International Food Research Journal 20(2): 769-774 (2013)
Journal homepage: *http://www.ifrj.upm.edu.my*

Mathematical modeling and quality characteristics of microwave dried medicinal borage leaves

[1*]Dwivedy, S., [1]Rayaguru, K. and [2]Sahoo, G.R.

[1]Department of Agricultural Processing and Food Engineering, College of Agricultural Engineering and Technology, [2]Department of Biochemistry, Orissa University of Agriculture and Technology, Bhubaneswar, Orissa, 751003, India

Article history

Received: 9 February 2012
Received in revised form: 6 August 2012
Accepted: 27 July 2012

Keywords

Microwave drying
modeling
total phenolics
antioxidant
sensory evaluation

Abstract

The leaves of Indian Borage (*Coleus aromaticus*) are very rich in nutritional as well as medicinal qualities. The present study is an effort to explore the possibility of effective utilization of the leaf which is perishable, for which dehydration is an essential method of preserving the leaves with minimum spoilage. Drying characteristics of Coleus leaves have been studied in microwave drying. To determine the kinetic parameters, the drying data were fitted to various models based on the moisture ratios versus drying time. Among the models proposed, the semi-empirical Midilli model gave the best fit for all drying conditions applied. The goodness of fit was determined using the coefficient of determination (R^2), residual sum square (RSS).The effect of the microwave power levels (180 to 900 W, at 180 W interval) on quality characteristics (total phenolics, antioxidant activity and sensory parameters) of the dried leaves has been studied. Considering the total drying time, therapeutic and sensory attributes of the dried leaves, it is proposed to dry the leaves at 540 W in a microwave dryer to obtain an acceptable product.

Introduction

Coleus aromaticus (Benth, Family:Laminaceae), commonly known as Indian/country borage is an important aromatic herb of the family Laminaceae which is routinely grown as a traditional medicinal herb in India and South East Asia .The leaves are mainly used for the treatment of stomach disorder, asthma, epilepsy and renal diseases. These are reported to have anti-oxidant and anti-microbial properties (Bos *et al*., 1983; Valera *et al*., 2003; Vijaya *et al*., 2008).

The fresh or dried leaves are also used for culinary purposes in most of the countries for flavoring, seasoning and as condiment and spice for different food preparations. Coleus leaves are a store house of vitamins and minerals. They also contain immense variety of bio-active non-nutritive health promoting factors such as antioxidants, total phenolics and dietary fibre. The high moisture content of the leaves renders them perishable and seasonal availability limits their utilization all round the year. Hence, there is a need to preserve this nature's gift through proper processing techniques for safe storage with efficient nutrition retention. (Warrier *et al*., 1995)

Dehydration is an essential method of preserving the leaves with minimum spoilage. Standardization of drying parameters is vital for producing good quality leaves which can be further used in food, pharmaceutical industries to produce spices and different drugs. Thus controlled and appropriate drying of the leaves appears to be the only alternative measure for preserving the aromatic qualities of the leaves. However, studies on the drying characteristics of Coleus leaves are scarce in the literature. Most of the conventional thermal treatments such as sun drying and hot-air drying result in low drying rates in the falling rate period which leads to undesirable thermal degradation of the finished products (Mousa and Farid, 2002). In addition to long time and environmentally dependent process, sun and shade drying is not recommended from the hygienic point of view. These also have disadvantages like inconsistent quality standards, contamination problems, low energy efficiency which are not desirable for the food industry.

As compared to the above said drying techniques, microwave drying systems offer opportunities as less

*Corresponding author.
Email: *suchi.44@gmail.com*

drying time, uniform energy distribution and high thermal conductivity with high quality of finished product (Arslan *et al*., 2008; Ozkan *et a*l., 2007). Microwave processing has been investigated as an alternative to traditional processing methods due to the speed of operation and efficient process control (Giese, 1992). Since heating takes place only in the food material and not in the surrounding medium, microwave processing can reduce energy costs. Shorter heating time also leads to greater nutrient retention, better quality characteristics such as texture and flavor. Therefore, the objectives of the present work were to: (a) Determine the effects of power level of microwave drying on drying parameters and examine the feasibility of using microwave drying to dry Coleus leaves efficiently to produce a high quality dried product. (b) Compare the fitting ability of several drying equations to express the microwave drying kinetics of Coleus leaves with the most suitable drying model.

