Drying characteristics of *Abelmoschus esculentus* thin piece on drying in a fabricated tunnel dryer

Abstract: For the storage of crops, various drying processes are used. It should be synthesized on the basis of drying time, product quality such as colour texture and the taste of the product when uses. To study the drying characteristics of *Abelmoschus esculentus* (bhindi) thin piece was performed for a temperature range of 38℃ and 88 ℃ and velocity of air is fixed at 1.1 m/s in the fabricated tunnel. For the investigation of drying, characteristics experiment was performed, the result was found, the drying rate was falling. The sample studied at 38℃ was much good in colour texture and aroma than sample studied at 58℃ to 88℃. The experimental data were used on different models proposed, by equating the determination coefficient r^2, Mean Bias Error (MBE), decreased χ^2 and Root Mean Square Error (RMSE) measured along with investigated moisture ratio.

Keywords: Drying of crops, quality of the product, colour, velocity of air and fabricated tunnel dryer.

Notation:

x_o= initial mass of thin piece bhindi (gram)
x_t = moisture evaporated mass at time t(gram)
x_d = dry mass of thin piece bhindi (gram)
m_0 = humidity at initial stage (kg / kg water)
m_e = humidity at equilibrium (kg / kg dry matter)
m_t = At t time, moisture content (kg / kg dry matter)
m_{t+dt} = at $t + dt$ time, humidity (kg / kg dry matter)
t = drying time in minute.
MR = moisture ratio dimension less
MR_{exp} = expected moisture ratio in i_{th} experimental observation
MR_{pre} = predicted moisture ratio in i_{th} experimental observation
n = number of observations
z = number of drying constants

1. Introduction:

In the whole world, the largest producer of bhindi is in India, about 3500000 metric ton per year. For the preservation of crops in various methods, the drying process is most important. In recent year the major objective is the reduction, in volume, in weight and minimizing packaging, transportation cost, storage cost and increase the storage period of the product (Sharma, 2014, 2016).

The main objective of the drying process is to extend the life of the product in preservation (Hossain, 2006). During the production of bhindi, formers sell the product below the cost price because at that time large production of bhindi. In those days farmers do not get appropriate output from their cultivation.

Though the price of dried bhindi is high in all season. So this increases the interest in dried of bhindi for a whole year, for market and abroad (Hossain, 2003). In recent hot air drier or indoor dryer mostly used because this is suitable for all season. Presently vegetables' and fruits are wasted about 20% to 26% of the production, from production point to consumers. Considering the suitable method of preservation and processing this can be reduced and also increase the life for storage so that it can be available in off season (Wankhade, 2012). Bhindi crops going up to 6.5 feet in a tropical country it can grow. The Indian Council of Agricultural Research (ICAR) data for Sep - 2013, the production of bhindi in India and abroad is about 8033 million tones. It also grown in west Bengal, Saudi Arabia, Benin, Mexico, Camroon and Egypt. Bhindi can consume as pickled, vegetable or as eaten raw may also use malnutrition and alleviate food (Sobukola, 2009). Crops Drying varies on diffusion of mass and diffusion of heat which happens in unsteady process simultaneously (Sahin, 2005).

For the design of the model, vital knowledge of temperature and distribution of moisture, control of quality, choice of suitable handling and preservation are essential. Models for drying mechanism of crops which provide the required moisture information and temperature (Parry, 1985). In the already proposed mathematical model for the drying process, widely used drying models are thin layer drying (Ozdemire and Devres, 1999). Recently for the tunnel, for drying of various agricultural products, in lab mechanical convection models have been studied by Pangavhane and Sawhney (2002). Here, we are adopting forced convection tunnel dryer for present, to plot the drying behaviour of bhindi thin piece for drying of bhindi.

2. Material and methods:

2.1 Materials:

The fresh sample of bhindi used in this study were collected from the department of agriculture plant protection, (Sam Higgins Bottom University of Agriculture and Technology, Naini Allahabad, India). This was done in March-April 2017 The bhindi samples used, was nearly 50-85mm long and in diameter 10-20mm approximately, with colour texture dark green These samples were first washed and cut in 4 mm thin piece with the help of steel knife, finally stored in the refrigerator at 10℃ until the drying experiments.

