DESIGN AND CALIBRATION OF A DRYING SYSTEM FOR OKRA

Conference Paper

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Abstract

Because of the wide acceptability of okra fruits as vegetable and when okra seed is roasted and ground could be used to form a non-caffeinated substitute for coffee, the development and calibration of an affordable dryer used in drying okra was done as part of effort to eradicate post-harvest losses usually experienced in developing countries due to the heat of respiration that causes temperature to rise quickly and thus result to rapid deterioration. The developed dryer is a rectangular structure having a holding capacity of 2.4m^3. The calibration was done by carrying out two different tests, the air distribution test and temperature distribution test. In the air distribution test, the velocity of the blower was measured to be 3.6m/s using a device known as anemometer. Temperature distribution test was carried out to know the distribution of temperature on each of the tray at different preset temperatures. This test was carried out for 2 hours for each preset temperatures and readings were taking at intervals of 20minutes. The maximum and minimum values of temperature obtained during the test period with preset temperature of 45^{0}C-70^{0}C are 34^{0}C and 75^{0}C respectively. More so, the square of the regression coefficients r^2, relating the temperature on trays to the preset one indicates a statistical correlation between the temperatures as the values obtained are positive. The maximum and minimum temperatures recorded for the ambient temperature are 36^{0}C and 27^{0}C respectively.

Keywords: Okra, Drying, calibration

INTRODUCTION

Okra (Abelmoschus esculentus) is a flowering plant valued for its edible green fruits. The species are annual or perennial, growing to 2.5m tall. The leaves are 10-20cm long and broad, palmate lobed with 5-7 lobes. The flowers are 4-8cm in diameter up to 20cm long, containing numerous seeds. (http://en.wikipedia.org/wiki/okra 2007). In Nigeria, Okra comsumption and production area ranks third, following tomato and pepper. (Ibeawuchi, 2007; Olubanjo, 2014). Okra serves as an important nutritious vegetable crop in Nigeria, cultivated in an estimated land area of about 1-2 million hectares (FMAWR & RD, 1989).

Abelmoschus esculentus is among the most heat and drought tolerant vegetable species in the world. In cultivation, the seeds are soaked overnight prior to planting to a depth of 1-2cm, germination occurs between six days (soaked seeds) and three weeks. The seed pod rapidly becomes fibrous and woody and must be harvested with a week of the fruit being pollinated to be edible. (http://en.wikipedia.org/wiki/okra, 2007)

In Nigeria, Iran, Egypt, Lebanon, Israel, Jordan, Ira, Greece, Turkey and other part of the eastern Mediterranean, okra is widely used in a thick stew made with vegetables. The immature pods are consumed as boiled vegetable and as soup thickener (Yadev & Chedda, 1983; Olubanjo, 2014). More so, Okra seeds may be roasted and ground to form a non-caffeinated substitute for coffee. Okra oil is pressed deed oil, extracted from the seeds of the okra. The high rate of deterioration and of respiration dictates rapid cooling of harvested okra, unless okra is cooled to below 15 degrees centigrade soon after being packed, the heat of respiration will cause the temperature in the package to rise quickly and result in rapid deterioration. Under ideal conditions, Okra can be held in air about 1 week without objectionable deterioration, or 10 days if lower quality is satisfactory (Anonymous, 2007).

In designing a drying system for okra, it is good to take into consideration some environmental factors which can affect both the physical and nutritional values of the product, two major factors which should be looked into are temperature and relative humidity of the system because when okra is stored under a high temperature, toughening, yellowing and decay are rapid and when stored under a low temperature say 5 degree centigrade, pitting could occur. Therefore, the main objectives of this study were to develop a drying system for okra and also calibrate the drying system.

MATERIALS AND METHODS

Description of the dryer: The dryer is a cubical structure with and external dimension of 1230 x 610 x 610mm. The drying chamber is cubical in structure having six sides with internal dimension of 1080 x 650 x 650mm and a hold up capacity of $340mm^2$. On the roof of the chamber is a chimney which helps prevent condensation within the chamber. On either side of the chamber are heaters partially covered with a metal sheet called heater bonnet to prevent products closer to the heater from getting burnt, the dimension of the bonnet is 510 x $210mm^2$. At the base of the chamber is a blower which aids the circulation of heated air within the chamber. There are five trays contained in the chamber and each tray is perforated at the bottom with a hole of $20mm^2$. A stainless wire mesh with a finer micron was used to reduce the tray perforation. The maximum dry area for the five trays of 540 x 540mm spaced at 1418mm is $291600mm^2$. In this design, effective utilization of energy is necessary to minimize energy loss, mineral cuttings was used to insulate the cabinet walls having a thickness of 20mm.