Materials and Methods

Sample preparation

Fresh leaves of Coleus were plucked, washed free of dirt, wiped using tissue paper. Moisture content was measured by the gravimetric method using an electric convection oven (Labotech Universal Hot air Oven, ABO-14, India) and an electronic balance (ANAMED, M7000 series). Three 30 g leaf samples were dried in the oven at 1050C for 24 h to determine initial moisture content. The initial moisture content of the Coleus leaves was 6.61 kg of H_2O per kg dry matter. For the mass determination, a digital balance of 0.0001 g accuracy was used.

Microwave drying technique

A programmable domestic microwave oven (LG Intellowave3850w2G031A) with maximum output of 900 W at 2450MHz was used for the drying experiments. The dimensions of the microwave cavity were 215 mm by 350 mm by 330 mm. The oven had a fan for air flow in the drying chamber and cooling of magnetron. The moisture from drying chamber was removed with this fan by passing it through the openings on the top of the oven wall to the outer atmosphere. The oven was fitted with a glass turntable (30 cm diameter) and had a digital control facility to adjust the microwave output power by the 20% decrements and the time of processing. The microwave oven had the capability of operating at five different microwave output power levels: 180, 360, 540, 720 and 900 W. The fresh leaf material with a density of 1.4 kg/m^2 was uniformly spread on the turntable inside the microwave cavity, for an even absorption of microwave energy. Three replicates were carried out for each experiment according to preset time schedule based on the preliminary tests. Depending on the drying conditions, moisture loss was recorded at 30 sec or 1 min intervals during drying at the end of power-on time by removing the turn-table from the microwave, and periodically placing the leaf sample, on the digital balance (Soysal *et al*., 2006) and the data analyzed was an average of these results. The reproducibility of the experiments was within the range of ±5%. All weighing processes were completed in less than 10 s during the drying process. The microwave power was applied until the mass of the sample reduced to a level corresponding to moisture content of about 0.06±0.01 kg of H_2O per kg dry matter.

Analysis of drying data

In order to determine the moisture ratio as a function of drying time, six popular thin layer drying models were used (Table 1). The moisture ratio and drying rate of the Coleus leaves were calculated using the following equations:

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

$$Drying\ Rate = \frac{(M_{t+dt} - M_t)}{dt} \quad (2)$$

where MR is the moisture ratio, Drying rate is in g/100g bone dry matter per unit time, M_t is the moisture content at a specific time (g water / g dry base), M_o is the initial moisture content (g water / g dry basis), M_e is the equilibrium moisture content (g water / g dry basis), M_{t+dt} is the moisture content at t + dt (g water/ g dry base) and t is the drying time (min). The equilibrium moisture content (M_e) was assumed to be zero for microwave drying (Akpinar, 2006; Demirhan and Özbek 2010; Maskan, 2000; Prasad *et al*., 2011; Soysal, 2004).

The Microsoft Excel 2007 was used in the numerical calculations. DATAFIT 9.0 (trial version) (Okdale Engineering, 1999, USA) was used for fitting of the curves into the models. The parameters were evaluated by the non-linear least squares method. Residual sum of square (RSS) and the coefficient of determination (R^2) were used as the primary criteria to select the best equation to account for variation in the drying curves of the dried samples which are described as follows:

$$R^2 = \frac{\sum_{i=z}^{N}(MR_{pre,i} - MR_{exp,avg})^2}{\sum_{i=z}^{N}(MR_{exp,i} - MR_{exp,avg})^2} \quad (3)$$

where $MR_{exp,i}$ is the ith experimental moisture ratio, MR_{pre},i is the ith predicted moisture ratio, $MR_{pre,\ avg}$ is the average experimental moisture ratio, N is the

number of observations, p is the number of constants in the drying model. Based on the criteria of lowest RSS and highest R^2, the best model describing the thin layer drying characteristics was chosen.

