum), this is use in determining the volume of items to be dried and that required for air circulation. The yam chips will be spread on the wire mesh within the chamber. The density of yam was obtained by experiments conducted in National Centre for Energy Research and Development, UNN, where a yam chips of weight 5.831g, when fully submerged in water weighs 5.761 g.

Upthrust = 5.831 - 5.761 = 0.07 g

Initial Volume of water = $24cm^3$ Final Volume of water =$20cm^3$

Volume of liquid displaced =24 − 20 = $4cm^3$.

Therefore, Density of Yam

$$\rho_y = \frac{0.07}{4} = 0.0175\, {}^{g}/_{cm^3} = \mathbf{17.5}\, {}^{\boldsymbol{Kg}}/_{\boldsymbol{m^3}}$$

From the above density, the volume of 2.5Kg of the yam chips is

$$V_u = \frac{2.5}{17.5} = \mathbf{0.1428\, m^3}$$

The dryer was design to accommodate above eight times this volume. This computation gives the unoccupied necessary volume used in free air circulation.

The real unoccupied air volume,

$$V_u = 8 * 0.1428 = \mathbf{1.1424\, m^3}$$

Therefore, the total volume of the drying chamber, $V_T = 0.1428 + 1.1424 = 1.2852m^3$.

Now, considering the specified dryer volume, Specified Volume V_s = Volume of Cuboid V_c + Volume of Triangular Prism V_{TP}.

Thus

$$V_s = V_c + V_{TP} \tag{4}$$

Considering the shape of the designed dryer,

$$V_s = L * B * H + \frac{b*h*l}{2} \tag{5}$$

Substituting the values of L = 0.55m, B = H = 0.47m, b = 0.47m, h = 0.44m and l = 0.36m;

$$V_s = 0.55 * 0.47 * 0.47 + \frac{0.47 * 0.44 * 0.36}{2} = 0.121495 + 0.037224 = \mathbf{0.15872m3}$$

From the above computation, the specified dryer volume of $0.15872m^3$ is greater than the design volume of $0.1428m^3$. Therefore, the maximum dryer capacity is approximately 2.5 Kg.

The maximum allowable temperature is 100^0C. The initial moisture content of yam is 75% from literature. For our analysis, we assume final moisture content of 15%. Therefore, from the foregoing, the percentage of moisture to be removed is 60%. Based on assumption that the designed mass capacity of the dryer is 2.5Kg.

Hence, for a 60% moisture removal, $0.6 \times 2.5Kg$, mass of moisture content = $1.5Kg$

Since the latent heat of vapourization (L_{vap}) is the amount of energy a product must absorbed before moisture is vaporized, it follows that the quantity of heat required, Q_w, to evaporate the moisture, M_w, is given by:

$$Q_w = M_w C_{p,w} \Delta T + M_w L_v \tag{6}$$

$Q_w = 1.5 \times 4182 \times (100 - 27) + 1.5 \times 2260 \times 1000$

$Q_w = \mathbf{3847929}\boldsymbol{J}$

Where C_{pw} is specific heat capacity of water given as $4182J/Kg^0C$, ΔT is the temperature difference between the ambient, the designed maximum temperature which is 100^0C, L_{vap} = $2260KJ/Kg$ and the ambient temperature is 27^0C.

The power required is calculated by dividing the quantity of heat transferred by the drying time,

$$P = \frac{Q_w}{t} \tag{7}$$

$$P = \frac{3847929}{5400} = 712.58W$$

7. Design and construction materials

The following materials were chosen for the fabrication of the designed dryer with respect to the properties of the material, economic consideration, material availability, prevailing environmental conditions, and processing properties. These materials include Plywood, Tungsten, Bulb, Blower, Electrical Box, wire mesh, The Wooden Stand, Anemometer, Thermocouple, Spring Balance and Glass.

Figure 2: Final Prototype

8. **Data Measurement**

Measurement of some basic parameters needed in evaluating the performance of the dryer. The ambient temperature will be measured using anemometer; this is to determine the overall temperature increase during the drying process. The temperature of the drying chamber will be maintained at 60^0C, 65^0C and 70^0C during drying operations. The power rating of the Electric bulb used is 800 W. The moisture content on dry basis in kilogram (Kg) will be computed. This will be evaluated for each of the drying temperature. The drying rate at every 10 mins (600 sec) will be calculated using equation 4 for each of the drying temperature.

