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Full Length Research Paper

Effect of Drying Parameters on Cabinet Pumpkin Seed Dryer

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Abstract

Selected drying parameters such as Temperature, Time of Drying, Feed rate and Air flow rate were studied using a pumpkin seed cabinet dryer in the department of Agricultural Engineering and Bio -Environmental Engineering, Kwara State Polytechnic, Ilorin, Nigeria. The type of cabinet drying used consist of drying chamber, temperature controller, fan controller, heat sensor, heating element and fan. To investigate the effect of the process parameters manipulated (temperature, feed rate, and air flow rate on drying rate), a 3x3 randomized block design experiment was carried out. Empirical results show that temperature and feed rate significantly affect the drying rate at 5% level. An optimum drying rate of 4.47 g/min was achieved using air flow rate of 0.6m/s, feed rate of 1500 g/min, and temperature of 50°C. When temperature and air flow rate was jointly investigated, the result was also significant at 5% level. This shows that the measured parameters (temperature, feed rate and air flow rate significantly affect the drying rate of pumpkin seeds (Cucursita Pepo L) for the cabinet dryer under study. The new Duncan multiple range tests reveal significant differences between the various levels of the process parameters.

Key words: *Air-flow-rate, Drying, Feed-rate, Temperature, Cabinet dryer*

Introduction

History had shown that food preservation have come a long way; with drying reported to be one of the oldest methods of preservation (Zomorodia et al, 2005). In rural communities and particularly among the poor people, sun-drying has been one common method of food preservation. Moreover, this method is weather dependent and exposes the food item to microbes and other contaminant (Kinsley et al. 2007). These food substances after such crude processing, are sold to unsuspecting consumers. Based on this, there is the need to look into ways of improving food product drying with such technology that will be cheap, simple, available and easily applicable to the poor and probably the uneducated. In addition, it is well known that drying have effects on the physical and chemical standards of the dried product as a result of the transformations that takes places. Hence, careful design is required to cater for the heat and mass transfers occurring during the process (Mujumbar and Zhongua, 2007).

In Nigeria, just like several other developing nations, agriculture is considered a factor for growth and development. The country is blessed with a landmass of 98.3 million hectares of which 72% is considered suitable for agricultural production (Makanjuola et al, 1991). However, the rate of growth in food production is very low, amounting to 2.5% per annum. This poor growth has been attributed to the level of agricultural preservation in the country (Odigboh, 1991). Her poor record of food preservation has led to improper management of agricultural produce and thus impinged on the growth of food production (Karim, 2010). Moreover, effort has been made towards achieving sustainable growth in a number of ways. These ways are however limited to some set of food stuffs which include: rice, beans, pumpkin, millet, soybeans; fruits and beverages all of which posses' moisture (Aasa et al, 2012).

Drying constitutes an alternative to the consumption of fresh fruits and vegetables, and allows 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. Moreover besides providing longer shelf-life, it also originates smaller space needs for storage and higher weight for transportation. The drying of agricultural products can be undertaken in closed equipment (solar or mechanical dryers) to guarantee the quality of the final product (Doymaz, 2007). From the engineering point of view, drying is a complex thermal process which involves simultaneous coupled unsteady heat and mass transfer phenomena occurring inside and at the border of the product being dried. Doymaz (2007) studied the kinetics of forced convective air drying of pumpkin slices. Results indicated that drying took place in the falling rate period moisture transfer from pumpkin slice was described by applying the fick's diffusion model. The effective diffusivity values changed from $3.88x10^{-10}$ to $9.38 \times 10^{-10} m^2/_s$ within the given temperature range. An Arrhenius relation with an activation energy value of 78.39kj/mol expressed the effect of temperature on the diffusivity. The experimental moisture loss data were fitted to selected semi-theoretical and empirical thin layer drying models.

Therefore, the objective of this study is to investigate the effects of some selected drying parameters pumpkin seeds using Cabinet dryer.

