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Equilibrium moisture content and drying behaviour of tamarind seed under thin layer condition

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Abstract

Drying behaviour of pretreated and whole tamarind seeds under thin layer condition in the temperature range of 40 to 70°C at constant air velocity of 2 ms^{-1} was investigated. The validation of modified Page's equation for evaluation of drying time was perform by using experimental drying data. Drying constants of modified Page's model were calculated for seed at each drying temperature. Equilibrium moisture contents of tamarind seed were determined at three different temperatures at 30°C to 70°C and three relative humidity (30 to70%) using a standard static method. Three EMC models such as modified Henderson; modified Chung-Pfost and modified Oswin models were used to compared and fit into experimental data. Drying of tamarind seeds at 70°C of 1 cm bed thickness showed best results. The EMC obtained for both types of seed for the selected models showed Modified Henderson model described the experimental data more closely within the experimental range of temperatures and relative humidities.

Key words : Drying behavior, drying model, equilibrium isotherm, thin layer drying

Introduction

Tamarind tree from the ancient time is known for its major importance in agriculture, because it is one of the major source in human nutrition. It is a source of high quality starch and contains cholesterol and saturated fatty acids (Bhattacharya *et al*., 1994). India is the largest producer of tamarind. It is consumed and utilized by several Indian cuisines of the Indian subcontinent, South East Asia and America, particularly in Mexico. Tamarind gum or Tamarind Seed Polysaccharides (TSP) is a polysaccharide polymer (D-galactose, D-xylose and D-glucose) obtained from endosperm of kernels of seeds. The polysaccharide constitutes about 65 percent of the seed components. It is extracted, purified and refined and used as a thickening, stabilizing and gelling agent in foods. The gum can also be used as a binder in pharmaceutical tablets, as a humectant and emulsifier. Proximate analysis of seed kernels shows that 65.1-72.2% is non-fiber carbohydrate, 15.4-22.7% is protein 3.9- 7.4% is oil and 0.7-8.2% is crude fiber. (Kotadiya *et al*., 2008)

Tamarind is one of the major source for developing the edible film as it contains the dietry fibres like *mucilage, pectin* & *tannins* from which pectin is isolated and used as thickening agent and clear sets when it gels. The drying process of any biological products may be predicted by empirical, theoretical or semi-theoretical equations (Crisp1999; Pathak *et al*., 1991) have fitted modified Page’s model successfully to predict drying behaviour of different biological materials. The EMC determines whether a product would gain or loose moisture under a given set of temperature and relative humidity conditions (Sahay and Singh 2004). The values of equilibrium moisture content of biological products are majorly depending on the temperature, relative humidity of the air, the species and variety of the product. The physiological maturity & the history of the product, as well as the way the equilibrium was obtained, also affect the equilibrium moisture (Brooker *et al*., 1992).

Modified Henderson (MH), modified Chung Pfost (MCP) and modified Oswin (MO) equations have been used to fit EMC data by many scientists for predicting equilibrium moisture content of various agricultural products (Basunia *et al*., 2005). Little information is available on the drying characteristics of tamarind and the effects of drying air temperature on quality of tamarind seeds (Jittanit *et al*., 2011; Ekpong *et al*., 2016). Therefore it was aimed to determine appropriate drying temperature and bed thickness for tamarind seed in this study. The data generated would be helpful for researcher and manufactures for designing dryers and drying resources. The present investigation was carried out with the objective

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to study the drying behavior of different types of tamarind seed under thin layer conditions and to determine Equilibrium Moisture Content (EMC) of tamarind seeds to predict EMC by using predefined equations.

