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International Journal of Current Research
Vol. 7, Issue, 09, pp.20010-20013, September, 2015

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

MATHEMATICAL MODELLING OF DRYING CHARACTERISTICS OF PEPPER (*CAPSICUM ANNUM*)

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ARTICLE INFO

Article History:
Received 05th June, 2015
Received in revised form
09th July, 2015
Accepted 23rd August, 2015
Published online 16th September, 2015

Key words:
Thin-layer, Drying time,
Moisture ratio, Kinetics,
Model, Moisture content.

ABSTRACT

The effects of drying condition on the drying behaviour of pepper (C. *annum*) and the applicability of three thin-layer drying models namely; Page, logarithmic and Flick's law, to predict the drying behaviour of pepper were studied. The experiments were conducted in a constant temperature hot air drying oven. Three temperatures (50, 60, and 70^0 C) were studied. Drying air temperature was found to be the main factor affecting the drying kinetics of pepper; raising the drying temperature from 50^0C to 70^0 dramatically reduced the drying times. Higher equilibrium moisture contents were obtained at lower temperatures. Furthermore, drying was observed only in the falling rate period, and comparison among drying models was made using statistical analysis to select the best fitting model for the drying curves. Among the three tested models, Page model was found to be superior to the other models in terms of fitting performance, in fitting the experimental data, providing the highest coefficient of determination (R^2) value -0.9944, and the lowest root mean square error *(RMSE) value* - 0.03032.

Citation: Nkwocha, A. C., Kamalu, C.I.O., Dadet, W.P., Uzondu, F.N. and Ogbonna, O.C., 2015. "Mathematical Modelling of Drying Characteristics of Pepper (*Capsicum annum*)", *International Journal of Current Research*, 7, (9), 20010-20013.

INTRODUCTION

Peppers are vegetable crops belonging to the solanaceae family ad genus capsicum (Grubben and Dentorn, 2004), which are native to tropical America and Africa (Jaliya and Sanni, 2006). In Nigeria, pepper fruit has high socio- economic importance that cuts across all classes of people and food industries. They are used both in their fresh form or paste, dried or ground in the preparation of deferent meals, stew and soup. Also, Nigeria happens to be the largest producer of pepper in Africa, covering about 50% of total African production. In 2001, FAO estimate of pepper production in Nigeria stood at 715,500 metric tonnes, from a total area of 90,000ha. There are quite a number of different cultivars of pepper both indigenous and exotic, with wide variation in morphological characteristics (Ado, 1988). The reduction of moisture is one of the oldest techniques for food preservation. Mechanical and thermal methods are two basic ways to remove the moisture in a solid material (karimi, 2010). The availability of various important food items such as pepper has led to various forms of preservation techniques. Two thirds of the world's population is inadequately fed and yet million of kilograms of food are wasted each year as a result of poor and inadequate storage and handling facilities.

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Many applications of drying have been successfully employed to decrease physical, biochemical and microbiological deterioration of food products which is due to the reduction of the moisture content to the level which allows safe storage over a long period. This brings substantial reduction in weight and volume, minimizing packaging, storage and transportation costs (Zielinska and Markowski, 2010). The necessity of high quality fast-dried foods is leading to a renewed interest in drying operations. The principle of modelling is based on having a set of mathematical equations which can satisfactorily explain the mechanics of the system. The solution of these equations must allow calculation of the process parameters as a function of time at any point in the drying process based only on the primary condition (kaleta and Gornicki, 2010). Hence, the use of a simulation model is an important tool for predication of performance of the drying system. The objectives of this study were to determine the drying kinetics of pepper, fit selected models to the kinetics, and determine which model best describes the drying behaviour.

MATERIALS AND METHODS

Sample preparation and drying

Local pepper fruits (*Capsicum annum*) were freshly harvested from the University farm of Federal University of Technology, Owerri, Nigeria.

The ripe fresh pepper were cleaned manually to remove dirt and extraneous materials, then cut into uniform slices and weighed. An electronic digital balance was used to weigh 10g per sample. Drying treatment was performed in a laboratory type electro thermal oven (Model DHG, E300 serials, Turkey). The pepper samples which were being dried were removed from the oven periodically (every ten minutes), and moisture loss during the drying period determined by weighing the sample on an electronic digital balance (3002N; 110628019, Germany) wih 0.01g, precision and capacity of 300g. Drying test were replicated three time at each drying trial and average weight loss were reported. This procedure was carried out for all the three drying temperatures (that is, 50^o **C,** 60^o C, and 70^{o}C).