Drying Theory

The drying theory consists of a constant and falling rate periods. In between the two periods lies the critical moisture content, where a sharp discontinuity in drying rate is observed. Most agricultural materials do not exhibit constant rate period because it is very short and insignificant for research studies (Geankopolis, 2003). Drying of agricultural materials is mostly in the falling rate period. This is controlled by moisture migration from the interior to outer surface of the material due to water vapor diffusion and is governed by moisture gradient (Ertekin and Yildiz, 2004). Mathematical equations have been formulated on theories of moisture migration and diffusion through capillaries of agricultural products Lewis formulated a diffusion model equation analogous to Newton law of cooling as (Sahay and Singh, 2005).

$$\frac{dm}{dt} = -K\,(m = mo) \qquad (1)$$

where;

M = Instantaneous moisture content (g water /100g solid), Mo = Initial moisture content (g water /100g solid), t = Drying time (minute), k = Drying constant (1/minute)

Integrating equation (1)

$$\frac{m - me}{mo - me} = MR = \exp(-kt) \qquad (2)$$

where

me = equilibrium moisture content, MR = moisture ratio

Another model equation that has been used by numerous researchers is the page's equation

$$MR = \exp(-kt^n) \qquad (3)$$

Equation (2) and (3) have been reported to lack accuracy in describing and predicting the drying rate throughout the drying periods of agricultural materials, they neglected the initial resistance to moisture movement within the drying particles, which negates the fact that moisture during of agricultural products is by diffusion of liquid, vapor or both (Satimenhin and Alabi, 2005). For distribution of moisture within the material, Fick's second Law was used to describe the moisture diffusion during drying of spherically shaped objects as follows (Sahay and Singh, 2005).

$$\frac{m = me}{mo = me} = MR = \frac{6}{\lambda 2}\left[\sum \frac{1}{\pi_2} \exp\left(\frac{n^2\pi^2}{6} \quad \frac{Defft}{R_2}\right)\right. \qquad (4)$$

Moisture ratio (MR) can further be simplified as (Domaz, 2004)

$$MR = \frac{m}{mo} \qquad (5)$$

Taking n = 1 (Gean Kopolis, 2003), equation (4) becomes

$$MR = \frac{6}{\pi_2} \exp\left(\frac{-\pi^2}{6} \quad \frac{Defft}{R^2}\right) \qquad (6)$$

Simplifying equation (6) further

$$\frac{m}{mo} = Ae = kt \qquad (7)$$

Linearizing equation (8), we have

$$In\left(\frac{m}{mo}\right) = In\ A = kt \qquad (8)$$

Where

$$A^2 \frac{6}{\pi^2} \qquad K = \frac{\lambda^2 Deff}{6R^2} \qquad (9)$$

Supposing drying is taken place from top and bottom parallel faces of the material, then the thickness of the sphere to be dried from one face is assumed to be half of the total thickness, hence;

$$\mathbf{R} = \frac{R\ total}{2} \qquad (10)$$

Where;
R total = total thickness of the sphere

$$K = \frac{2\lambda^2 \ Deff}{3R^2} \qquad (11)$$

Materials and methods

Sourcing of test materials

The test materials/ crops for this research work were pumpkin (Cucursita Pepo L). Fresh pumpkins were obtained from a produce merchant in Ile-Ife in Osun State of Nigeria.

Sample Preparation

The pumpkin seeds that were used for the experiment were cleaned and sorted so that neat and good seeds would be use for the experiment. Air velocities selected were achieved by setting the regulator of the fan on the value selected based on the literature review consulted. Feed rate of the experiment were achieved by weighing the samples selected on a digital weighing machine, while the temperature of drying were obtained by setting the temperature monitoring and control system on the temperature selected.

Experiment Design

The factors considered in the study were:-

- Air flow rate (3 levels), i.e. $0.6m^3/s$, $0.8m^3/s$, $1.0m^3/s$
- Drying temperature (3 levels), i.e. 50^0 C, 60^0 C, and 70^0 C
- Feed rate (3 levels). i.e. 500g/min , 1000g/min and 1500g/min

The 3 x 3 x 3 treatment combination equal to 27 runs, and each treatment was replicated three (3) times. The experiment was arranged in a complete randomized block design.

Experimental Procedure

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 pumpkin seeds were arranged in the trays of the dryer at the selected feed rate. The drying process was allowed to continue until no more weight loss is recorded between two successive readings.

