D-5669
[1-7]

RESEARCH ARTICLE

Agricultural Science Digest, Volume Issue : ()

Mathematical Modelling of Dried *Carica papaya* Leaves

J. Saritha[1], Kavita Waghray[1]

10.18805/ag.D-5669

ABSTRACT

Background: Papaya leaves botanically classified as *Carica papaya* and are used medicinally in teas to aid in digestion. The Carica Papaya leaves are often considered as wastes, but they are actually beneficial for health. The study was aimed to achieve the suitable drying parameters of operation that makes the drying process to complete in less time without effecting the keeping quality of the product.

Methods: The study was conducted using 3 drying methods which consisted of tray drying at temperatures 50°C, 60°C and 70°C, microwave drying at power levels 20% (180 Watts), 30% (270 Watts) and 40% (360 Watts), microwave vacuum drying at pressures of vacuum 400 mmHg, 500 mmHg and 600 mmHg and power levels 20% (180 Watts), 30% (270 Watts) and 40% (360 Watts). Twelve different mathematical drying models were compared based on their correlation coefficient, root mean square error and reduced chi-square to estimate the drying curves.

Result: Experimental results showed that page model and weibulls distribution gave the best results, evidenced by the highest average correlation coefficient value of 0.9796, lowest average RMSE (Root mean square error) value of 0.0286 lowest average SSE value of 0.014 and the reduced average χ^2 value of 0.0019. It is concluded that page model and weibulls distribution could sufficiently describe the tray drying, microwave and microwave vacuum drying respectively of carica papaya leaves.

Key words: *Carica papaya* leaves, Drying curves, Mathematical modeling, Microwave drying, Microwave vacuum drying.

INTRODUCTION

Papaya leaves (*Carica papaya*) grow in tropical climates around the world, recognised by their scar marked stem and all parts of the tree including the fruit, seeds and leaves can be consumed. Carica papaya, belongs to the family of Caricacecae and many species from Caricacecae had been used as remedy for different diseases (Alabi *et al*., 2012). The plant can grow upto 5-10 m high. The leaves are large, 50-60 cm in diameter. It is herbaceous succulent plant with self-supporting stems.Papaya leaves are crisp, have a fresh, green flavour and can be bitter, depending on maturity. Papaya leaves are available year round. The leaves increase appetite,improve digestion and can be used as an additive to tenderize meat as well (Aravind *et al*., 2013). Carica papaya leaf was compared to few other plants for its efficacy on malaria treatment (Avwioro 2010). In the comparison to other medicinal plants, *Carica papaya* leaves had comparatively higher composition of tannins, terpenoids and phenolic acids (Fasola and Iyamah 2014). Other than malaria, papaya leaves were used for the curing of dengue.Carica papaya leaves contain Acetogenin, which is an active component that causes cure of dengue fever.

In many agricultural countries, large quantities of food products are dried to improve shelf life, reduce packing costs, lower shipping weights, enhance appearance,encapsulate original flavour and maintain nutritional value. In this regard, the goals of drying process research in the food industry may be classified in three groups as follows:

a. Economic considerations,
b. Environmental concerns and
c. Product quality aspects.

[1]Department of Food Technology, University College of Technology, Osmania University, Hyderabad-500 007, Telangana, India.

Corresponding Author: J. Saritha, Department of Food Technology, University College of Technology, Osmania University, Hyderabad-500 007, Telangana, India. Email: sarithajukuri83@gmail.com

How to cite this article: Saritha, J. and Waghray, K. (2023). Mathematical Modelling of Dried *Carica papaya* Leaves. Agricultural Science Digest. doi:10.18805/ag.D-5669

Submitted: 09-09-2022 **Accepted:** 15-03-2023 **Online:** 10-05-2023

Though the primary objective of food drying is preservation, depending on the drying mechanisms, the raw material may end up a completely different material with significant variation in product quality.