Statistical analysis

Analysis of Variance was carried out for quality characteristics i.e for total phenolics (TP), antioxidant activity (AO) and sensory parameters for individual power levels by using the statistical software GENSTAT (Trial version). The significant tests have been carried out from least significant difference (LSD) values.

Quality analysis

Microwave assisted extraction (MAE)

Extraction of plant material was done by closed system of microwave assisted extraction system. (Multiwave 3000- SOLV, Anton Paar, Microwave Reaction System, Germany) following the method of Eskilson *et al*. (2000). 2 g of grounded plant sample and 20 ml of methanol: water (6:4) as solvents was taken in each vessel of the extraction unit. The temperature was maintained at 80°C during the procedure of extraction with maintaining pressure of 5.5 bras for 10 min. About 25 min was spent for cooling system. During the extraction the initial temperature was 27°C-34°C with initial pressure between 2.6 bars to 3.7 bars.

Estimation of total phenolics (TP)

The amount of the total phenolics in the extract was determined according to the Folin-Ciocalteu procedure modified by Negi and Jayaprakasha (2003). Sample was dissolved in methanol: water (6:4v/v) to make volume 0.2 ml which was then mixed with 1 ml of 10 fold diluted Folin-Ciocalteu reagent (FCR) and 0.8 ml of 7.5% of Na_2CO_3 solution. After standing for 30 min. at the room temperature the absorbance was measured at 765 nm using Perkin-Elmer UV visible spectrophotometer. The total phenolics in the test sample were calculated from the standard curve, and were expressed as Gallic Acid Equivalent (GAE) per gram of sample. 0.2 ml of methanol: water (6:4v/v) was taken in the place of plant sample as blank.

Evaluation of antioxidant property (AO)

Phospho-Molybdenum method was followed for evaluation of antioxidant activity. The assay is on the reduction of MO (VI) to MO (V) by the extract and subsequent formation of a green phosphate/MO (V) complex at acid pH. The total antioxidant capacity of plant extract as evaluated by the method of Prieto *et al*. (1999). Phospho-Molybdenum Reagent was prepared as per the standard procedure. An aliquot of 0.1 ml of plant extract having 10 µg of polyphenol was mixed with 1ml of Phospho-Molybdenum reagent. In case of blank, 0.1 ml of methanol was used in place of plant extract. The tubes were capped and incubated in a boiling water bath at 95°C for 90 min. After that the samples were cooled to room temperature, and then the absorbance of the aqueous solute as one of each was measured at 695 nm against a blank in a Perkin–Elmer UV-visible spectrophotometer.

Sensory analysis

Sensory characteristics of dried leaf samples were determined as an average score of the ten-member consumer panel using 9-point Hedonic scale. The sensory data on quality characteristics were statistically analyzed for microwave drying process conditions. Like denoted flatness (9 equivalent to most flat) and dislike denoted distortedness (1 equivalent to most distorted) for shape and intensity of greenness for colour.

Surface Colour analysis (Hunter lab colorimeter)

The surface colour of leaves obtained from different drying conditions was measured by Hunter Lab colorimeter (Colour Flex) to record the L^*, a^* and b^* value. The total color change i.e total chromatic aberration value (ΔE) was calculated by equation,

$$(\Delta E) = [(L_0 - L)^2 + (a_0 - a)^2 + (b_0 - b)^2]^{1/2}$$

The L, a and b values correspond to the values of samples at different drying temperature, whereas the values of L_0, a_0 and b_0 are related to the fresh leaf samples.

Results and Discussion

Details of drying yield and time

To investigate the effect of microwave output power on moisture content, moisture ratio, drying time, five microwave output powers 180, 360, 540, 720 and 900 W were used for drying of 1.4 kg/m^2 Coleus leaves. But the drying time requirement at 180, 360, 540, 720, 900 W was 13, 6.5, 6, 5.5 and 5 min respectively. The moisture content reduced to 6.553 to 8.059% dry basis from an initial value of 1607.65% dry basis during drying at different power levels.