Instrumentation for determination of oven parameters

The parameters being regulated and controlled in this research work using the developed instrumentation system are oven temperature and air velocity. K -type, model WRX – 31, thermocouple was used 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 regulate the air velocity, 12-volt dc motor was used to drive the fan that blows drying air into the drying chamber. The selection of dc motor was favoured because of easy of speed control associated with dc motor most especially separately excited type. The air flow 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 the calibration curve on which the dc motor speed settings were plotted against airflow. Attached to the drying cabinet are the airflow regulator and temperature controller labeled A and B respectively as shown in Plate 1.

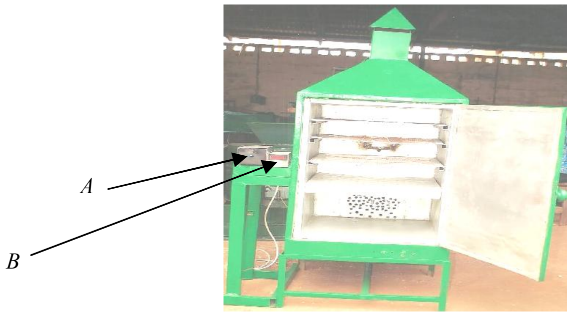

Plate 1: The Pumpkin Seed Cabinet Dryer Used

Output Parameters

The output parameters measured was based on drying rate and the system drying efficiency.
Drying rate: Drying rate can be mathematically expressed as:

$$DR = \frac{Ww}{T}$$

Where DR =Drying Rate (g/min), WW = weight of Water removed (g), T = Time taken (min) (Onipede, 2013).

Results and Discussions

This section presents the result of the statistical analysis on effect of Feed rate and Temperature on the Drying Rate of pumpkin seed of these process parameters were investigated using SPSS version 16.0 computer software. The raw data obtained from the Cabinet dryer was subjected to statistical analysis and the result is presented in table 1.

Table 1: Average drying rate at Various Treatment Combinations

Feed rate (g)	Temperature(°C)	Time(min)	Airflow rate(m^3/s)	Average Drying rate (g/min)
500	50	90	0.6	3.0
500	60	60	0.8	2.3
500	70	75	1.0	2.5
1000	50	90	0.6	3.1
1000	60	105	0.8	2.2
1000	70	120	1.0	2.0
1500	50	135	0.6	3.2
1500	60	150	0.8	2.6
1500	70	165	1.0	2.4

Effect of Temperature and Feed Rate on Drying Rate

Table 2 shows the effect of temperature and feed rate on drying rate. The table shows that both feed rate and temperature significantly affect the drying rate at five 5% level. This implies that at least one level of treatment means differs significantly from the other. The interaction between feed rate and temperature was not significant at 5% level.

Table 2: Effect of Feed Rate and Temperature on Drying Rate

Source	Sum of Squares	Df	Mean Square	F	Sig.
Feed Rate	87.065	2	43.532	46.240	0.001
Temp	15.948	2	7.974	8.470	0.001
Feed Rate x Temp.	3.325	4	0.831	0.883	0.475
Error	169.461	180	0.941		
Total	275.799	188			

**significant at 1% ($p \leq 0.01$)*

The Duncan multiple range test on Table 3 shows where the significance differences lies. Inferences from Table 3 shows that the mean of drying rate was statistically different at each of the three levels of feed rate studied. Drying rate observed at 500g/min was statistically lower than the drying rate observed at 1000g/min. The highest and most significant drying rate of 4.47 was recorded at 1500g/min while the lowest drying rate of 2.67 was at 500 g/min.
Drying rate at temperature of 50ºC was statistically higher than the drying rate at temperature of 60ºC. The highest drying rate was recorded at 50ºC and this was significantly different from the drying rate recorded at 60ºC and 70ºC respectively.

Table 3: Multiple Comparison of the Treatment Effect

Feed Rate (g)	Drying rate (g/min)
500	2.67a
1000	3.38b
1500	4.47c
Temperature (°C)	Drying rate (g/min)
50	4.23a
60	3.66b
70	3.50b

Means with different alphabets are significantly different from each other

Figures 4 and 5 show the graphical relationship of the effect of feed rate and temperature on drying rate respectively. Figure 1 shows a progressive increase in drying rate of pumpkin seed as the feed rate increases from 500g/min through 1500g/min. This suggests proportionate relationship. Drying rate was seen to decrease progressively with increase in temperature as depicted by Figure 2.