Drying is an energy intensive operation of some industrial significance. In most industrialized countries, the energy used in drying accounts for 7-15% of the nation's industrial energy, often with relatively low thermal efficiencies ranging from 25% to 50%. The most important aspect of drying technology is the mathematical modelling of the drying processes and equipment. Its purpose is to allow design engineers to choose the most suitable operating conditions and then size the drying equipment and drying chamber accordingly to meet desired operating conditions. The principle of modelling is based on having a set of mathematical equations that can adequately characterize the system. In particular, the solution of these equations must allow prediction of the process parameters as a function of time at any point in the dryer based only on the initial conditions.

In recent years, the drying behaviour of different products had been studied by many investigators. Some products studied are as follows: Grass, Sultana Grape, Banana, Apricot, Seedless Grape, Fig, Green pea, Tomato and Onion, Pistachio, Potato slice, Pumpkin slice. There are, however, few works on the drying process of Carica papaya leaves in the literature Menzies and O'Callahan (1971), Midilli *et al*., (2003), Queiroz *et al*., (2001), Togrul *et al*., (2002) and Yaldiz *et al*., (2001).

The main objective of the present study is to develop a mathematical model for drying of Carica Papaya leaves.

MATERIALS AND METHODS

The Carica Papaya leaves were brought from a local market and were washed with water and kept for surface drying so that excess water goes off. Then the leaves were used for drying (Period of work: April 2020 to March 2022, University College of Technology, Osmania University).

Tray drying

The leaves were cut into small pieces ranging from 3-5cm each and then kept in the tray provided in the tray drying equipment. The air from the inlet comes into the cabin where the tray is placed. The air then passes through the perforated tray taking away the moisture from the leaves making them dry. The tray drier was operated at 3 different temperatures (50°C, 60°C and 70°C) and at a constant air velocity of 1m/s.

Microwave drying

The sample was spread in a single layer on the microwave safe glass dish and placed on the turntable for uniform drying in a microwave oven. The oven was operated at 3 power levels (20% (180 Watts), 30% (270 Watts) and 40% (360 Watts) by keeping air velocity constant 1m/s and constant frequency 2450 MHz. The microwave oven was run idle for 15s to set the drying conditions and achieve steady state prior to the commencement of each drying experiment.

Microwave vacuum drying

Microwave vacuum drying was also conducted in an oven which was connected to the vacuum. The operation was done at three pressures of vacuum (400 mmHg, 500 mmHg, 600 mmHg) and at the three microwave power levels (20% (180Watts), 30% (270 Watts) and 40% (360 Watts) by keeping air velocity constant 1 m/s and constant frequency 2450 MHz.

The microwave oven was run idle for 15s along with the vacuum to set the drying conditions and achieve steady state prior to the commencement of each drying experiment.During drying, the sample was periodically weighed using the electronic balance having accuracy of 0.0001 error. Drying experiments were conducted till the product achieved approximately constant weight. The moisture content was determined by placing the papaya leaves sample in an oven maintained at 105°C for 3hours. The sample was cooled in the desiccators before its final weight was taken and the difference in weights was expressed as g water/g dry matter (dm).

Drying Kinetics

For the purpose of drying kinetic study, estimated dimensionless moisture ratio was calculated using the following expression:

$$\text{Moisture ratio (MR)} = \frac{(M_t - M_e)}{(M_o - M_e)}$$

Where,

M_t = Moisture content at time t,

M_o and M_e = Initial and equilibrium moisture content respectively.

All moisture content was expressed in g water/g dry matter. The final moisture content of each experiment was taken as the equilibrium moisture content Prabhanjan *et al*., (1995); Ren and Chen (1998).

Drying rate was calculated using the equation:

$$\text{Drying rate (DR)} = \frac{(M_{t+dt} - M_t)}{dt}$$

Mathematical modelling

The drying data was fitted to 12 drying models (as per equations in Table 1) for all the drying experiments to describe the drying kinetics Chua *et al*., (2002) I, El- Sebaii *et al*., (2002).

Table 1: Mathematical model equations.