Effect of power level on drying characteristics

The moisture content of the material was very high during the initial phase of the drying which resulted in a higher absorption of microwave power and higher drying rates due to the higher moisture

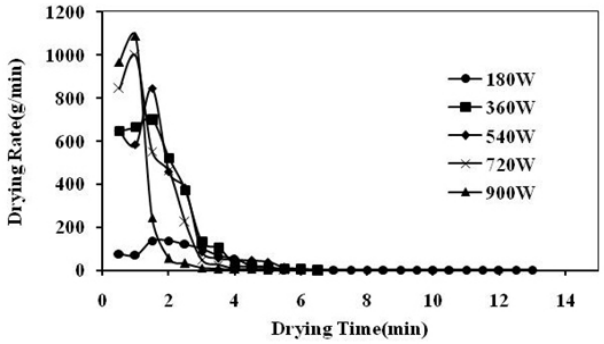

Figure 1. Variation of drying rate with drying time at different power levels

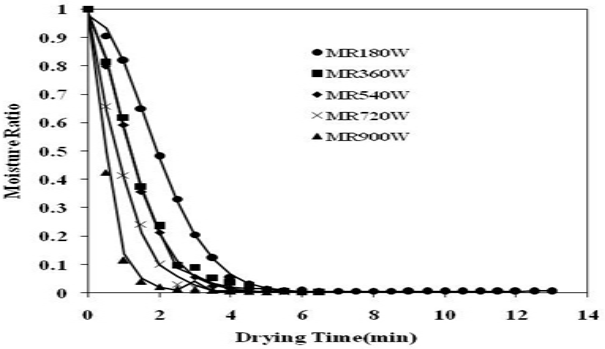

Figure 2. Variation of moisture ratio with drying time at different power levels

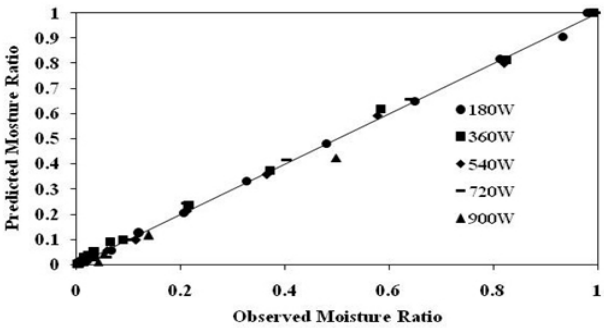

Figure 3. Variation of predicted moisture ratio (Midilli model) with

diffusion. As the drying progressed, the loss of moisture in the product caused a decrease in the absorption of microwave power and resulted in a fall in the drying rate. The drying rates increased with the increasing microwave power levels. Therefore microwave power level has an important effect on the drying rates (Figure 1). The results are in agreement with previous studies (Maskan, 2000; Soysal, 2004). As the microwave output power was increased, the drying time of samples was significantly decreased. The microwave drying process which reduced the moisture content of Coleus leaves from 1607.65% dry basis to 5.122% took 5.0-13.0 min, depending on microwave output power applied. By working at 900 W instead of 180 W, the drying time was shortened by 60%. For comparison no literature is available on drying of Coleus leaves. After a short heating period, the drying rate of sample was increased to very high values of 1058 g/ 100 g.min at 900 W to 136 g/100g. min at 180 W. As the microwave output power was increased, the drying rates also increased causing a noticeable reduction in total drying time. After a constant rate period, a falling rate period was followed, in which moisture content decreased to about 7±1% dry basis for all microwave output powers. However, these results are in agreement with the study of parsley leaves dried in a domestic microwave oven as reported by Soysal (2004) who claims that after a short heating period, a long constant rate period and a falling rate period were observed. In the present work the initial heating period decreased with increase in output power and the constant rate period is very short in some case. However, careful observation indicates that there is no significant difference in drying rate achieved at 360 W and 540 W.

Modeling of drying kinetics

Figure 2 shows the decreasing trend of MR with drying time. To describe the effect of microwave output power on the drying kinetics of the Coleus leaves, 6 different semi-empirical thin layer drying models as mentioned in Table 1 were used. Among these models examined, the Midilli model was observed to be the most appropriate one for all the experimental data with the higher value for the coefficient of determination (R^2) and lower standard error and RSS compared with those obtained for other models. Silva *et al*. (2008) also reported that Midilli model is the best model describing drying behavior of coriander and parsley leaves. The estimated parameters and statistical analysis of the models examined for the different drying conditions were illustrated in Table 2. It was observed that the value of drying rate constant (k) increased with the increase in microwave output power. This implies that with the increase in microwave output power drying curve becomes steeper indicating faster drying rate. The fitness of the data was illustrated in Figure 3.

