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Study on Thin Layer Drying Characteristics Star Fruit Slices

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1. Introduction

Food drying is a most important process for preserving food products since it has a great effect on the quality of the dried products. Drying prevents occurrence of undesirable changes due to microbial activity. It also lowers the product mass and volume which improves the efficiency of packaging, storing and transportation. It is essential to know the drying characteristics of star fruit and the transfer processes during drying to obtain quality dried product, and in order to conserve energy during drying. The major objective of drying kinetic study is the reduction of the moisture content to a level which does not affect the quality of the star fruit and also allows safe storage over an extended period.

Star fruit, with botanical name A*verrhoacarambola L., was originated in South East Asia and has been found cultivated in many tropical and subtropical countries like India, China, Brazil, Thailand, Malaysia and Indonesia (*Tsai *et al., 2005). They are especially known for its unique, star like shape and attractive flavour* (Winterhalter and Schreier, 1995). The mature fruit is sweet and juicy and golden yellow in appearance and are used in making fruit juice fruit salads, jellies a (Macleod et al. 1990)

Previous studies showed that star fruit have a natural antioxidant property and are used traditionally in treating mouth ulcers, toothache, nausea, diarrhea, ascites etc. (Shui and Leong, 2006). It is the content of carotenoids in the star fruit that exhibit their antioxidant activity mainly by physical quenching effects. In the field of Ayurvedic medicine, star fruits are believed to have properties to relieve pain form indigestion and bleeding haemorrhoids and to reduce fever (Khare, 2008)

The high moisture content of the star fruit makes it a perishable food and can lead to extensive postharvest losses caused by chemical and microbial deterioration. So it is very much desirable to set up a simple and inexpensive process for its preservation (Karim and Wai, 1999). Drying can be used as an effective method of preservation to extend the shelf life of food products (Togrul and Pehlivan, 2003). Drying is a process in which water is removed to halt or retard the growth of spoilage microorganisms and also the occurrence of chemical reactions (Vega-Mercado et al., 2001). While fresh vegetables can be kept only for a few days under normal ambient conditions, dry products can be stored for months or even years without considerable loss of nutrients Apart from food preservation, drying also contribute to the reduction in cost of packaging, storage and transportation by reducing the weight and final volume of the product (Tasirin et al, 2007).

So, the objective of this study is to model the drying kinetics of star fruit to investigate the thin layer drying characteristics of star fruit slices in a convective tray dryer.

2. Materials and Methods

2.1. Star fruit sample

The fruits were directly collected from trees of Tezpur region Assam and brought to the laboratory in plastic bags. The shape of these fruits varies from oblong to ellipsoid, with 8-12 cm in length, with 4-5 longitudinal cuts. The rind is translucent, smooth and shiny. The fruits picked while mature and still slightly green but turned yellow in storage at room temperature. The fruit has distinctive ridges running down its sides and its cross-section resembles a star. The entire fruit is edible and is usually eaten out of hand. They may also be used in cooking, and can be made into relishes, preserves, and juice drinks. The entire fruit is edible, including the slightly waxy skin. The flesh is crunchy, firm, and extremely juicy.

Initially the fruits were thoroughly washed before peeling to remove any dirt or dust particles attached to the surface. They were then rinsed again in tap water and transversally cut to form into star shaped slices with a thickness of about 4 mm. The fresh and dry weight was measured with electronic weighing balance.

2.2. Drying procedure

In this study, the drying process of star fruit slices was conducted in a laboratory scale convective tray dryer. The samples were placed in plates in single layers over the trays of the drier and drying of samples was carried out at specified temperature of hot air and fixed air velocity. Initial weights of the samples were noted and samples were kept inside the pre heated drying chamber after steady state condition was achieved. The sample plates were taken out for weighing at every 30 min interval till constant weight was achieved. Each experiment was replicated thrice and average values were taken for analysis. The experiment was carried out at 50, 60, 70 and 80 ºC. Before each experiment the temperature and velocity of air were checked and fixed.

2.3. Mathematical modelling of drying curves

Drying kinetics of food products and mathematical models are essential to describe thin layer drying characteristics of the product. Studies and analysis of drying curves allow us to understand and better visualize the drying process and choose the procedure, treatment, equipment, and temperature suitable to allow dehydration of fruit for best sensory and technological quality. The knowledge of the initial and final (equilibrium) water content of the material and its relationship with the solid structure and water transport inside the material to its surface enables to substantiate the drying process. Drying kinetics and model parameters are generally affected by air temperature, relative humidity, air velocity and material size.

Drying of moist food generally takes place in the falling rate drying period during which water migrates from the interior to the surface of material by diffusion.

As drying proceeds, the moisture content of the material decreases and the mechanism of drying changes. To describe the drying kinetics of star fruit in a tray dryer, eleven simplified drying models have been used (Table 1).

Table 1: Mathematical model applied to drying curve.