Name of the model	Model	References
Lewis Thin layer Model	MR=exp (-k.t)	(Lewis 1921)
Pages model	MR=exp (-k.t^n)	(Page 1949)
Henderson and Pabis Exponential Regression	MR=a.exp (-k.t)	(Henderson and Pabis1961)
Logarithmic model	MR=a.exp (-k.t)+c	(Yagcioglu *et al*., 1999)
Midilli *et al.*	MR=a.exp (-k.t^n)+bt	(Midilli *et al*., 2002)
Modified Henderson and Pabis	MR=a.exp (-k.t)+b.exp (-g.t)+c.exp (-h.t)	(Karathanos 1999)
Modified Pages model	MR=a.exp (-k.t^n)	
Overhults Model	MR=exp- $(k.t)^n$	(Overhults *et al*., 1973)
Thompson model	t = a.ln (MR) +b.ln $(MR)^2$	(Thomson *et al*., 1968)
Two term model	MR=a.exp (-k.t)+b.exp (-g.t)	(Henderson 1974)
Wang andSingh model	MR=1+a.t+b.t^2	(Wang and Singh1978)
Weibull Distribution	MR=a-b.exp (-k.t^n)	(Babalis *et al*., 2006)

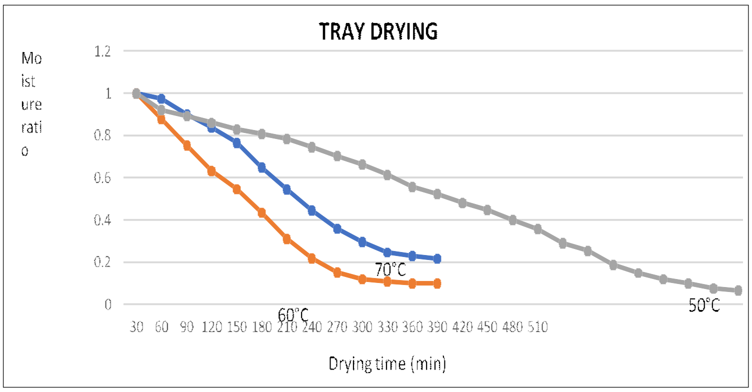

Fig 1: Moisture ratio vs drying time for tray drying.

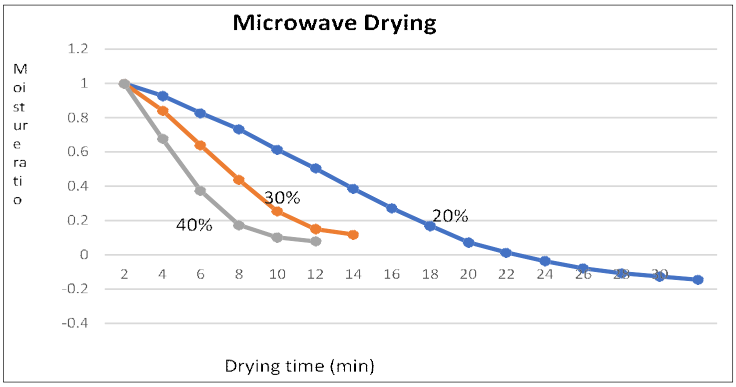

Fig 2: Moisture ratio vs drying time for microwave drying.

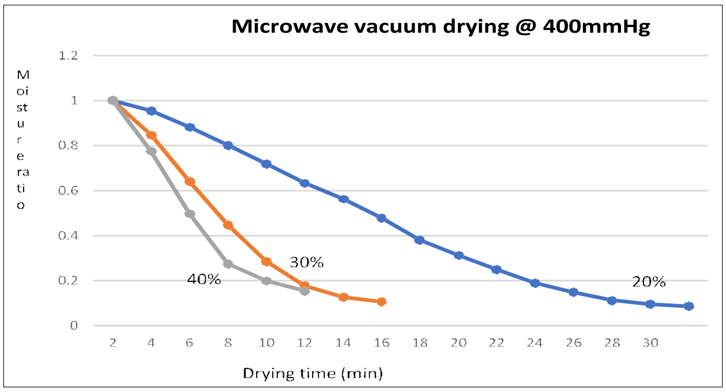

Fig 3: Moisture ratio vs drying time for microwave vacuum drying @ 400 mmHg pressure.