The moisture content of the samples at different time internals were expressed on dry basis, as more convenient for modelling (Saeed *et al*., 2006). As the initial moisture content of the products varied from one sample to another, the moisture content was converted to dimensionless moisture ratio (MR) expressed below:

$$MR = \frac{M_t - M_e}{M_0 - M_e} \quad \text{......................... (1)}$$

Where M_o, M_t, and M_e are the initial, instantaneous, and equilibrium moisture content respectively. Also, the data obtained from the drying experiments were used to plot a graph of dimensionless moisture ratio (MR) against drying time (t).

Modeling

The procedure here is to fit selected thin layer models to the scatter diagrams of MR versus t data generated. The selected thin-layer models and their equations are shown below:

Table 1. Selected thin-layer models used for modeling

Model name	Expression	Reference
Page	$MR = \exp(-at^b)$	Page (1949)
Logarithmic	$MR = a\exp(-bt)+c$	Togrul and Peblivan (2002)
Fick's law	$MR = a\exp(-bt)$	Jena and Das (2007)

These models describe the drying characteristics of the samples by showing the moisture ratio (MR) as a function of drying time t (min); where a, b, and c are the coefficients of the models. By non-linear regression technique using Matlab curve fitting tool (Matlab version 7.9.0, Math- works, Inc.), the selected models were fitted to the respective data to determine the values of coefficients a, b, and c of the models.

Goodness of fit of the models is characterized by root mean square error (RMSE) and coefficient of determination (R^2). The purpose of the study was to determine which of the three models best describes the drying characteristics or kinetics of the samples. The model indicating minimum RMSE as well as maximum R^2 values was considered the best.

RESULTS AND DISCUSSION

Drying characteristics

The change in moisture profile with respect to time for the various drying temperatures is presented in terms of moisture ratio (MR) versus time (t) graphs shown in Fig 1. It could be observed that drying rate increased initially, then decreased continuously with time until equilibrium moisture content was attained.

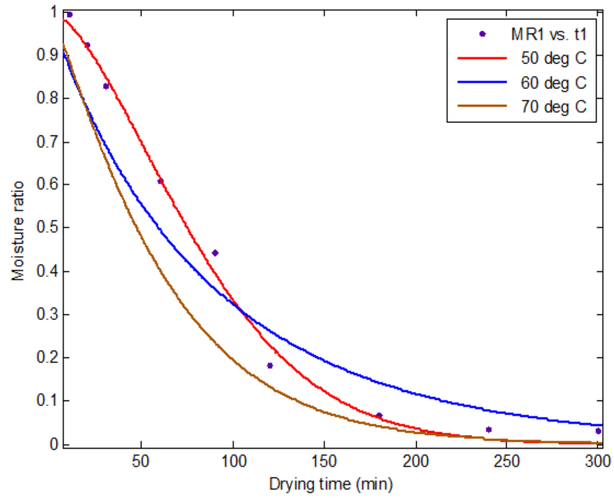


Fig. 1. Variation of moisture ratio with time at different drying temperatures (using Page model)

As the drying progressed, the loss of moisture in the product resulted in a fall in the drying rate; this shows that diffusion is the dominant physical mechanism governing moisture movement in pepper. Furthermore, for a constant drying temperature, the curves exhibited a steeper slope for higher temperature. This impresses the fact that drying temperature was a significant factor affecting the drying behaviour of pepper fruit. The increase in temperature resulted in a decrease in drying time. The drying time at equilibrium moisture was 300, 240 and 180 min for samples dried at 50, 60, and 70^{0}C respectively. This hehaviour of decreasing drying time with increasing drying temperatures has been reported for many food stuffs (Akgun and Doymaz, 2005; Wang *et al*., 2007; Doymaz 2007; Jain and Pathcare, 2004; Sharma *et al.,* 2005).

Mathematical modeling

The MR versus t data were fitted to the selected thin layer models described in Table 1, the model coefficients were estimated by non-linear regression analysis technique. The goodness of fit of the models is characterized by the highest value of coefficient of determination (R^2) and lowest value of root mean square error (RMSE). The statistical results of the models are presented in Tables 2-4. For all the models the R^2 and adjusted R^2 were higher than 0.98, while the RMSE was lower the 0.053, with the exception of the logarithmic model, which exhibited negative correlation. Page model provided the highest R^2 (0.9944) and the lowest RMSE (0.03032) results. Therefore, the Page model was selected as the model that could adequately describe the thin- layer drying characteristics of pepper fruit.