Effect of power level on colour indices of dried leaves

Average surface colour values in terms of 'L', 'a', 'b' of fresh and dried leaves under different power levels are shown in Table 3. Lightness (+L), greenness (-a) and yellowness (+b) of fresh leaves were found to be 37.06, -7.10 and 19.55 respectively. After microwave drying all the three values decreased but the reduction in L values was not significant. Though the -a values reduced significantly, still these

Table 1. Mathematical modeling equations for drying characteristics

Name of the model	Equation	References
Midilli	$MR=a\exp(-kt^n)+bt$	Midilli *et al.,* 2002
Page	$MR=\exp(-kt^n)$	Karathanos and Belessiotis, 1999
Modified page	$MR=\exp(-kt)^a$	Yaldiz and Ertekin, 2001
Henderson and Pabis	$MR=a\exp(-kt)$	Akpinar *et al.,* 2003
Newton	$MR=\exp(-kt)$	Ayensu, 1997
Wang and Singh	$MR=1+at+bt^2$	Wang and Singh, 1978

Table 2. Results of statistical analysis on the modeling of moisture ratios and drying time for the microwave dried leaves

Power Level (Watt)	Model name	R^2	Std Error	RSS	Coefficients
180	Midilli	0.999	0.007	0.001	a=0.984,b=5.09E-04,k=0.089,n=1.925
	Page	0.999	0.009	0.002	a = 1.847, k=0.206
	Modified Page	0.951	0.071	0.124	a=0.677, k =0.677
	Henderson Pabis	0.962	0.061	0.093	a=1.132, k=0.508
	Newton	0.950	0.069	0.124	k = 0.458
	Wang and Singh	0.904	0.097	0.238	a =1.47E-02,k = -0.451
360	Midilli	0.999	0.011	0.001	a=0.991,b=6.52E-04,k =0.378, n =1.5205
	Page	0.999	0.010	0.001	a = 1.489, k = 0.550
	Modified Page	0.974	0.055	0.036	a = 0.844, k =0.843
	Henderson Pabis	0.979	0.031	0.051	a = 1.068, k =0.753
	Newton	0.974	0.053	0.036	k = 0.712
	Wang and Singh	0.974	0.055	0.037	a = 4.79E-02, k= -0.378
540	Midilli	0.997	0.019	0.003	a =0.992, b =2.50E-03,k = 0.546,n=1.527
	Page	0.996	0.019	0.004	a =1.471, k = 0.554
	Modified Page	0.973	0.057	0.036	a = 0.8341, k = 0.853
	Henderson Pabis	0.978	0.052	0.030	a =1.067, k = 0.773
	Newton	0.973	0.054	0.036	k=0.797
	Wang and Singh	0.977	0.053	0.031	a =5.13E-02, k =-0.366
720	Midilli	0.999	0.007	0.0004	a =0.996,b =1.91E-03,k =0.618,n =1.281
	Page	0.999	0.009	0.0009	a =1.256,k =0.667
	Modified Page	0.996	0.017	0.003	a =1.003,k=1.892
	Henderson Pabis	0.996	0.017	0.003	a =1.374,k=1.373
	Newton	0.996	0.016	0.003	k =1.887
	Wang and Singh	0.654	0.182	0.331	a = 9.05E-02,k =-0.255
900	Midilli	0.998	0.017	0.002	a=0.992,b = -9.01E-04,k = 0.723,n =1.25
	Page	0.990	0.015	0.009	a = 1.248,k =0.721
	Modified Page	0.9903	0.034	0.010	a = 0.991,k =1.991
	Henderson Pabis	0.9902	0.033	0.009	a = 1.024,k = 1.403
	Newton	0.9903	0.032	0.011	k =1.982
	Wang and Singh	0.968	0.062	0.350	a = 8.23E-02, k = -0.118

were within the greenness range and then same was with the +b values for which the product obtained was of yellowish green colour. The maximum loss in brightness values was observed in 180 W energy application with least 'L' value as compared to those in leaves dried under rest of the power levels. This could be due to longer drying period (13 min). Analyzing ΔE values, it is observed that the colour of the samples dried at 540 W and 720 W is closest to that of fresh leaves. No significant difference in ΔE could be observed between the samples dried at 540 and 720 W.

