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Full Length Research Paper

Development of Tray Dryer for Pumpkin Seed

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Abstract

Drying constitute an alternative to the consumption of fresh fruits and vegetables, and allow their use during the off-season. It is one of the most widely used methods for food preservation and its objective is to remove water from the food to a level in which microbial spoilage and deterioration reactions are greatly minimized. The objectives of this study are: to develop a tray dryer for drying pumpkin seeds (Cucurbita pepo L); to fabricate the components of the dryer based on design specification and; to test the dryer for performance. The material selection was based on availability, cost, maintenance friendly and energy requirement. The cabinet dryer consist of drying chamber, drying tray, temperature controller, fan controller, heat sensor, heating element, vent and fan. In operation, the drying chamber is where the drying operation is carried out, the fan helps in circulating the hot air throughout the drying chamber, the temperature controller regulate the drying chamber and the moisture extracted from the crop escape through the vent to the surrounding. The system drying efficiency rose from 35% to 53.2% after the modification.

Key words: Development, Fabrication, Drying efficiency, Pumpkin seed, Air velocity.

Introduction

Pumpkin (Cucurbita pepo L) is a squash fruit most commonly orange in colour when ripe, that has been used traditionally both as human and animal feed. In culinary terms, it is widely regarded as a vegetable. It is very appreciated when cooked or pureed, and has numerous culinary uses either as a vegetable or as an ingredient in pies, soups, stews, breads and many other dishes. Pumpkin is a seasonal crop, and since fresh pumpkins are very sensitive to microbial spoilage, even at refrigerated conditions, they must be frozen or dried (Doymaz, 2007). The knowledge of the nutritive value of food, particularly the fruits and vegetables, is necessary in order to encourage the increase in their consumption and use for nutritive and technological applications. Pumpkin is a good source of carotene, water. Soluble vitamin and amino acid .It is relatively low in total solids, usually ranging between 7% and 10% (Arevalo- Pinedo and muor, 2006; Alibas, 2007). This chemical composition, rich in antioxidants and vitamins allows the pumpkin to have an important health protecting effects.

In fact, the range of values of lipoplulic substances as carotenoids present in Pumpkin varieties can contribute significantly to the uptake of provitamin A and especially lutein a carotenoids with special physiological function (Murkovic et al, 2005). The yellow orange colour of the pumpkin flesh arises from this group of substances. Additionally, the good performance of the pumpkin fiber products in relation to water and glucose highlights the possibility of their use as food ingredient (Escalade et al, 2006).

Drying is a mass transfer process consisting of the removal of water or another solvent by evaporation from a solid, semi – solid or liquid. This process is often used as a final production step before selling or packaging products. To be considered dried, the final product must be solid, in the form of a continuous sheets (e.g. paper), long pieces (e.g. wood), particle (e.g cereal grains or corn flakes) or powder (e.g. sand, salt, washing powder, milk powder). A source of heat and an agent to remove the vapour produced by the process are often involved. In bio- products like food, grains and pharmaceuticals like vaccines, the solvent to be removed is almost invariably water (Doymaz, 2007)..

Agricultural products drying methods can be classified into two: *(1) Traditional or natural drying method, which is sun/solar drying and (2) Artificial drying with mechanical means. Mechanical dryers are also classified according to the mode of heat transfer as (1) Conduction drying (2) convection drying and (3) radiation drying (Doymaz, 2007). This study was therefore carried out to develop and test the performance of batch tray dryer.*

Materials and Methods

Description of the Dryer

An existing dryer in the department of Agric Engineering and Water Resource Kwara State Polytechnic was used for the Experiment. The modified dryer consist of the following component parts. Main frame, drying chamber, fan, temperature controller, heat sensor, fan controller, drying tray, and chimney. The main frame gives support to the whole body of the dryer, the drying chamber is where the drying operation is carried out, and the fan helps in circulating the hot air throughout the drying chamber. The temperature controller works regulate the temperature of the drying chamber and also vary the temperature. The drying tray is where the sample to be dried is placed, the fan controllers regulates the speed and also vary the speed, heat sensor determine the heat in the drying chamber. The chimney is where the vapor escapes from the dryer as shown in plate 1 and 2.