Processing of Trifoliate Yam (Dioscorea dumetorum)

(Akinoso, Kk, and Oo 2016) used the following stages to prepare Dioscorea dumetorum before drying. The stages are as shown in the flow chart of figure 3.4. Hence we adopt the same way to prepare our trifoliate yam prior to drying. Trifoliate yam tubers were purchased from the market. They were sorted to separate the ones that are fit for the project from the bad ones. The needed ones were cleaned for the next processing method. This involves removing the outer surface of the yam which is a common feature of tuber crops. The tubers were washed after peeling in order to remove the accumulated dirt during the previous stages. The trifoliate yam tubers were cut to rectangular shape to enhance moisture diffusion during process. The dimension of the trifoliate yam chip is $50mm \times 30mm \times 5mm$. The alkaloid and carotenoid content of the trifoliate yam will be reduced by soaking it in water for at least four hours. This involves placing trifoliate yam tubers in warm water for 10 mins in order to remove some of its anti-nutritional contents. The processed trifoliate yam chips will be dried in the fabricated dryer in order to carry out the performance assessment of the dryer.

Figure 3: Unprocessed Trifoliate Yam

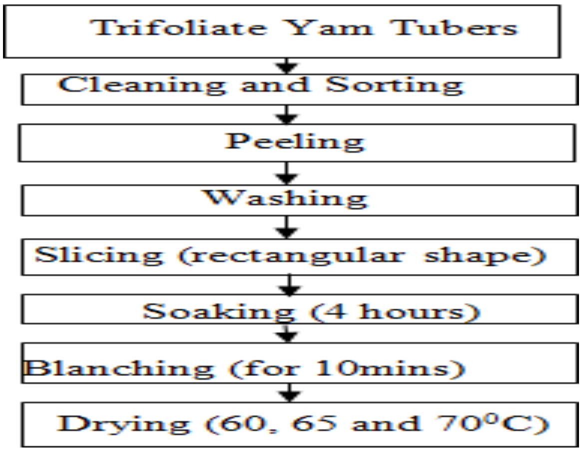


Figure 4: Trifoliate Yam processing

9. Results and Discussions

Dryer Testing

Figure 5: Drying of Trifoliate Yam

Before the commencement of drying of Dioscorea dumetorum at the three specified temperatures, the dyer was tested. It was found that the power required to get the specified drying temperatures (which are 60^0C, 65^0C and 70^0C). The designed power was 712.58W. Hence, an additional power input of 87.42W was made to account for heat losses. The efficiency of the dryer was found to be dependent on temperature. Though at higher temperature, the physical attribute of the product may not be conserved.

Figure 6: Trifoliate Yam before and after drying

Weight Changes at 60^0C, 65^0C and 70^0C

The initial weight of the sample was 0.3Kg. It was dried to 0.11Kg at each temperature. The drying rate R_d is a function of the weight loss and time; it was calculated using equation 3.4 as shown below. The moisture content on dry basis M_{db} is a fraction of the weight decrease to the final weight; it was calculated using equation 3.6 as shown below. Instantaneous moisture content on dry basis $M_{db}t$ was calculated using equation 3.12 as shown below.

Figure 7: Dryer in Operating at different temperature

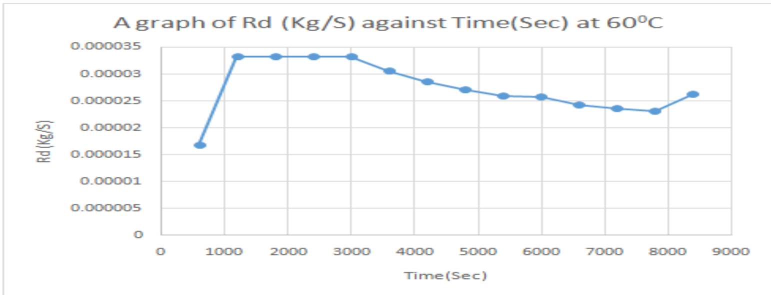


Figure 8: Graph of drying rate (Kg/s) against time (sec) at temperature of $60^{o}C$