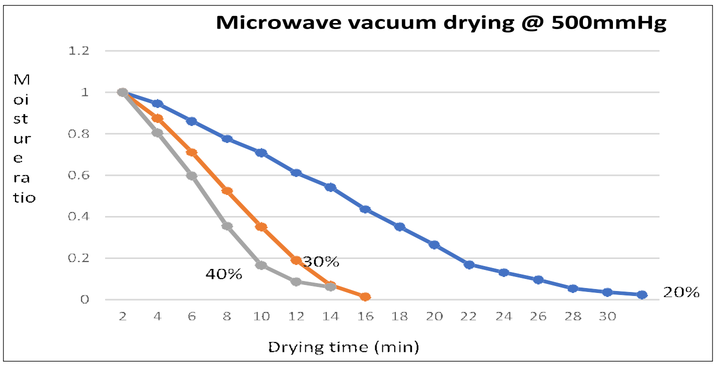

Fig 4: Moisture ratio vs drying time for microwave vacuum drying @ 500 mmHg pressure.

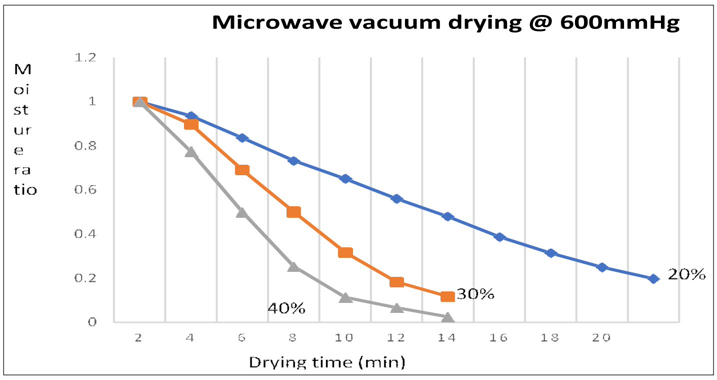

Fig 5: Moisture ratio vs drying time for microwave vacuum drying @ 600 mmHg pressure.

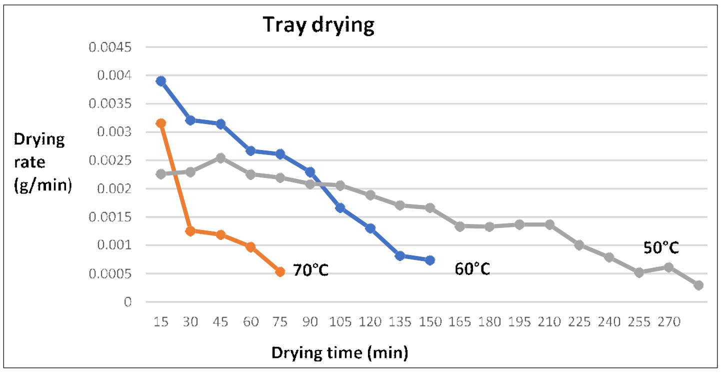

Fig 6: Drying rate vs drying time of tray drying.

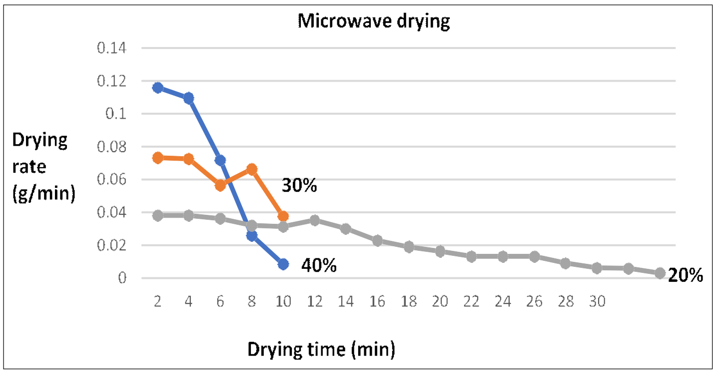

Fig 7: Drying rate vs drying time of microwave drying.