Table 2. Statistical results of selected thin-layer models at 50^{0}C

Model	a	b	c	R^2	Adjusted R^2	RMSE
Page	0.00067	1.607		0.9944	0.9936	0.03188
Logarithmic	1.212	0.01123	0.05031	0.9669	0.9826	0.05238
Fick's law	1.182	0.01255		0.9848	0.9826	0.05233

Table 3. Statistical results of selected thin-layer models at 60^{0}C

Model	a	b	c	R^2	Adjusted R^2	RMSE
Page	0.01542	0.9318		0.9849	0.9834	0.03496
Logarithmic	-36.76	11.20	0.4281	-2.22e-16	-0.2222	0.29990
Fick's law	0.9957	0.01134		0.9825	0.9808	0.03763

Table 4. Statistical results of selected thin-layer models at 70^{0}C

Model	a	b	c	R^2	Adjusted R^2	RMSE
Page	0.008384	1.1450		0.9914	0.9905	0.03032
Logarithmic	-0.8160	3.1570	0.3692	5.107e-15	-0.2500	0.3471
Fick's law	1.0770	0.01685		0.9899	0.9887	0.03294

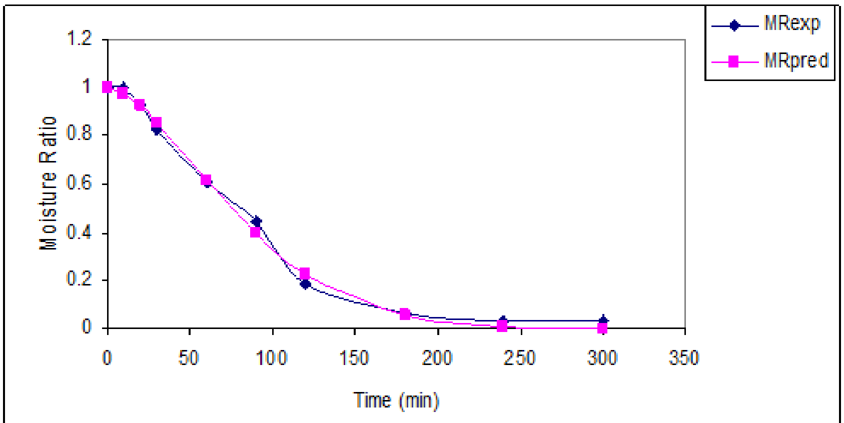


Fig. 2: Expreimental and predicted moisture ratio with time at 50 deg C

MRexp=experimental moisture ratio MRpred=predicted moisture ratio

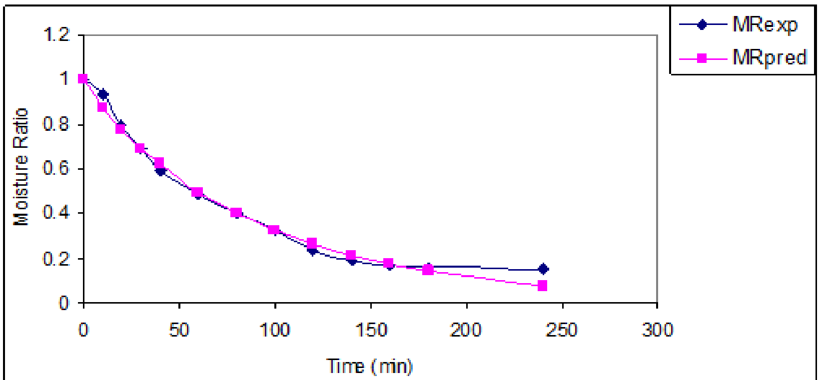


Fig. 3: Experimental and predicted moisture ratio with time at 60 deg C

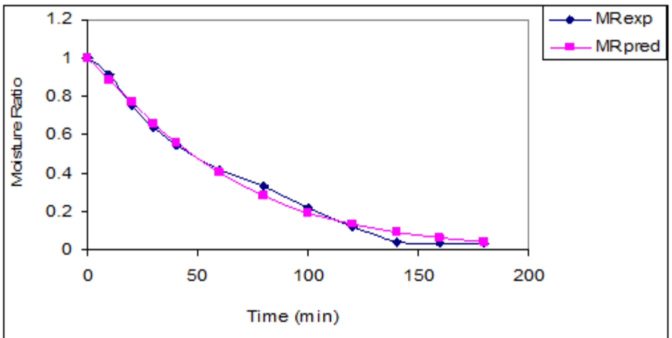
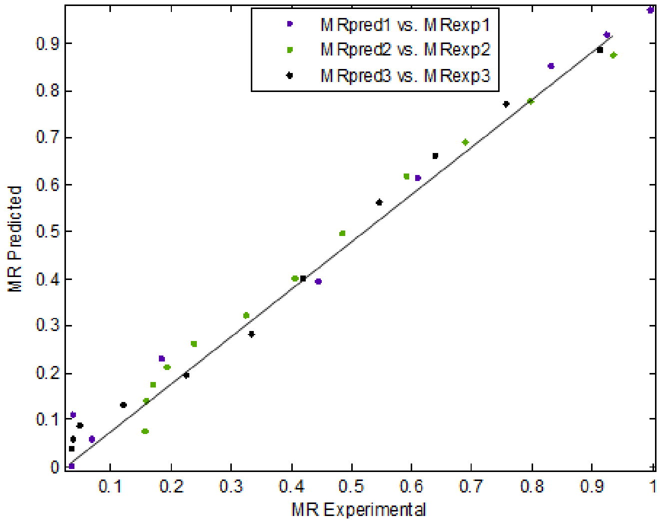