No	Model name	model	References
1	Newton	MR = exp(-kt)	(Mujumdar, 2006; Erenturk et al., 2004)
2	Page	MR = exp(-ktn)	(Page, 1949)
3	Modified page	MR = exp[- (kt)n]	(Yaldiz et al., 2001)
4	Henderson and Pabis	MR = aexp(-kt)	(Henderson and Papis, 1961)
5	Logarithmic	MR = aexp(-kt) + c	(Yagcioglu et al., 1999)
6	Two term	MR = aexp(-kot) + bexp(-k1t)	(Madamba et al., 1996)
7	Two term exponential	MR = aexp(-kt) + (1- a)exp(-kat)	(Sharaf-Elden et al., 1980)
8	Wang and Singh	MR = Mo + at + bt2	(Ozdemir and Devres,1999)
9	Approximation of diffusion	MR = a exp(-kt) + (1- a)exp(-kbt)	(Yaldiz et al., 2001)
10	Verma et al.	MR = a exp(-kt) + (1 - a)exp(-gt)	(Verma et al., 1985)
11	Aghabashlo model	MR = exp(-k1t / 1+k2t)	(Aghabashlo et al., 2008)

In these models, MR represents moisture ratio and is expressed as given in Eqn. (1).

$$MR = \frac{M_t - M_e}{M_o - M_e} \tag{1}$$

Where, MR = Moisture Ratio
M_o = initial moisture content
M_t = moisture content at time t

M_e = equilibrium moisture content

Since equilibrium moisture content is zero, moisture ratio can be reduced to MR = M_t /M_o (Yaldiz et al., 2001).

Moisture ratios were calculated at all four temperatures using Eqn. (1) and were used to interpret the drying kinetics. These readings were used in fitting the different mathematical models. The non-linear regression analysis was conducted using Origin (OriginLab, Northampton, MA) to fit the experimental data to the selected models which are given in the Table 1. The coefficient of determination (R^2) is one of the primary criteria in order to evaluate the fit quality among these models (Kassem, 1998). In addition to R^2, other statistical parameters such as reduced chi-square (χ^2) was also used to determine the quality of the fit. These above mentioned Parameters can be calculated as given in Eqn. (2).

$$\chi^2 = \frac{\sum_{i=1}^{N}(MR_{ei} - MR_{pi})^2}{N - z} \quad (2)$$

Where,

MR_{ei} is the ith experimental moisture ratio, MR_{pi} is the i^{th} predicted moisture ratio, N is the number of observations and z is the number of constants used in the model (Meziane et al., 2011).The best model chosen would be the model having highest R^2 value and the lowest χ^2 values. (Hii et al., 2012).

3. Results and Discussions

3.1 Analysis for drying curve

The drying kinetics is presented in terms of the moisture ratio as a function of drying time. Figure (1) shows the relation between moisture ratio and drying time for all the four drying temperature.

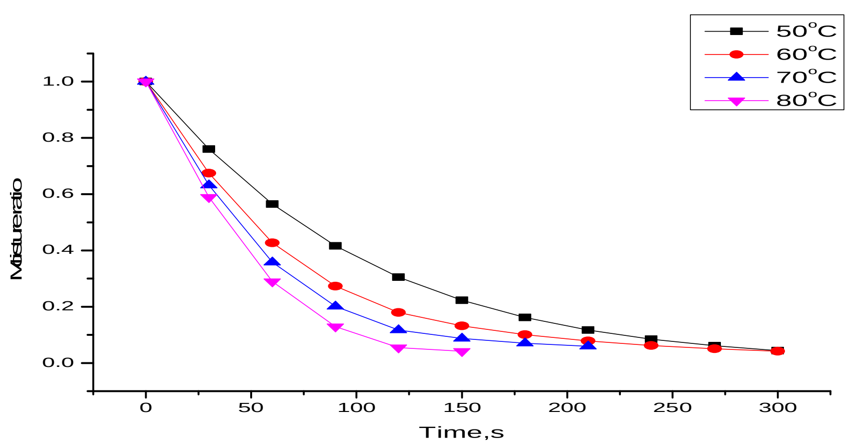

Fig. 1: The drying curves of Star fruit at temperatures 50, 60, 70, & 80 oC

The result showed with increase in drying temperature the drying time was decreases. Drying rate decreases continuously with time and decreasing moisture content. *The data that was recorded during the experiment were fitted to the 11 mathematical models. The values of determination coefficient (R^2) and the reduced chi-square* (χ^2) for different air temperature determined using regression analysis are shown in Table 2. Two term exponential model was found to be the best fitted model with lowest Chi-square value (0.000193) and highest R^2 value (0.998248). The constant parameters of two term exponential model are presented in Table 3 and using the constant values of two term exponential model, theoretical MR can be calculated.

Table 2: Average chi-square values and R^2 values of different drying models.

Sl No	**Models**	**Average Chi-square values**	**Average R-square values**
1	Newton model	0.000418	0.996535
2	Page model	0.000219	0.997993
3	Modified page model	0.000218	0.997993
4	Henderson & Pabis model	0.000472	0.99611
5	Logarithmic model	0.000338	0.997333
6	Two term model	0.000333	0.996915
7	Two term exponential model	0.000193	0.998248
8	Wang & Singh model	0.001769	0.982765
9	Approximation of diffusion model	0.000302	0.997188
10	Verma et al. model	0.000257	0.997605
11	Aghabashlo model model	0.000498	0.995898

Table 3: Drying kinetic constants of two term exponential model.

MODELS	Constants	
Two term exponential model	k	a
50°C	0.01156	1.47105
60°C	0.0167	0.51079
70°C	0.0194	0.99978
80°C	0.02806	1.76826

4. Conclusion

Drying of star fruit slices was studied for its drying kinetics. Moisture removal process followed falling rate stage which was governed by the diffusion process. In order to explain the drying behaviour different models were applied and fitted to the experimental data. According to the statistical analysis applied to all the models and on the basis of highest R^2 and lowest χ^2 value of two term exponential model was found to be best suited model adequately describing the drying behaviour of star fruit. . The drying time is inversely proportional to temperature, as expected. The final empirical relation established can be used to calculate effective diffusivities at any temperature for drying of star fruit slices.

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