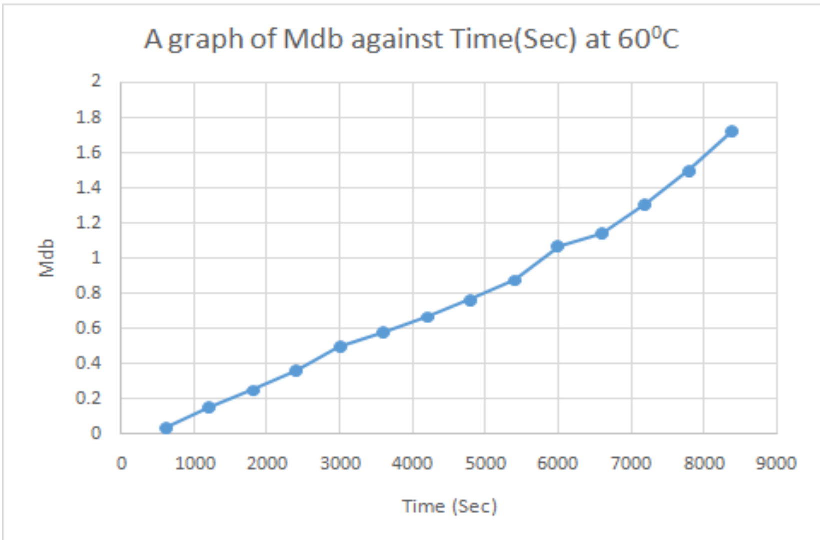


Figure 9: Graph of moisture content against time (sec) at temperature of $60^{o}C$

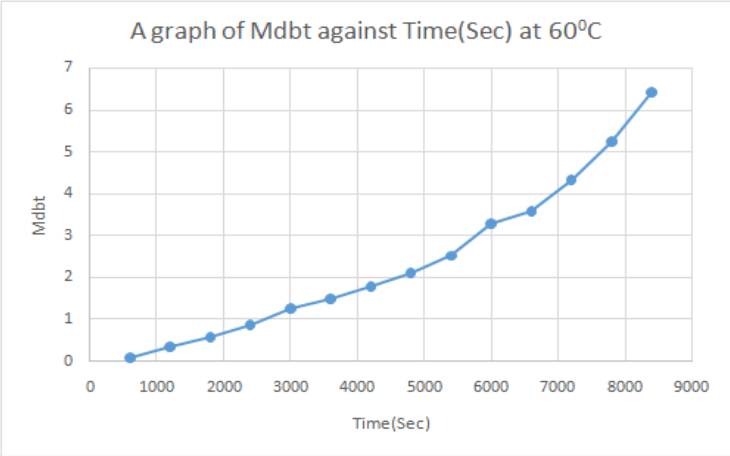


Figure 10: Graph of Instantaneous Moisture Content against time (sec) at temperature of 60^oC

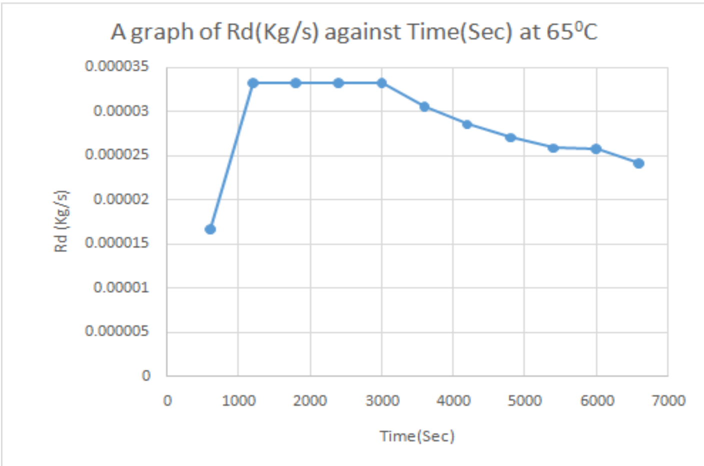
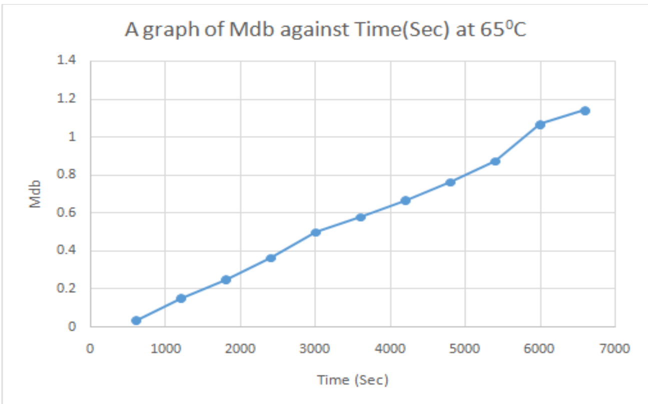