2.2 Method:

For the drying of the bhindi and to obtain the effect of velocity and temperature of hot air, the fabricated setup is redesigned. The thin pieced bhindi was weighted 110 gram for each sample. The distribution of the sample 110 gram in single layer uniformly in the tray for the drying in the tunnel. The experiment was observed at hot air temperature of 38℃, 58℃ and 88℃ and at velocity of air 1.1 m/sec. the record of loss in weight and variation in the colour texture of thin piece was taken in each sample in 10 minutes alternatively. The colour texture was also tested of dried thin piece bhindi by breaking it. The hot air velocity is fixed measured by an anemometer. The temperature and relative humidity were recorded by digital thermometer and digital hygrometer throughout the drying period.

The hot air velocity 1.1 m/sec was constant. In every sample, 110 gram thin piece bhindi was taken. The observations were recorded for moisture losses, in 10 minutes interval, in the first hour and in 20 minutes interval thereafter for drying of drying characteristics.

During the experiments, the observation of moisture loss was recorded by digital electronic weighing machine in each interval. The accuracy of weighing machine was ±0.01 gram. The observations were recorded by performing repeated experiment to achieve accuracy in the result, finally, that means values were used. The drying process on the experiment was continued till the moisture reached to the desired level (14.75 -15.25 %, w. b.).

2.3 Mathematical modelling:

The calculation of moisture content for thin pieced bhindi was determined as follows:

$$M_t = \frac{(x_0 - x_t) - x_d}{x_d} \qquad \text{(i)}$$

The moisture ratio (MR), during drying process was calculated as follows,

$$MR = \frac{m_t - m_e}{m_o - m_e} \qquad \text{(ii)}$$

The drying rate model (dr) of thin piece bhindi was analyzed as fallows (Yuenan Zhou, 2016). Using equation (ii) and (iii) humidity ratio and drying rate was calculated from experimental observations.

Drying rate

$$dr = \frac{m_{t+dt} - m_t}{dt} \qquad \text{(iii)}$$

The non-linear regression optimization was performed using the computer software package. For the best model coefficient of determination r^2 was one main criteria for the data analysis also used mean bias error (mbe) , root mean squire eror (rmse) and χ^2 (reduced chi-square) used. For the goodness of curve fitting of the mathematical modeling the values are calculated as follows: (Demire, Gunhan, 2004)

$$\chi^2 = \frac{\sum_{i=1}^{i=n}\left(MR_{exp} - MR_{pre}\right)^2}{n - z} \qquad \text{(iv)}$$

$$mbe = \frac{1}{n}\sum_{i=1}^{i=n}\left(MR_{exp} - MR_{pre}\right) \qquad \text{(v)}$$

And root mean squire error was calculated as follows:

$$rmse = \left\{\frac{1}{n}\sum_{i=1}^{i=n}\left(MR_{exp} - MR_{pre}\right)\right\}^{1/2} \qquad \text{(vi)}$$

For the quality fitness the value of r^2 should be higher and the value of mbe, rmse and χ^2 should be lower (R. K. Goyal 2006, D.R. Pangvhane 2002, Togrul and Pehlivan 2003). For the flavour and color of the dried sample at 38℃, 58℃ and 88℃ was tested.

Table 1.

Commonly used thin layer mathematical models proposed by various authors in the study.