Materials and methods

Freshly harvested tamarind seeds of ripen tamarind were separated from pulp and the outer cover. In present investigation tamarind seed without removing the coat i.e. whole seed and seed without coat i.e. pretreated seeds were used. The Initial moisture content was determined as per (AOAC 1995). Equilibrium moisture content of the selected variety of tamarind seed was calculated using the modified equations. The constants of this equation were determined experimentally using static method. Drying behavior at 40, 50, 60 and 70°C and at constant air velocity of 2 m/s was studied and thin layers (1, 2 and 3 cm depth) setup in tray dryer (M/s Bajaj Process Pack Ltd, India) was used. The moisture content of the samples during drying was computed using mass balance equation. Modified Page's equation (1) was tested for predicting the drying rates of tamarind seed.

$$MR = \frac{Mt - Me}{Mo - Me} = \exp\left(-Kt^{n}\right) \quad \ldots(1)$$

Where, MR = moisture ratio, dimensionless;

Mt = moisture content, % at time, t (db);

Mo = initial moisture content, % (db);

Me = equilibrium moisture content, % (db);

t = drying time (min); and K, n = equation constants.

Methods for determination of EMC

Different saturated salt solutions such as Magnesium chloride, H_2So_4 and sodium chloride were used for obtaining the EMC between 30 to 70% and at three constant temperature levels viz., 30°C, 50°C and 70°C. Standard static method (Wink, 1946) was used to determine the sorption behavior of rapeseed. A set of three desiccators, were used to obtain the desired relative humidity in the range of 30 to 70%. A total of three such sets were prepared & each set of three desiccators was kept in three different temperature controlled chamber at 30°C, 50°C and 70°C. Ten gram sample of freshly harvested tamarind seeds of with initial moisture contents of 16.13 % (d.b.) 15.85 % (d.b.) and 15.03 % (d.b.) were kept in container of three different desiccators maintaining three different relative humidity's. The samples kept in the desiccators were then placed in three different temperature controlled chambers. The samples were weighed at intervals of 24 hours till constant weight was obtained (Kumar *et al.*, 2011).

EMC Equations

ASAE Standards (ASAE D245.5) provides isotherm equations & equation constants for the moisture relationship of agricultural products. The following EMC equations were used for the present study:

Modified Henderson equation (Thompson *et al*., 1968)

$$1 - RH = \exp\left(-A\left(T + C\right)Me^{B}\right) \quad \ldots(2)$$

Modified Chung Pfost equation (Chung and Pfost, 1976)

$$RH = \exp - \left(\frac{A}{T + C}\exp\right) B \times \frac{Me}{100}\Big) \quad \ldots(3)$$

Modified Oswin equation (Chen and Morey, 1989)

$$RH = \frac{1}{\left(\frac{A + B \times T^{C}}{Me}\right) + 1} \quad \ldots(4)$$

Where from equations 2 to 4 RH is the relative humidity in decimal, A, B and C are the equations constant and M_e is the equilibrium moisture content, % d.b.

Statistical analysis was performed using MS-excel 2007 to evaluate the different in thickness of seed bed to the moisture ratio in experimental test. It was also used to observe the effect of drying air temperature on thickness of tamarind seeds.

Results and discussion

Whole seed and pretreated tamarind seed utilized 60 to 240 min for drying when dried at 40 to 70°C (Fig. 1). Drying graph of both the tamarind seeds at different drying air temperature was obtained by plotting moisture content versus different temperature. Prediction of drying rate of biological material is more complicated during falling rate period. A modified drying equation described by Page's was fitted to predict the drying rate of seeds. (Bhattacharya *et al*., 1997)

Effect of drying air temperature on drying time was significant (p=0.01). A systematic trend in the variation of modified Page's model constants 'K' and 'n' with drying air temperature for all tamarind seed was observed (Pathak *et al*, 1991). The drying rate i.e moisture ratio obtain for whole seeds were (0.002, 0.003 and 0.006) for 40°C, (0.18,0.16 and0.10) for 50 °C ,(0.77,0.57 and 0.41) for 60 °C (0.94, 0.75 and 0.69) for 70 °C with 1-3cm thickness of seed bed. Similarly result were obtain for pretreated seeds (0.017, 0.043 and 0.07) for 40 °C (0.26,0.24 and 0.20) for 50 °C (0.83,0.64 and 0.62) for 60 °C (0.90, 0.69 and 0.65) for 70 °C with 1-3cm thickness of seed bed. Drying at 70°C air temperature and 1 cm bed thickness of