Material used for the dryer: A galvanize metal sheet was used for the construction of the external part of the dryer and was where t_1, t_2 and t_3 are dry bulb temperature of ambient air, dry bulb temperature of heated air and dry bulb temperature of exit air in degree centigrade.

- **Co-efficient of performance:**

$$\frac{t_3 - t_1}{t_2 - t_1} \qquad \text{………………(2)}$$

painted to prevent rust why stainless steel was used for the interior part. All trays were made of stainless steel. Electric heater used was made of metallic coil so as to produce the required heat needed within the chamber. An axial fan was selected for the design because it produces the required velocity of air needed.

Design Consideration:

1. To reduce the heat loss, it was considered to lead the chamber wall, therefore a walled chamber was considered appropriate

2. For easy flow of heated air into the product, the trays must have provision for opening for the air, therefore perforated tray was used.

3. For uniformity in drying, an automated electrically controlled temperature regulator and a manually controlled fan were used.

Performance Evaluation

- **Heat utilization factor**

$$\frac{\text{Drop in dry bulb temperature of drying air } (^0c)}{\text{Increase in dry bulb temp. of ambient air}} \%$$

$$\frac{t_2 - t_3}{t_2 - t_1} \qquad \text{………………(1)}$$

- **Effective heat efficiency:**

$$\frac{t_2 - t_3}{t_2 - t_{w2}} \qquad \text{………………(3)}$$

t_{w2} = web bulb temp.of the drying air, ^0c.

- **Volumetric flow rate of air delivered by fan:**
  $Q_v = V_l \times A_d$ ………………(4)

Where $Q_{v,}$ A_d and V_l are volumetric flow rate (m^3/s), Measured outlet area (m^2) and Linear velocity (m/s) respectively.

$$V_l = \frac{\pi DN}{60} \quad \text{………………..(5)}$$

Where D and N are the measured diameter of fan (m) and No of revolution of fan (rpm) respectively.

- **Energy supplied to the drying chamber:**

$$q = \frac{Q_v(h2 - h1)}{V} \quad \text{…………………(6)}$$

Where q, Q_V, V and Δh are Energy required (kg/s), Volume of air delivered (m^3/s), Specific volume of air (m^3/kg) and Change in enthalpy kj/kg respectively.

Two major tests namely Air distribution test and Temperature distribution test were carried out in order to know the evenness of air and temperature within the drying chamber. A digital Anemometer was used for the air distribution test why thermometers was placed through a bored hole on the dryer above each of the tray were read at intervals of 20minutes for 2hours for different preset temperature. The ambient temperatures were also observed at intervals of 20minutes so as to relate it with the variation in the drying chamber. The speed of the fan was kept constant throughout the experiment to ensure even distribution of temperature in the drying chamber.

RESULT AND CONCLUSION

Temperature distribution test was conducted in other to calibrate the dryer. This test was performed at different preset temperatures, starting from 40^0C to 70^0C the aim of which is to know if the actual preset temperature correlates with the temperature inside the drying chamber or to what degree the preset temperature varies to the temperature within the chamber.

Presented below are graphical representations of data obtained from the temperature distribution test for different preset temperatures within the drying chamber of the dryer