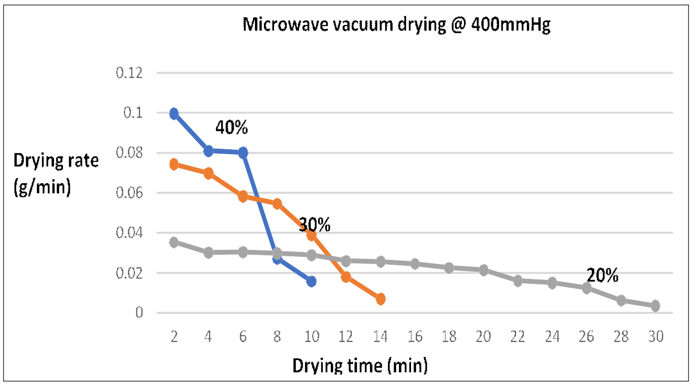

Fig 8: Drying rate vs drying time of Microwave Vacuum drying @ 400 mmHg pressure.

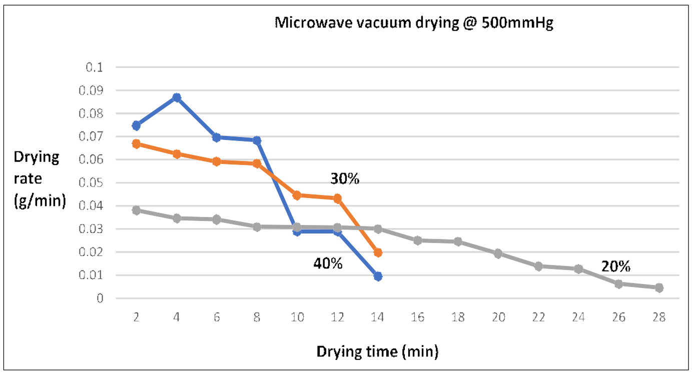

Fig 9: Drying rate vs drying time of microwave vacuum drying @ 500 mmHg pressure.

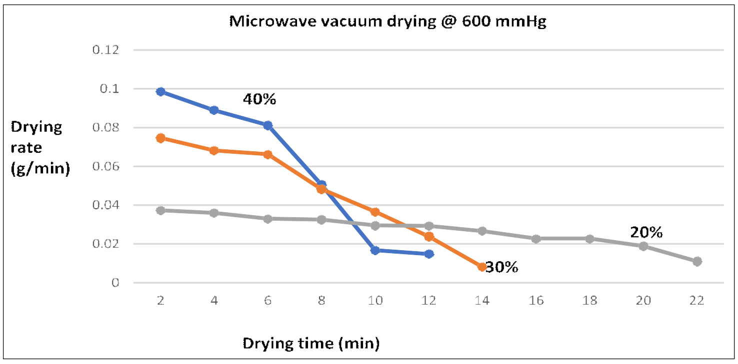

Fig 10: Drying rate vs drying time of Microwave vacuum drying @ 600 mmHg pressure.

Table 2: Statistical results of page's model.

Experiment	k	n	RMSE	R^2	SSE	χ^2
Tray drying						
50°C	0.0008	1.2976	0.0314	0.990	0.0158	0.0012
60°C	0.000894	1.3812	0.0205	00.9899	0.0042	0.0015
70°C	0.002388	1.1580	0.0156	0.9969	0.0024	0.0004
Microwave drying						
20%	0.1687	1.2642	0.0318	0.9976	0.0101	0.0002
30%	0.0579	1.4957	0.0154	0.9980	0.0014	0.0001
40%	0.0106	1.8423	0.0187	0.9923	0.0017	0.0007
Microwave vacuum drying @ 400 mmHg						
20%	0.1217	1.2501	0.0116	0.9929	0.0020	0.0009
30%	0.5509	0.4188	0.1517	0.7522	0.1612	0.0231
40%	0.01190	1.5850	0.0291	0.9987	0.0042	0.0002
Microwave vacuum drying @ 500 mmHg						
20%	0.0614	1.5846	0.0230	0.9974	0.0079	0.0002
30%	0.0267	1.7970	0.0239	0.9962	0.0040	0.0003
40%	0.0093	1.7223	0.0188	0.9960	0.0021	0.0004
Microwave vacuum drying @ 600 mmHg						
20%	0.0852	1.5371	0.0088	0.9993	0.0008	0.0002
30%	0.0391	1.6130	0.0148	0.9983	0.0015	0.0004
40%	0.0239	1.3966	0.0100	0.9990	0.0006	0.0001

