Drying characteristics of bhindi thin piece on drying in a fabricated tunnel dryer

Abstract: For the storage crops, various drying process are used. It should be synthesize on the basis of drying time, product quality such as color texture and the taste of the product when uses. To study the drying characteristics of bhindi thin piece was performed for a temperature range of 38℃ to 88 ℃ and velocity of air is fixed at 1.1 m/s in the fabricated tunnel. For the investigation of drying characteristics experiment were performed, the result was found, the drying rate was falling. The sample studied at 38℃ was much good in color texture and aroma than sample studied at 58℃ to 88℃. The experimental data were performed on different models proposed, by equating the determination coefficient r^2, mbe, decreased χ^2 and rmse measured and investigated moisture ratio.
Keywords: Drying of crops, quality of product, color, 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 production of bhindi is in India, about 3500000 metric ton per year. For the preservation of crops in various methods, 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.

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

Though the price of dried bhindi are high in all season. So this increase the interest in dried of bhindi for 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 suitable method of preservation and processing this can be reduce and also increase the life for storage so that it can be available in off season (P. K. Wankhade, 2012). Bhindi crops going up to 6.5 feet in 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 (O. Sobukola). Crops Drying varies on diffuision of mass and diffuision of heat which happens in unsteady process simultaneously. (A. Z. Sahin)

For the design of model, a 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 already proposed mathematical model for drying process, widely used drying models are thin layer drying (M. Ozdemir, WAM Mcminn). Recently for the tunnel drying researchers opting, for drying of various agricultural products, in lab mechanical convection models studying (P. and S., 2002). Here, we are adopting forced convection tunnel dryer for present, to plot the drying behavior of bhindi thin piece for drying of bhindi.

2. Material and methods:
2.1 Materials:
The fresh sample of bhindi used in this study which were collected from the department of agriculture plant protection, Sam Higgins Bottom University of Agriculture and Technology, Naini Allahabad, India in the April-March 2017. The dimensions of bhindi nearly 50-85mm long and in diameter 10mm-20mm approximately, in color texture dark green collected for the sample in the experimental study. This sample is first washed and the cut in 4 mm thin piece with the help of steel knife. The collected bhindi for the sample for the sample is 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 color texture of thin piece was taken in each sample in 10 minutes alternatively. The color texture was also tested of dried thin piece bhindi by breaking it. The hot air velocity is fixed measured by anemometer. The temperature and relative humidity was recorded by digital thermometer and digital hygrometer throughout the drying period.

The drying process was performed at 38℃, 58℃ and 88℃ temperatures. 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 result, finally that means values were used. The drying process on the experiment was continue till the moisture reached to the desire level (14.75 -15.25 %, w. b.).

2.3 Mathematical modeling:

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

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

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)

Drying rate

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

The non linear regression optimization was performed using computer software package. For the best model coff. 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-squire) 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)

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:

Using equation (ii) and (iii) humidity ratio and drying rate was calculated from experimental observations. The drying characteristics is drown and shown in figure 1 at various temperature, that shows the drying rate in drying period continuously decreases of the thin piece bhindi. The figure 2 was drown b/n drying rate and humidity per kg of matter, that characteristics shows 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 decreases by 20.20, 14.60 and 5.14 % respectively when observation was taken in every 10℃ temperature diference. 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 (I. 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 temperature of the air more effective that reduces the humidity at the beginning respect to 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).

For the flavor and color of the dried sample at 38℃, 58℃ and 88℃ was tested.

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

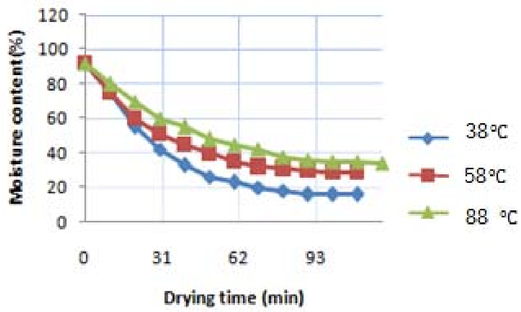

Fig. 1: Drying curve vs. time

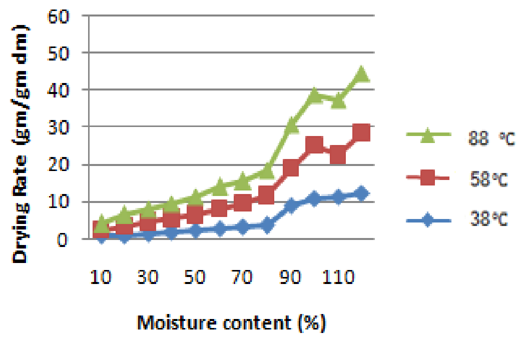

Fig. 2: Drying rate curve vs. moisture

Conclusion:

The drying characteristics of thin piece bhindi were investigated at three drying temperatures. The time taken when the 90% moisture removed for the equilibrium. To explain the drying characteristics of thin piece bhindi proposed model in the literature was applied. 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 increasing. 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 hotness on drying rate of bhindi and on drying time, if at higher value of moisture content, drying temperature increased then drying rate will increased and falling the drying time. The effect of relative humidity ratio of dryer, on drying time and drying rate, the drying rate of the bhindi increases with 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 quantsity wise required high and water loss is increases.

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