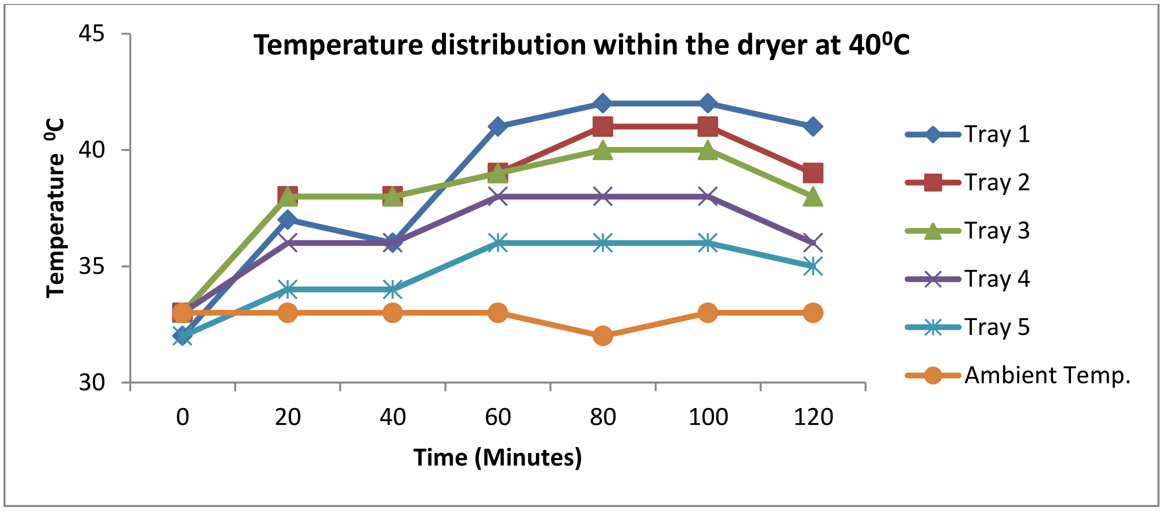

Fig. 1: Temperature distribution within the dryer at 40^{0}C

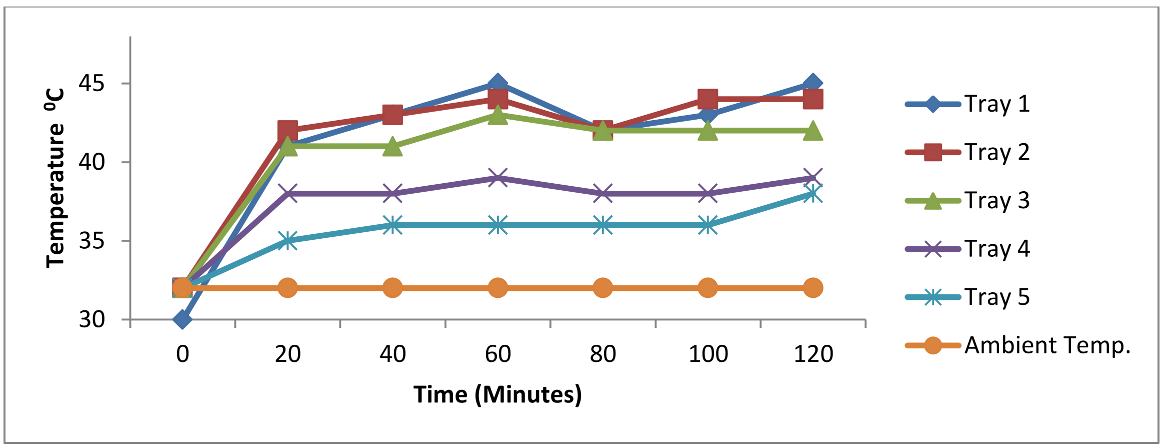

Fig. 2: Temperature distribution within the dryer at 45^{0}C

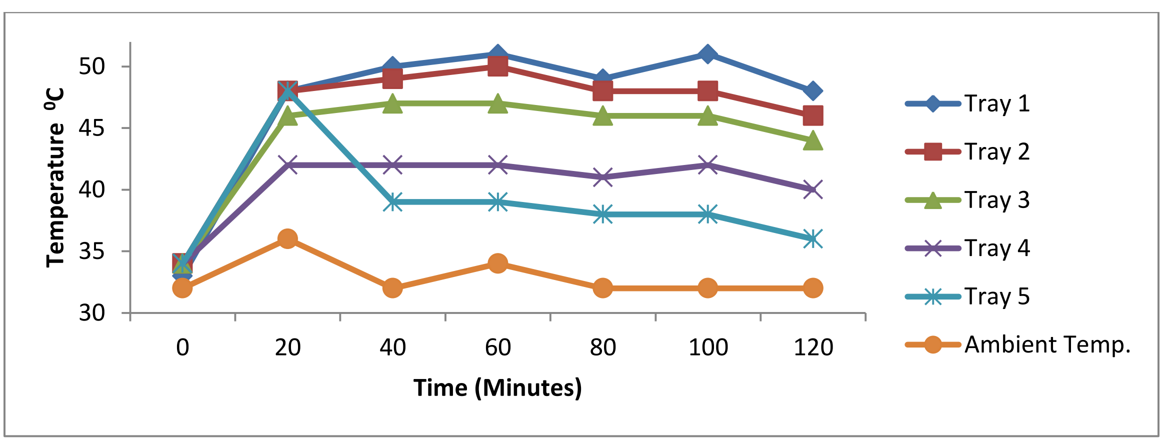

Fig. 3: Temperature distribution within the dryer at 50^{0}C

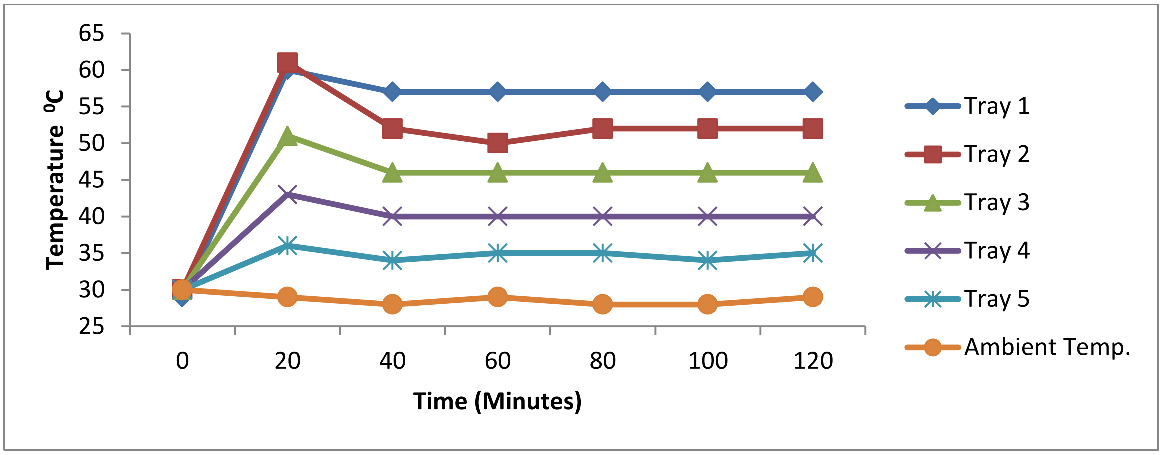

Fig. 4: Temperature distribution within the dryer at 55^{0}C

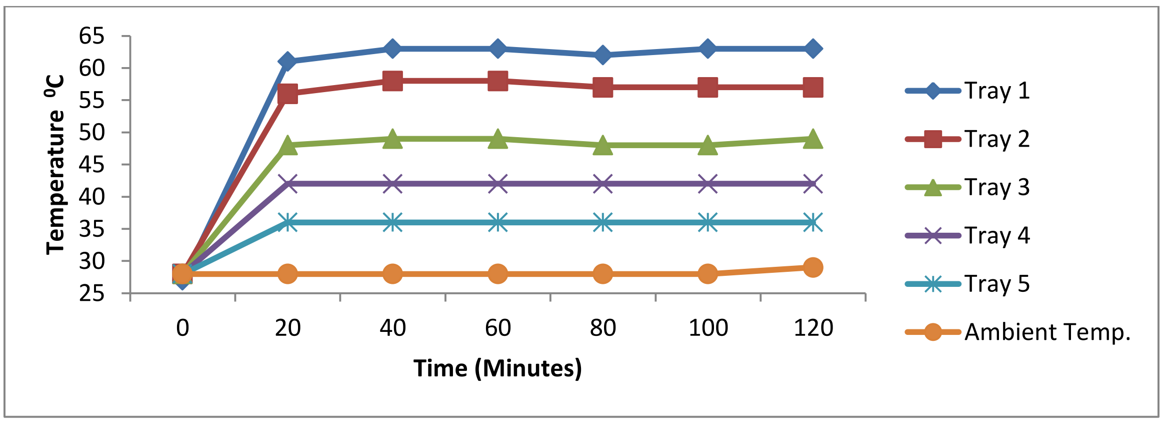

Fig. 5: Temperature distribution within the dryer at 60^{0}C

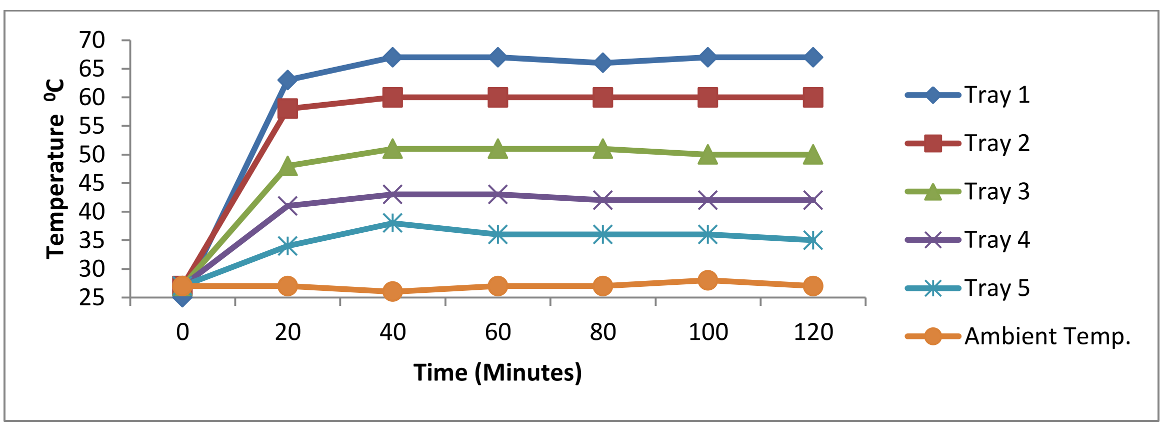

Fig. 6: Temperature distribution within the dryer at 65^{0}C

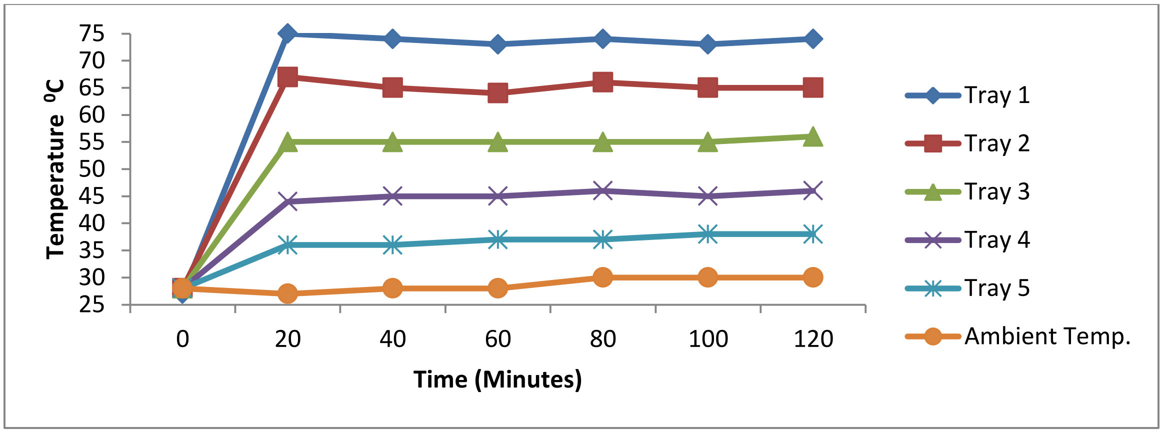

Fig. 7: Temperature distribution within the dryer at 70^{0}C

The following equations were used to get the regression equation that relates the dependent variable (Temperature, Y) with the independent variable (Time, X). By this, temperature profile on each of the tray must be examined against time.

$n\sum x^2 - (\sum x)^2$ ………………..(7)