Design Consideration

The engineering properties of the pumpkin seeds that are relevant to the development and testing of the dryer were considered. The properties include size and shape of the seed, moisture content, volume, true and bulk density. Other factors considered were equilibrium moisture content of the crop, crop temperature, relative humidity, volume of the air passing through the dryer, depth of the crop through which air moves, feed rate of the crop, drying method and heat losses in dryer by radiation and conduction.

Design Analysis and Calculations

Design for Tray Capacity

The volume of the tray was determined mathematically as:

$$V_T = L \times\times B \times H \ (m^3) \qquad 1$$

where:

V_T = *Total volume of the tray (m^3),*

L = *Length of the tray (m),*

B = *Breadth of the tray (m),*

H = *Height of the tray (m)*

Design for the amount of water to be extracted from the product

The mass of water to be extracted correspond to what has to be taken out of the fresh product

$$M_w = \frac{(m_i - m_f)M_i}{(100 - m_f)} \text{ (in kg of water per kg of fresh product to be dried)} \qquad 2$$

where:

m_i: *Initial moisture content of fresh product (%),*

m_f: *Final moisture content of dried product (%)*

M_w: *Amount of water to be extracted from the product (kg)*

M_i: *quantity of fresh product to be dried after pre-drying processing (kg), this process consisting in removing the skin and other waste parts from the fresh product.*

Design for Energy necessary to evaporate the moisture

According to Jean (1997), which stated that for a given air flow rate the required power to reach the maximum admissible temperature is given by

$$P_n = \rho_{air} \frac{(E_{ex} - E_{en})}{3{,}600} \qquad 3$$

where:

P_n =*Power required for drying (kW),* ρ_{air} = *density of air = 1.2 kg/m³,* $E_{ex} - E_{cn}$ =*energy contained in the air at the exit and entrance to the air heating system (kJ/kg dry air),* F_d = *air flow rate (m^3/h)*

Design for Air flow rate in the Tray Dryer

The average air flow rate in a dryer should be such that it allows the moisture in the product to be evacuated at average velocity is given by:

$$F_d = 1{,}000 . \frac{M_w}{(T_d . q_w)} \qquad 4$$

And

$$q_w = \rho_{air} . (h_a - h_c) . \eta_d \qquad 5$$

where;

F_d = *Air flow rate in the dryer (m^3),*

M_w = *Mass of moisture to be extracted (kg),*

T_d = *Ideal drying time for a given product (hours),*

q_w = *Average amount of moisture extracted by a cubic meter of air (g/m^3),*

ρ_{air} =*Density of dry air: 1.2 kg/ m*^{3}*,*

h_a = *Average absolute humidity of out-coming air over the total drying period, in g per kg of dry air*

h_c = *Absolute humidity of air, on entering the drying chamber (after being heated), in g per kg of dry air,*

η_d = *Drying efficiency.*

Design for Power required for the Dryer fan

The power transmitted by the fan must be the equivalent of the air flow rate times the friction losses. The required electric power of ventilator is equal to this power multiply by the ventilator output coefficient expressed as:

$$P_f = \frac{1}{\eta_{vent}} \cdot \frac{F_d}{3{,}600} \cdot \Delta P_t \qquad 6$$

where:

P_f =*Fan power (W),*

F_d = *Required flow rate (m*^{3}*/h),*

ΔP_t = *Total loss of energy due to friction (Pa),*

η_{vent} = *Ventilator output (given by the manufacturer),*

$3{,}600$ = *Hour to second's conversion coefficient.*

Fabrication Procedure and Assembly of the Dryer

Fig. 2 shows pictorial view of the dyer. The main frame was made from an angle iron of dimension 50 x 50 x 4 mm which was cut to the required dimensions and welded together. The drying chamber was made from mild steel sheet of dimension 800 x 590 x 590mm at the outer part, the wall was doubled with the inner part, made from 1mm thick Galvanized sheet and in between, it was lagged with 450mm thick fiber-glass. The door is made from mild steel sheet at the outer part while the inner part is made from Galvanized steel sheet and lagged in between them with fiber glass. The trays were made from Galvanized steel sheet of 840 x 440mm and drilled based on the physical properties of the crop. The vent was made from mild steel sheet of 590 x 590 x 104mm and cap at top to allow moisture movement to the surrounding. Fabrication process included: marking out, cutting, joining, drilling and fitting. The workshop tools and machines used included: scriber, steel rule, compass, and centre punch, powered guillotine for cutting and welding machine for joining. The specification of the fabrication materials is shown in Table 1.