Table 3. Comparison between power levels for colour parameters during drying

Power level (Watt)	L	a	b	ΔL^2	Δa^2	Δb^2	ΔE^2	ΔE
Fresh	37.06	-7.10	19.55	-	-	-	-	-
180	31.10	-0.25	8.20	35.52	46.92	128.82	211.26	14.535^d
360	34.45	-0.61	12.65	6.81	42.12	47.61	96.54	9.825^c
540	36.16	-2.12	15.78	0.81	24.80	14.21	39.82	6.310^a
720	35.23	-2.48	16.26	3.35	21.34	10.82	35.52	5.959^a
900	35.11	-1.77	14.88	3.80	28.41	21.81	54.02	7.349^b

*The values having same superscript in a column are not significantly different at p<0.05

Table 4. Quality analysis of the leaves dried at different power levels

Power level (Watt)	Total phenolics (mg/100g)	Antioxidant (µM/g)	Sensory Evaluation			
			Colour	Shape	Aroma	Overall Acceptability
180	335^a	205^a	6.0^a	6.5^a	6.5^a	6.0^a
360	436^{ab}	281^b	8.0^{bc}	7.5^{bc}	8.0^{bc}	8.0^{bc}
540	692^c	377^c	8.5^c	8.0^c	8.5^c	8.5^c
720	553^{bc}	287^b	8.0^{bc}	8.0^c	8.0^{bc}	8.0^{bc}
900	372^a	181^a	7.5^b	7.0^{ab}	7.5^b	7.5^b

*The values having same superscript in a column are not significantly different at p<0.05

Effect of power level on quality parameters and sensory evaluation

Total phenolic content and Antioxidant value for fresh leaves were found to be 1180 mg/100 g and 516 µM / g respectively on dry weight basis. From Table 4 it was observed that the total phenolics and antioxidant content varied with change in microwave output powers because of its temperature sensitivity. The retention of both total phenolics and antioxidant content was more in samples dried at 540 W output power, than that obtained at rest of the power levels. This may be due to the relatively long drying time or higher temperature development, which facilitated for removal of volatile compounds. Statistical analysis indicated that the therapeutic values (TP and AO) of the dried samples were significantly less than that of fresh leaves. However, a considerable amount was still preserved in samples dried at 540 W. It is observed that 540 W yielded products with highest sensory score on all parameters .Though, change in these parameters was insignificant when the power level was increased from 540 to 720 W; there was a significant reduction in antioxidant properties in 720 W. Therefore, 540 W may be considered as suitable for drying of Coleus leaves.

Conclusion

Microwave drying technique can be successfully used to dry Coleus leaves with maximum preservation

of aroma. Drying time decreased considerably with increase in microwave output power. After a short heating period, the process attained very high drying rates followed by the falling rate period during which maximum drying took place. Among the six models proposed to describe the drying kinetic of Coleus leaves, the Midilli model provided a good agreement between experimental (observed) and predicted moisture ratio values with higher coefficients of determination (R^2) and lower reduced standard error (SEE) and residual sum square (RSS) values. The value of the drying rate constant, k, increased with the increase in microwave output power. So keeping in view the drying time and sensory attributes of the leaves, it is proposed to dry the leaves at 540 W in a microwave dryer to obtain an acceptable product with higher retention of therapeutic components.

Acknowledgement

The authors gratefully acknowledge the support provided by Orissa University of Agriculture and Technology, Bhubaneswar for carrying out the present research work.

References

Akpinar, E.K., Bicer, Y. and Yildiz, C. 2003. Thin layer drying of red pepper. Journal of Food Engineering 59: 99–104.