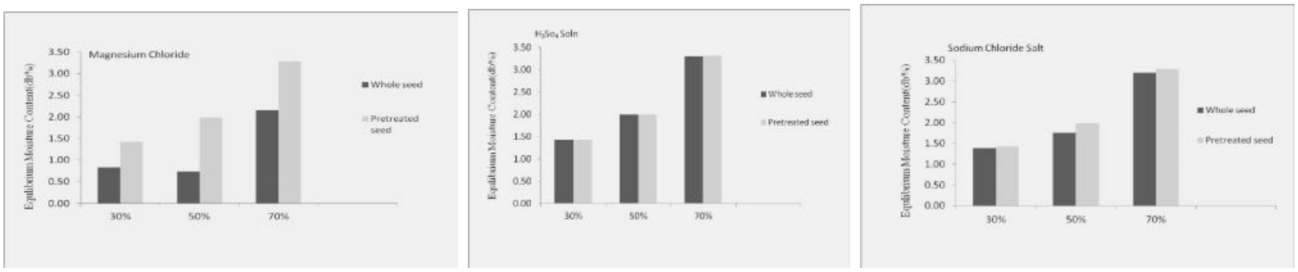

Fig. 1: Equilibrium moisture content isotherm for tamarind seed under Modified Henderson Equation

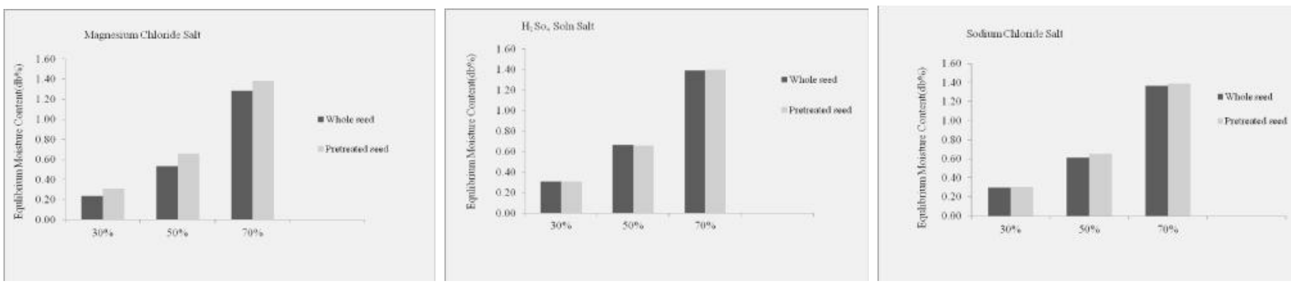

Fig. 2: Equilibrium moisture content isotherm for tamarind seed under Modified Chung Post Equation

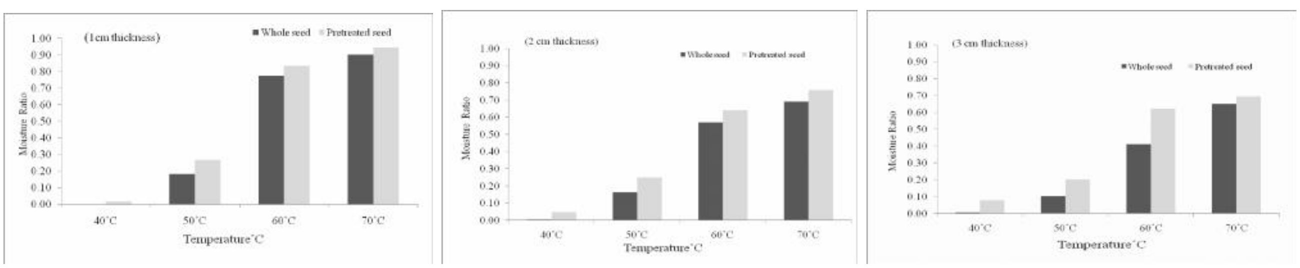

Fig. 3: Variation of moisture ratio with temperature of tamarind seed

seed; at constant air velocity of 2 ms^{-1} proved best for both the tamarind seeds.