Fig. 4: Experimental and predicted moisture ratio with time at 70 deg C



1=50^{0}C 2=60^{0}C 3=70^{0}C

Fig. 5. Comparison of experimental and predicted moisture ratio with time at different temperatures using Page model

Figs 2-4 show the suitability of Page model to predict the experimental moisture ratio values with drying time for the different drying temperatures. It can be observed that the experimental versus predicted moisture ratio for the operational conditions clearly depict good agreement, as they lie close to each other. Similarly, comparison of moisture ratio values (Fig. 5) clearly backs up this fact as the experimental and predicted values lie closely around the 45^o straight line, confirming that Page model is appropriate for predicting the drying behaviour of pepper fruit. Page model has been selected by earlier researchers also to predict the drying behaviour of various food products (Therdthai and Zhou, 2009; Mitra *et al.*, 2011.

Conclusion

Drying air temperature was found to be the main factor that influenced the drying kinetics of pepper. In the oven drying process of pepper, drying took place mainly in the falling rate period after a very short accelerating period at the beginning, in drying processes of samples, and no constant rate period was observed. Also, drying time decreased considerably by increasing the drying temperature. The Equilibrium moisture content and the time needed to reach this equilibrium also reduced with increasing drying-air temperature. Therefore, temperature had a crucial effect on the drying rate. Finally, the results showed that pepper drying kinetics were best fitted by Page model and it can be used, sufficiently, to describe the drying behavior of pepper in the range of the tested drying conditions.

REFERENCES

Ado, S.G. 1988. Evaluation of capsicum in Nigeria RGRCIE News letter, Vo/17,pp16-17.

Akgun, N.A. and Doymaz, 1. 2005. Modelling of olive cake thin-layer drying process, *Journal of Food Engineering,* 68:455-461.

Doymaz, I. 2005. The kinetics of forced convective air – drying of punkin slices, *Journal of Food Engineering*, 79: 243-208.

Grubben, H.G. and Dentorn, O.A. 2004. Plant resources of tropical Africa to IROTA Foundation, Netherland, pp 27-29.

Jain, D. and Pathare, P.B. 2004. Selection and evaluation of thin- layer drying models for infrared radiactive and convective drying of onions slices. *Biosystems Engineering,* 89 :289-296.

Jaliya, T. and Sanni, M. 2006. Classification of peppers in Nigeria, *Africa Journal of Biotechnology*, Vol.5 (19), pp 1226-1238.

Jena, S. and Das, H. 2007. Modelling for vacuum drying characteristics of coconut presscake. *Journal of Food Engineering,* 79:92-99.

Karimi, F. 2010. Application of superheated steam for the drying of food products, *Int. Agro physics,* 24:195-204.

Kaleta, A. and Gornicki, K. 2010. Some remarks on evaluation of evaluation of drying models of red beed particles. *Energy convers manage*, 51:222967-2978.

Mitra, J., Shrivastava, S.L. and Rao, P.S. Vacuum dehydration kinetics of onion slices, *Food and Bioproducts Processing*, 89: (2011), 1 – 9.

Page, G.E. 1949. Factors influencing the maximum rate of air drying shelled corn in thin- layers. M.S Thesis, Department of Mechanical Engineering, Purdue University, Purdue, U S A.

Saeed, I.E., Sopian, K. and Zainol, A.Z. 2006. Drying kinetics of Roselle (*Hibiscus sabsariffa L.*): dried in constant temperature and humidity chamber. Proc. SPS 2006. Permata, Bangi, S.D.E., Maalaysia: 143-148.

Sharma, G.P., Verma, R.C. and Pathare, P.B. 2005. Mathematical modelling of infrared radiation thin layer drying of onion slices. *Journal of Food Engineering*, 71:282 – 286.

Therdthai, N. and Zhou, W. 2009. characterization of microwave vacuum drying and hot air drying of mint leaves (*Mentha cordifolia Opiz ex. Fresen*). *Food Engineering*, 91: 482 – 489.

Togrul, 1.T. and Pehlivan, D. 2002. Mathematical modelling of solar drying of apricot in thin layers. *Journal of Food Engineering,* 55,209-216.

Wang, J., Sun, J., Liao, X., Chen, F., Zhou, G. and Wu, J. 2007. Mathematical modelling on hot air drying of thin layer apple pomace. *Food Research International,* 40:39-46.

Zelinska, M. and Markowski, M. 2010. Air drying characteristics and effective moisture diffusivity of carrots, *Chemical Engineering Processes,* 49:212-218.

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