Mathematical Equation	**Name of model**	**Source**
$MR = \exp(-kt)$	The Newton model	Mujumdar 1987, Ayesu 1997
$MR = a\exp(-kt)$	The Henderson and Pabis model	Westerman et. al. 1999
$MR = \exp(-kt^n)$	The page model	Page 1994, Citeden Bruce 1985
$MR = a\exp(-kt) + c$	Logrithmic model	Yagcioglu et. al. 1999
$MR = 1 + at + bt^2$	The wang and singh model	Wang and singh 1998
$MR = \exp(-\mathrm{kt})^{\mathrm{n}}$	The modified Page model	Overhults et. al. 1973
$MR = a\exp(-k_o t) + b\exp(-kt)$	Two termed model	Henderson 1974
$MR = a\exp(-k_o t) + (1-a)\exp(-kat)$	Two term exponential model	Sharaf eldeen et. al. 1980
$MR = a + kt^{1/2}$	The magee model	Magee et. al. 1983

3. Results and discussion:

Experimental Drying Characteristics:

The drying rate in drying period continuously decreases of the thin piece bhindi (Figure 1). Figure 2 was drown b/n drying rate and humidity per kg of matter, that characteristics show never the drying rate reached the fixed value during the drying time of thin piece bhindi that are in falling, in the drying period. The drying time of thin piece bhindi was observed with the humidity. At temperature 38℃, 58℃ and 88℃ respectively for the fresh sample. It was found the drying time is decreased by 20.20, 14.60 and 5.14 % respectively when the observation was taken in every 10℃ temperature difference. Also, it was found the maximum time reduction indicated at the starting temperature from 38℃ to 58℃ as compared with 58℃ to 88℃ respectively.

The figure 1 shows when the drying time increased; the humidity ratio decreases exponentially (Domyaz, 2011). This reduction in humidity indicates mass diffusion from the thin piece bhindi. The overall experimental results indicate for the drying, drying temperature is one of the effective parameter. In the drying curve, very short drying accelerating period was shown at the beginning. This indicates the larger value of the temperature of the air more effective that reduces the humidity at the beginning respect to the smaller vale of effective temperature of drying air but at the end almost effect of temperature are negligible. Finally this results the drying rate are the factor at the beginning comparatively at the end. Due to the content humidity at the ending stage of drying process, the drying rate decreased (Prasad & Sharma, 2001).

As concerned to flavor and colour, The tested sample shows, the sample dried at 38℃ was better to compare to test at 58℃ and 88℃.

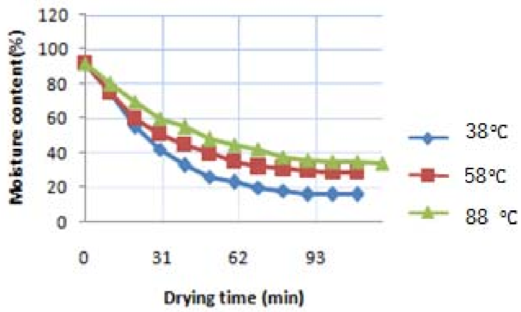

Fig. 1: Drying characteristics showing drying curve vs. time

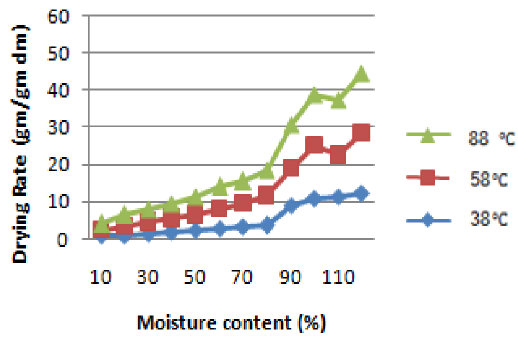

Fig. 2: Drying characteristics showing Drying rate curve vs. moisture

Conclusion:

The drying characteristics of thin piece bhindi were investigated at three drying temperatures. The results of the experiment analysis were showing good agreement with the models. This concluded observations during falling rate, decreasing the drying time because drying temperature increases. On the basis of results, it was found the drying characteristics of thin piece bhindi in the experimental study at the temperature range 38℃ - 88℃, relative humidity of air 19.8-59.8% and air velocity of 1.1 m/sec. The effect of relative humidity ratio of the dryer, on drying time and drying rate, the drying rate of the bhindi increases with a change of drying time, if humidity ratio were decreasing. This result with low humidity ratio of air for drying, diffusion of heat and mass in quantity wise required high and water loss is increased.

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