Akpinar, E.K. 2006. Mathematical modeling of thin layer drying process under open sun of some aromatic plants. Journal of Food Engineering 77: 864-870.

Arslan, D. and Özcan, M.M. 2008. Evaluation of drying methods with respect to drying kinetics, mineral content and colour characteristics of rosemary leaves. Energy Conversion and Management 49: 1258-1264.

Ayensu, A. 1997. Dehydration of food crops using a solar dryer with convective heat flow. Solar Energy 5: 121–126.

Bos, R., Hendriks, H. and Van Os, F.H.L. 1983. The composition of the essential oil in the leaves of *Coleus aromaticus* Bentham and their importance as a component of the Species antiaphthosae Ph. Ned. Ed. V. Pharmacy World and Science 5: 129-130.

Demirhan, E. and Özbek, B. 2010. Drying kinetics and effective moisture diffusivity of purslane undergoing microwave heat treatment. Korean Journal of Chemical Engineering 27(5): 1377-1383.

Eskilson, P., Hellstrom, G., Claesson, J., Bolomberg, T. and Sanner, B. 2000. Earth Energy Designer-EED version 2.0.

Giese, J. 1992. Advances in microwave food processing. Food Technology (Chicago) 46(9): 118-123.

Karathanos, V.T. and Belessiotis, V.G. 1999. Application of a thin layer equation to drying data of fresh and semi-dried fruits. Journal of Agricultural Engineering Research 74(4): 355–361.

Kumar, D., Prasad, S. and Murthy, G.S. 2011. Optimization of microwave-assisted hot air drying conditions of okra using response surface methodology. Journal of Food Science and Technology Issn 0022-1155:1-12.

Maskan, M. 2000. Microwave/air and microwave finish drying of banana. Journal of Food Engineering 44(2): 71–78.

Midilli, A., Kucuk, H. and Yapar, Z. 2002. A new model for single layer drying. Drying Technology 20 (7): 1503–1513.

Mousa, N. and Farid, M. 2002. Microwave vacuum drying of banana slices. Drying Technology 20: 2055–2066.

Negi, P.S. and Jayaprakasha, G.K. 2003. Antioxidant and antibacterial activities of Punica granatum peel extracts. JFS – Food Microbiology and Safety 68 (4):1473–1477.

Oakdale Engineering 1999. Data fit version 6.1. Oakdale PA15070, USA.

Ozkan, A.I., Akbudak, B. and Akbudak, N. 2007. Microwave drying characteristics of spinach. Journal of Food Engineering 78(2): 577–583.

Prieto, P., Pineda, M. and Aguilar, M. 1999. Spectrophotometric quantification of antioxidant capacity through the formation of a phosphomolybdenum complex: specific application to the determination of vitamin E. Analytical Biochemistry 269(2): 337-341.

Silva, A.S., Almeida, A.C.F., Lima, E.E., Silva, F.L.H. and Gomes, J.P. 2008. Drying kinetics of Coriander (C*oriendrum sativum*) leaves and stem. Ciencia y Tecnologia Alimentaria 6(1): 13-19.

Soysal, Y., Oztekin, S. and Eren, Ö. 2006. Microwave drying of parsley: modelling, kinetics, and energy aspects. Biosystems Engineering 93(4): 403–13.

Soysal, Y. 2004. Microwave drying characteristics of parsley. Biosystems Engineering 89(2): 167–173.

Valera, D., Rivas, R. and Avila, J.L. 2003. The essential oil of *Coleus amboinicus* Loureiro chemical composition and evaluation of insect anti-feedant effects. Ciencia 11(2): 113-118.

Vijaya, K.S., Syed, M.A., Badami, S., Anil, T.M. and David, B. 2008. Antibacterial activity of aqueous Extract of *Coleus amboinicus*. Pharmacognosy online 3: 224-226.

Wang, C.Y., and Singh, R.P. 1978. A single layer drying equation for rough rice. ASAE 78-3001.

Warrier, P.K. and Nambiar, V.P. 1995. Indian Medicinal Plants, 1st Ed, Orient Longman Ltd. Madras.

Yaldiz, O. and Ertekin, C. 2001. Thin layer solar drying of some vegetables. Drying Technology 19(3): 583–596.