The experimental values of equilibrium moisture content at different temperatures & relative humidities were from 0.2 to 3.5 % (d.b.) at 30°C to 70°C temperature and 30 to 70 % for relative humidity. The results showed that an increase in temperature at increased in relative humidity increases the EMC. (Bhattacharya *et al*., 1997; Wink., 1946) EMC values using Modified Henderson equation for pretreated seeds were from 1.42, 1.98 and 3.27 for magnesium chloride salt for RH (1.42, 1.99 and 3.31) for H_2So_4 for RH (1.42, 1.97 and 3.29) and for sodium chloride salt for 30°C to 70°C temperature & 30 to 70 % for relative humidity. Similarly for whole seeds result were from (0.82, 0.73 and 2.15) for magnesium chloride salt for RH (1.42, 2.00 and 3.30) for H_2So_4 , RH (1.38, 1.75 and 3.20) and for sodium chloride salt for 30°C to 70°C temperature & 30 to 70 % for relative humidity.

EMC values using Modified Chung Pfost equation for pretreated seeds were from 0.308, 0.656 and 1.385 for magnesium chloride salt for (RH 0.310, 0.661 and 1.39) for H_2So_4 for (RH 0.307, 0.653 and 1.38) and for sodium chloride salt for 30°C to 70°C & 30 to 70 % for relative humidity. Similarly for whole seeds result were from 0.237, 0.531 and 1.286 for magnesium chloride salt (RH 0.310, 0.667 and 1.392) for H_2So_4 (RH 0.295, 0.615 and 1.368) and for sodium chloride for 30°C to 70°C temperature & 30 to 70 % for relative humidity (Kumar *et al*., 2011).

The values for modified Oswin equation were much more higher compared to modified Henderson and Modified Chung Post equations therefore, they were not considered in the present study. Effect of temperature on moisture ratio was also examined using Analysis of Variance (ANOVA). Modified Page's model equation represented the moisture ratios slight difference experimental data. Statistical analysis showed the effect on moisture ratios of tamarind seeds for both type of seeds at all drying temperature at 5% level of significance (Table 1). Table 2 showed the modified Henderson equation constants value ranged from 1.8260 to 1.70´10^{-5} for the of tamarind seeds.

Table 1. ANOVA to examine the effect of types of seeds on temperature used in EMC determination

S.No	EMC Equations	Temperature °C	F_{cal}	P-value	R^2	RMSE
1	Modified	30	33.62*	0.02	0.94	0.085
2	Henderson	50	863.9*	0.01	0.97	0.048
3	Equations	70	703.4*	0.01	0.99	0.019
4	Modified	30	1.56**	0.27	0.62	0.090
5	Chung Pfost	50	1.81**	0.24	0.68	0.052
6	Equations	70	1.67**	0.26	0.76	0.038

* Significant at 5%, ** Non Significant

Effect of temperatures and relative humidity on EMC

Effect of temperature and relative humidity on EMC was also examined using Analysis of Variance (ANOVA). Modified Henderson equation represented the experimental data more closely. Statistical analysis revealed that temperature had significant effect on EMC of tamarind seeds for both the type of seeds at all relative humidity at 5% level of significance (Table 3). In addition to ANOVA R^2 and RMSE are given to identify the appropriate model.