$$a' = \frac{n\sum XY - \sum X\sum Y}{n\sum Y^2 - (\sum Y)^2} \quad \text{…………….(8)}$$

$a = \underline{n\sum XY - \sum X\sum Y}$

$b = \bar{Y} + a\ddot{X}$ ……………..(9)

$y = ax + b$ ………..….(10)

$r = \sqrt{aa'}$ …………...(11)

where $\bar{Y}$ and $\ddot{X}$ are mean value of dependent and independent variables. n, a, b, r and y are number of elements, slop, interception, regression coefficient and regression equation respectively.

Presented below are regression coefficients for preset temperature 40 -70 ^{O}C

Temp. ^{O}C	Tray1 Regress. Coefficient(r)	Tray 2 Regress. Coefficient(r)	Tray 3 Regress. Coefficient(r)	Tray4 Regress. Coefficient(r)	Tray 5 Regress. Coefficient(r))
40	0.87	0.76	0.83	0.20	0.76
45	0.71	0.49	0.67	0.66	0.85
50	0.61	0.49	0.48	0.45	0.21
55	0.56	0.39	0.44	0.45	0.47
60	0.56	0.39	0.44	0.45	0.47
65	0.66	0.64	0.64	0.61	0.56
70	0.66	0.64	0.64	0.61	0.56

Since the values of the regression coefficient (r) on all the trays at different preset temperature are positive, it implies that the variable x and y are positively or statistically correlated and can be used to predict what the next value of y will be.

CONCLUSIONS

The following conclusions were made:

1. The high temperature figures recorded on the first and second trays compare to the third, fourth and fifth tray is due to the position of the blower and heater which are placed at the bottom and sides of the dryer respectively. As heat is been produced at the middle of the drying chamber, the blower blows the heated air up where the first and second trays are located which account for the high temperature on these trays.
2. The regression equations obtained for each of the trays help to predict what temperature profile will look like at any time on the trays. It can also be used to predict the time it will take to dry a product.
3. The effect of ambient temperature on the obtained temperature is insignificant and can be neglected.

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