Instrumentation of the dryer

In this work, two important oven parameters, temperature and air velocity were controlled. This is because different materials required different temperature and air velocity for optimum drying. Since the temperature and velocity are two separate quantities, there is the need for us to adopt two separate methods for the control of these oven parameters. For the purpose of this work, we used K - type, model WRX – 31, thermocouple for sensing the temperature. The thermocouple was connected to a digital temperature controller for controlling the oven temperature. For reliability, sensitivity and robustness, model XMTD – 2301M digital temperature controller was used for this work.

To control the air velocity, 12-volt dc motor was used to drive fan that blows drying air into the drying chamber. The selection of dc motor was favored because of easy of speed control associated with dc motor most especially separately excited type. The airflow rate is directly related to motor speed setting, therefore, the flow rate was calibrated in terms of the settings by taken note of the setting on the pot and read the airflow rate using airflow meter. Because the setting on the pot bears linear relationship with airflow rate, the airflow rate was determine using speed settings. The Calibration graph from where the flow rate could be determined was plotted using the obtained speed setting and measured airflow rate.

The airflow rate regulator and temperature controller are attached to the dryer as shown in plate 1 where the airflow regulator and temperature controller are labeled A and B respectively.

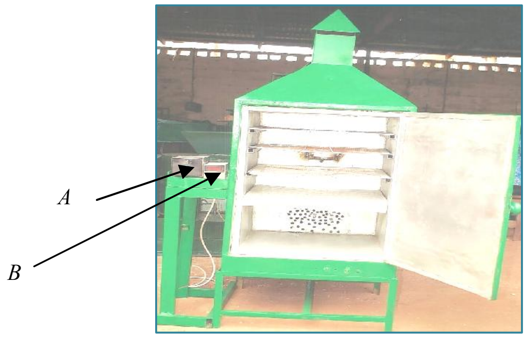

Plate 1: Cabinet dryer

Materials and Methods used for Testing

Pumpkin seeds were obtained from a produce merchant in Ile-Ife, Osun State,Nigeria. The seeds were cleaned, sorted and arranged in the trays. Before drying, the heater of the dryer was switched on and the dryer fan was allowed to run for about 30 minutes to allow the heated air to stabilize at the desired temperature. Three temperature settings, namely: 50 ^{0}C, 60 ^{0}C and 70 ^{0}C were used for the experiment. At the above selected temperatures, the trays containing the pumpkin seeds were loaded in the dryer. The drying process was allowed to continue until no more weight loss is recorded between two successive readings. From the data obtained, drying rate and drying efficiency were calculated according to Onipede and Agbetoye (2013) as:

$$Drying\ efficiency = \frac{heat\ utilized\ for\ moisture\ removal}{Heat\ available\ for\ moisture\ removal} \quad 6$$

$$D_R = \frac{W_w}{T} \quad 7$$

Were, D_R= drying rate (g/min), W_w = weight of water removed (g), T = time taken (min)

Table 1. Materials for Fabrication of the Tray Dryer

Materials	Specifications	Quantity
Angle Iron	50mm x 50mm	1½
Mild Steel Sheet	2mm	1.5
Fan	TA450DC	1
Fuse Plug	13A	1
Temperature Controller	1	1
Fan Controller	1	1
Cable	2.5mm	6yrd
Insulation Tape	Black	1
Fiber glass	5”	1 bag
Welding electrode	Guage 12 mild steel	1 packet

Conclusion

A tray dryer was developed, fabricated and tested for pumpkin seed drying. The dryer was design to dry crops based on the principle of crop, air and dryer parameters. Materials used for fabrication were locally sourced and cheap. Performance tests were carried out to investigate the effect of some selected drying parameters. The dryer was found to be satisfactory in drying pumpkin seeds. The system drying efficiency was calculated to be 53.2%.

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