Model adequacy was tested using root mean square error (RMSE), chi square (χ^2).

Model having maximum R, minimum RMSE and χ^2 was chosen as the best fit Mohapatra and Rao (2005); Throat *et al*., (2012); Pardeshi *et al*., (2013).

RESULTS AND DISCUSSION

The Fig 1-10 describes the changes in the moisture ratio of carica papaya leaves with drying time and drying rates versus drying time. It is clear from these figures that the drying rate decreases continuously with the moisture content or drying time.

All the drying operations are seen to occur in the falling rate period (as shown in Fig 6 to Fig 10). The final drying duration was different for all the drying operations performed.

Tray drying took a maximum of 8 hours and minimum of 5 hours for drying of carica papaya leaves while microwave drying and microwave vacuum drying took a maximum of 30 minutes and a minimum of 10 minutes for the completion of drying. From the figures, we can observe one important factor influencing the drying kinetics of *Carica papaya* leaves is the drying air temperature during the falling rate drying period. The increase in drying air temperature resulted in a decrease in the drying time. The moisture content data obtained for different drying operations were converted to the moisture ratio expression and then curve fitting computations with the drying time were performed on the 12 drying models given by the previous investigators. Comparative studies were done for all the experiments. The model with highest R^2 value of RMSE and least values of SSE and χ^2 was selected as the best fit for the drying experiments. The results have shown that the highest values of R^2 and the lowest values of RMSE, SSE and χ^2 could be obtained with the Page, Overhult's, Wang and Singh and Weibull distribution expressions. In this study, the Page's model was preferred due to its simplicity. Thus, the Page model may be assumed to represent the drying behaviour of Carica Papaya leaves.

The statistical analysis results are shown in Table 2.

CONCLUSION

In this study, the drying behaviour of *Carica papaya* leaves was investigated. The drying process occurred in the falling rate period, starting from the initial moisture content to the final moisture content. In order to describe the drying behaviour of Carica Papaya leaves, 12 models proposed by previous investigators were applied to the drying process, while a new model was developed. Among these models, the drying model developed by Page showed good agreement with the data obtained from the experiments of the present study. It concludes that the model developed adequately explained the drying behaviour of the product studied at Microwave vacuum drying at 500mmHg pressure and 30% (270 Watts) microwave power level.

Conflict of interest: None.

REFERENCES

Alabi, O.A, Haruna, M.T, Anokwuru, C.P, Jegede, T, Abia, H, Okegbe, V.U, Esan, E.B. (2012). Comparative studies on antimicrobial properties of extracts of fresh and dried leaves of *Carica papaya* (L.) on clinical bacterial and fungal isolates. Pelagia Res. Libr. 3(5): 3107-3114.

Aravind, G., Debjit, B., Duraivel, S., Harish, G. (2013). Traditional and medicinal uses of *Carica papaya*. J. Med plant stud 1(1): 7-15.

Avwioro, G. (2010). Effectiveness of some medicinal plant decoction in the treatment of malaria in Nigeria. Annals Bio. Res. 1(2): 230-237.

Babalis, S.J., Papanicolaou, E., Kyriakis, N. and Belessiotis, V.G. (2006). Evaluation of thin layer drying models for describing drying kinetics of figs (*Ficus carica*). Journal of Food Engineering. 75: 205-214.