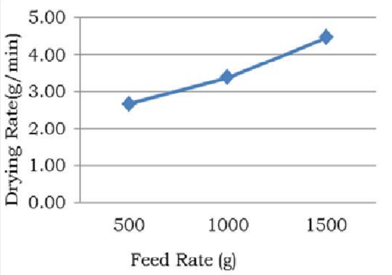

Figure 1: Effect of Feed Rate on Drying Rate

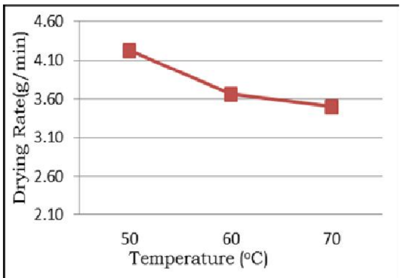

Figure 2: Effect of Temperature on Drying Rate

Effect of Feed Rate and Air Flow Rate on Drying Rate

The treatment effect of air flow rate and feed rate on drying rate is as presented on Table 4. Table 4 shows that both air flow rate and feed rate had significant effect on drying rate at 5% level of significant. This implies that both air flow rate and feed rate independently influenced drying rate. The interaction between air flow rate and feed rate had no significant effect on the drying rate. It can therefore be concluded from the foregoing that at least one treatment effect is significantly different from the others.

Table 4: Effect of Feed Rate and Air Flow Rate on Drying Rate

Source	Sum of Squares	Df	Mean Square	F	Sig.
Feed Rate	87.065	2	43.532	46.240	0.001
Air Flow Rate	15.948	2	7.974	8.470	0.001
Feed Rate x Air Flow Rate	3.325	4	0.831	0.883	0.475
Error	169.461	180	0.941		
Total	275.799	188			

**significant at 1% (p≤0.01)*

The New Duncan Multiple Range Test (DMRT) on Table 5 shows the comparisons between the different levels of the process condition (drying rate and air flow rate). In comparing the means of drying rate at the three levels of feed rate considered in the study, it was observed that the highest mean drying rate of 4.47 was obtained at 1500g, while the lowest mean drying rate 2.67g/min was at 500g. Each level of feed rate recorded significantly different drying rate.

The drying rates vary with various levels of air flow rates. Drying rate of 3.50 was record at air flow rate of $1.0m^3/s$ and was statistically different from drying rate recorded at $0.8m^3/s$ and $0.6m^3/s$ at 5% level of significant respectively. The highest drying rate of 4.23 g/min was observed at 0.6m3/s while the lowest was at $1.0m^3/s$. Figure 3 shows that drying rate generally decreases along the scale as the air flow rate increases.

Table 5: Multiple Comparison of the Treatment Effect

Feed Rate(g)	Drying Rate(g/min)
500	2.67a
1000	3.38b
1500	4.47c
Air Flow Rate (m/s)	Drying Rate(g/min)
1.0	3.50a
0.8	3.66b
0.6	4.23c

Means with different alphabets are significantly different from each other

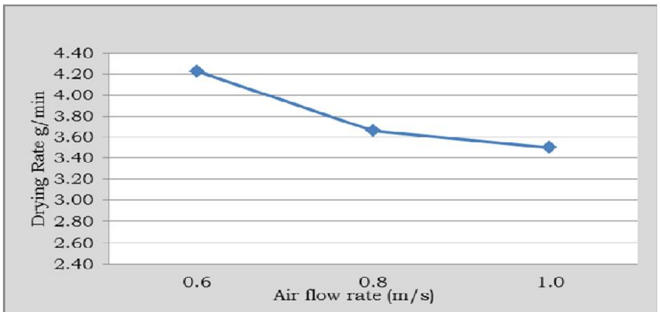

Figure 3: Effect of Air Flow Rate on Drying Rate

Conclusions

The results obtained from the performance evaluation carried out on the cabinet Dryer shows that:

- Temperature significantly affects the drying rate at 5% level. This implies that at least one level of treatment differs significantly from the other
- The highest drying rate was recorded at 5^{o}C and this was significantly different from the drying rate recorded at 60^{o}C and 70^{o}C respectively
- Both airflow rate and federate has significant effect on drying rate at 5% level of significant. This implies that both feed rate and airflow rate independently influenced drying rate.

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