Figure 11: Graph of drying rate (Kg/s) against time (sec) at temperature of 65^oC



F igure 12: Graph of Moisture Content against time (sec) at temperature of 65^oC

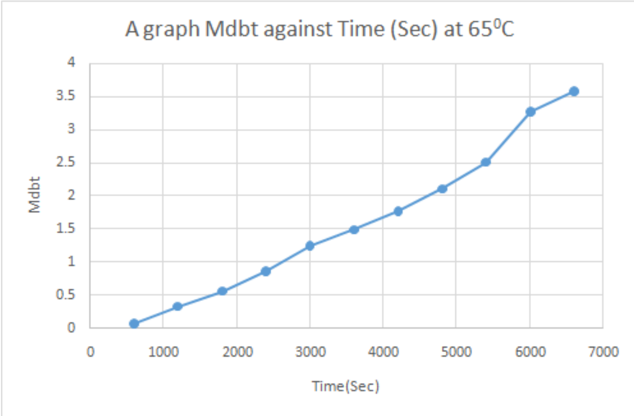


Figure 13: Graph of Instantaneous Moisture Content against time (sec) at temperature of 65^oC

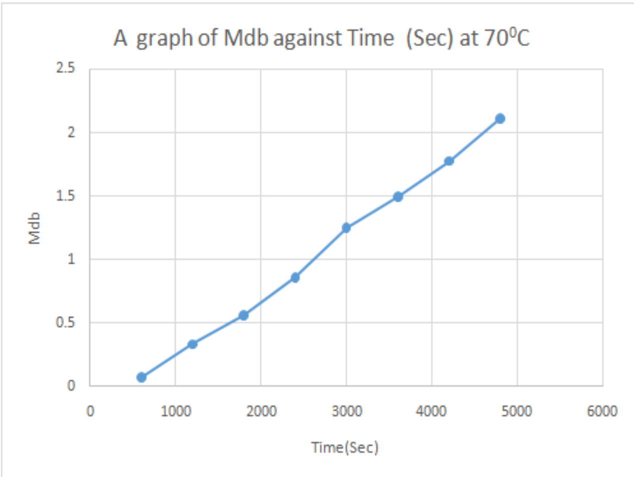


Figure 14: Graph of drying rate (Kg/s) against time (sec) at temperature of 70^oC