Table 2. Values of constants A, B and C of modified Henderson equation and modified Chung Post equation for tamarind seed

Temperature (°C)	A	B	C
30 - 70	1.96 x 10-4	1.8260	21.4079

Conclusion

Modified Page's equation with individual model constants for both the seed types and drying air temperature predicted the drying behavior increases with increase in temperature and decreases with bed thickness for the experimental range (40 to 70°C). The effect of drying air temperature on drying time was significant. Drying at 70°C and air velocity 2 m/s is best suited for 1 cm bed thickness in case of both tamarind seeds. The modified Henderson equation was identified as the most appropriate equation for describing the variation of the hygroscopic EMC for tamarind pretreated seed.

Table 3. ANOVA to examine the effect of moisture ratio on temperature used in drying behavior of tamarind seeds

S.No	Temperature °C	F_{cal}	P-value	R^2	RMSE
1	40	34.88**	0.10	0.9721	0.004
2	50	87.83*	0.05	0.9874	0.060
3	60	6.62**	0.23	0.8687	0.093
4	70	189.1*	0.04	0.9947	0.013

* Significant at 5%, ** Non Significant

References

AOAC, 1995. Official methods of analysis. Association of Official Analytical Chemists, Washington DC.

ASAE, D245.5, 1997. Moisture relationships of plant based agricultural products, ASAE standards, 44th Edn. Michigan, St. Joseph, USA.

Basunia, M. A. and Abe, T. (2005). Adsorption isotherms of barley at low & high temperatures. *J. Food Engineering,* 66(1), 129-136.

Bhattacharya, S., Bal S., Mukherjee, R. K. and Bhattacharya, S., 1997. Kinetics of tamarind seed hydration. *J. Food Engineering* Vol. 33, (1-2), 129-138.

Bhattacharya, P. K., Bal, S. and Mukherji, R. K. (1994). Studies on the characteristics of some products from tamarind (*Tamarindus indica* L.) kernels. *J. Food Science and Technology* (India), 31(5): 372-376.

Brooker, D. B., Bakker, Arkema, F.W., Hall, C. W. 1992. Drying cereal grains. The AVI publishing company, Inc. west port, Connecticut.

Chen, C. C., Morey, R. V. 1989. Comparison of four EMC/ERH equations. Transactions of the ASAE 32(30), 983-990.

Chung, P. S., Pfost, H. B**.** 1976. Absorption and desorption of water vapour by cereal grains and their products, Part 2nd. Development of general isotherm equation. Transactions of the ASAE 10, 552-555.

Crisp, J., Wood, J. L. 1999. The Drying Properties of Rapeseed. *J Agric Eng Res,* 57: 88-97.

Ekpong, A., Phomkong, W. and Onsaard, E. (2016). The effects of maltodextrin as a drying aid and drying temperature on production of tamarind powder and consumer acceptance of the powder. *Int. Food Research J.,* 23(1): 300-308

Jittanit, W., Chantara-In M., Deying, T. and Ratanavong, W. 2011. Production of tamarind powder by drum dryer using maltodextrin and arabic gum as adjuncts. Songklanakarin, *J. Sci. Technol,* 33 (1), 33-41.

Kotadiya. R., Patel. V. and Patel. H. 2008. Tamarind Seed Polysaccharides: A Novel carrier for drug delivery systems pharmaceutical reviews.

Kumar, R., Jain, S., Garg, M. K. and Dixit, A. K. 2011. Sorption behavior of rapeseed (Toria). *American J. Food Technology,* 6(10) 945-950.

Pathak, P. K., Agrawal, Y. C., Singh, B. P. N. 1991. Thin layer drying model for rapeseed. Trans ASAE 34(6): 2505-2508.

Sahay, K. M. and Singh, K. K. 2004. Unit operation of agricultural processing. Vikash publishing house Ltd. New Delhi, 150-320pp.

Thompson, T. L., Peart, R. M., Foster, G. H. 1968. Mathematical simulation of corn drying-a new model. Trans. ASAE., 24(3), 582-586.

Wink, W. A. 1946. Determination of moisture equilibrium curves for hygroscopic materials. *Ind. Engng. Chem., Analytical* Edition, 18.

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