Chua, K.J., Hawlader, M.N.A., Chou, S.K., Ho, J.C. (2002). On the study of time-varying temperature drying-effect on drying kinetics and product quality. Drying Technology. 20(8): 1559-1577.

Fasola, T.R, Tyamah, P.C. (2014). Comparing the phytochemical composition of some plant parts commonly used in the treatment of malaria. Int. J. Pure Appl. Sci. Tech. 21(1): 1-11.

Henderson, S.M. and Pabis, S. (1961). Grain drying theory I: Temperature effect on drying coefficient. Journal of Agricultural Research Engineering. 6: 169-174.

Henderson, S.M. (1974). Progress in developing the thin layer drying equation. Trans ASAE. 17: 1167-8.

Karathanos, V.T. (1999). Determination of water content of dried fruits by drying kinetics. J. Food Eng. 39: 337-44.

Lewis, W.K. (1921). The rate of drying of solid materials. Journal of Industrial Engineering. 13: 427-443.

Menzies, D.J., O'Callahan, J.R. (1971). The effect of temperature on the drying rate of grass. Journal of Agricultural Engineering Research. 16(3): 213-222.

Midilli, A., Kucuk, H. (2003). Mathematical modelling of thin layer drying of pistachio by using solar energy. Energy Convers Manage. 1111-22.

Midilli, A., Kucuk, H., Yapar, Z. (2002). A new model for single layer drying. Drying Technol. 20(7): 1503-13.

Mohapatra, D. and Rao, P.S. (2005). A thin layer drying model of parboiled wheat. Journal of Food Engineering. 66: 513-518.

Overhults, D.D., White, G.M., Hamilton, M.E., Ross, I.J. (1973). Drying soybeans with heated air. Trans ASAE. 16: 195-200.

Page, G. (1949). Factors Influencing the Maximum Rates of Air Drying Shelled Corn in Thin Layers. MSc Thesis, Purdue University, Indiana, USA.

Pardeshi, I., Burbade, R.G. and Khood, R.N. (2013). Cost effective drying for high quality tender wheat grass powder. Journal of Food Research and Technology. 1(1): 1-10.

Prabhanjan, D.G., Ramaswamy, H.S. and Raghavan, G.S.V. (1995). Microwave assisted convective air drying of thin layer carrots. Journal Food Eng. 25: 283-293.

Queiroz, M.R., Nebra, S.A. (2001). Theoretical and experimental analysis of the drying kinetics of bananas. J. Food Eng. 47: 127-32.

Ren, G. and Chen, F. (1998). Drying of American ginseng (*Panax quinquefolium*) roots by microwave hot air combination. J. Food Eng. 35: 433-443.

Togrul, I.T., Pehlivan, D. (2002). Mathematical modelling of solar drying of apricots in thin layers. J. Food Eng. 55: 209-16.

Thomson, T.L., Peart, P.M., Foster, G.H. (1968). Mathematical simulation of corn drying: A new model. Trans ASAE. 11: 582-6.

Throat, I.D., Mohapatra, D., Sutar, R.F., Kapdi and Jagtap, D.D. (2012). Mathematical modelling and experimental study on thin-layer vacuum drying of ginger) *Zingiber officinale* R.) slices. Food and Bioprocess Technology. 5(4): 13779-1383.

Wang, C.Y. and Singh, R.P. (1978). A single layer drying equation for rough rice. ASAE paper no :78-3001. St. Joseph, MI: ASAE.

Yagcioglu, A., Degirmencioglu, A., Cagatay, F. (1999). Drying Characteristics of Laurel Leaves under Different Conditions. In: Proceedings of the 7th International Congress on Agricultural Mechanization and Energy. 26-27 May, Adana, Turkey. [Bascetincelik, A., (Editor)]. Faculty of Agriculture, Cukurova University. P. 565-9.

Yaldiz, O., Ertekin, C., Uzun, H.I. (2001). Mathematical modelling of thin layer solar drying of Sultana grapes. Energy. 26(5): 457-65.