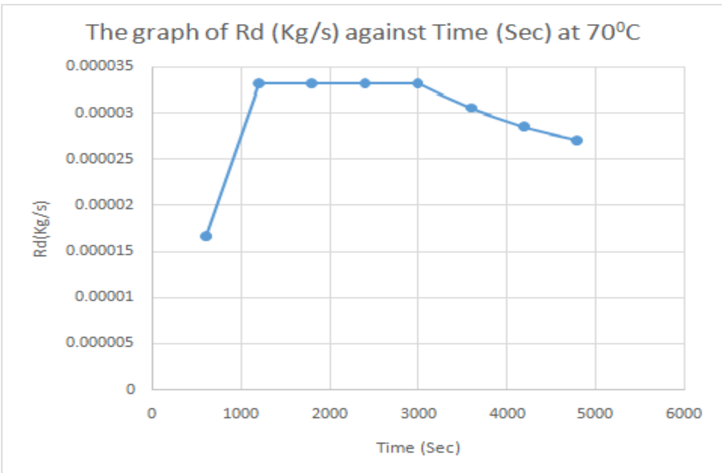


Figure 15: Graph of moisture content against time (sec) at temperature of 70^oC

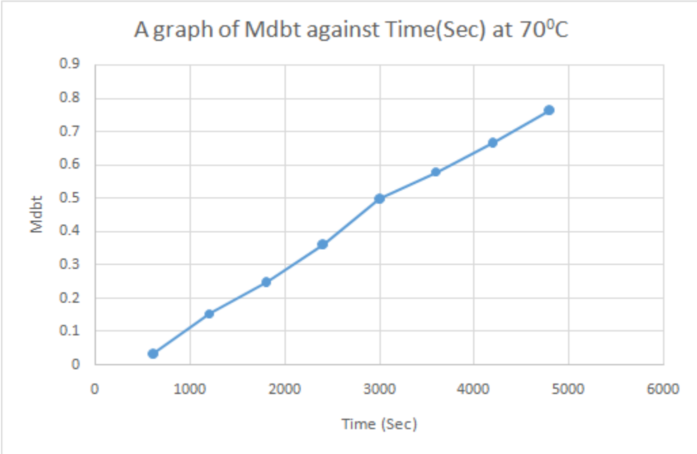


Figure 16: Graph of Instantaneous moisture content against time (sec) at temperature of 70^oC

10. **Efficiency**

The dryer efficiency was evaluated based on the specified drying temperatures in other to compare the results at each temperature and to obtain an optimal drying temperature of Trifoliate Yam among the three selected temperatures. The result of the performance assessment showed that the efficiency of the dryer is a function of temperature. Hence at elevated temperature better values of efficiency can be obtained but this can affect the desirable properties of the products. Figure 6 shows the appearance of some samples of Dioscorea dumetorum before and after drying.

Drying Kinetics

The Dioscorea dumetorum slices was dried at 60^0C, 65^0C and 70^0C in the prototype dryer. The dimension of the slices was maintained at $50mm \times 30mm \times 5mm$. When drying at the temperature of 60^0C, the overall drying time recorded was 140 mins. Whereas for 65^0C and 70^0C, the respective period of drying was 110 mins and 80 mins. It was obviously observed that high drying temperature will increase the average kinetic energy of water molecules, therefore stimulating the degree of water evaporation. Thus, reducing the required drying time. The increase in drying temperature from 60^0C to 70^0C, minimized the overall time required for drying to approximately 43%. Similar observations have been reported by (Chin and Law 2012), (Chin, S. K., Siew, E. S. and Soon 2015) and (E. Doymaz 2014).

Drying Rate

From the experiment conducted, it was observed that an increase in temperature will produce a significant addition in the drying rate of the Dioscorea dumetorum slices because higher thermal potential is attributed to an increased rate of heat transfer, enhancing the permeability of moisture from the interior to the surface of the material. From the graphs of drying rate plotted, drying rate reduced as the moisture content decreases (improving drying time) as the drying progresses. This shows that the rate of drying is dependent on both the moisture content, thermal potential as well as time. Drying rate curve has the following regions; proportional region, constant rate region and the falling rate period for all the drying temperatures. As an indication, internal moisture diffusion was the dominant phenomenon in the drying. Initially, the moisture reduction was faster at the commencement of the drying process and then became slow towards the termination of process. This obvious observation was traceable to the fact that the reduction in the degree of drying was majorly as a result of slow decrease in moisture content as the drying process progresses. Authors whose works support these assertions are (Zhu 2018) and (Pornpraipech et al. 2017).

11. Conclusions

The design and fabrication of an Arduino-Controlled Convective Heat Dryer has been actualized. The performance of the dryer has been examined by drying Dioscorea dumetorum at different temperatures and the results obtained show that the drying time is a function of the dryer's operating temperature. The dryer's efficiency was also computed and results showed that the efficiencies are functions of drying time. It also yielded a better-dried product as compared with the traditional means of drying. The power requirement of the dryer is 800W, hence a portable generator of 900 W can be used to power the system. The fabricated dryer was not location-specific, hence any agricultural product can be dried in it provided the drying temperature is specified, and this implies making relevant modifications to the Arduino code shown in the appendix. This can be varied. The moisture content of yam is usually between $56 - 78\%$, hence high moisture content of 75% was used for the analysis. By implication, an agricultural product of high moisture content can dry in the dryer provided the temperature of drying is within the range of the designed maximum temperature, which is 100^oC.

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