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Microwave Convection Drying Characteristics of Beet Root (*Beta Vulgaris* L.) Using Modeling Equations for Drying

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Abstract

In the present work, an attempt has been made to study the effect of microwave convection drying on the drying characteristics of (*Beta vulgaris L.*). Beet root was dried at the 7% moisture content level on dry basis. The temperatures selected were 100°C to 150°C and thickness of beet root cube was 10 mm. It was also observed that the beetroot samples obtained from the Microwave convection drying system had lower final moisture content than those obtained from the other system. Two mathematical models, the Page's and the generalized exponential models, available in the literature were fitted to the experimental data. Curve expert has been used as statistical program for calculation. It shows that both model had approx same & satisfactory value for R^2 in all experiment runs and similarly standard errors of estimate are same in both models. The performance of these models is evaluated by comparing the coefficient of determination (R2) and standard error between the observed and predicted moisture ratio.

Keywords: Microwave convection drying; Beetroots; *Beta vulgaris L*; Chukander

Introduction

Beetroot (*Beta vulgaris L.*) commonly known as 'chukander', is mainly cultivated in India for its juice and vegetable value. A.D.A.M., Inc. ed. Beetroot is a rich source of potent antioxidants and nutrients, including magnesium, sodium, potassium and vitamin C, and betaine. The green leafy part of the beetroots is also of nutritional value, containing beta-carotene and other carotenoids. The nutritional benefits of beetroot are very well known. They are loaded with vitamins A, B1, B2, B6 and C. They are also an excellent source of calcium, magnesium, copper, phosphorus, sodium and iron. Fresh beetroots are exposed to spoilage due to their high moisture content. One of the preservation methods ensuring microbial safety of biological products is drying [1]. Dried beetroots can be consumed directly in the form of chips as a substitute of traditional snacks, that are rich in trans fatty acids [2], or after easy preparation as a component of instant food [3]. The goal of food preservation is to increase the time for keeping food safe while retaining quality and nutrients. Fruits and vegetables play an important role in human diet and nutrition but are highly perishable due to their high moisture content. Decreasing the moisture content of fresh foods to make them less perishable is a simple way to preserve these foods. This and other preservation methods result in the availability of a greater variety of fruits and vegetables. Drying increases the storage stability of fruits and vegetables making them available throughout the year. Drying products also play a great role in processed foods of all kinds (i.e., in soups) and ways to achieve high quality dehydrated products are desired. New techniques like infrared processing, microwave, radio frequency, and ohmic heating processes are developed to achieve the same. Drying with the microwave method is a modern, efficient method of food preservation. During Microwave drying processes, the heating period is relatively short and moisture loss is small. Microwave drying presents the following advantages over conventional thermal heating drying methods: speed of heating (time saving), uniform volumetric heating, self regulating and automatic system, higher efficiency, lower cost of processing (low energy consumption) and compatibility with conventional heating. The increased demand for plant-origin foods in fast-dehydrated form has increased interest in MW-assisted dehydration.

Materials and Method

The laboratory dryer

The Drying experiments were performed in laboratory scale microwave installed in the post harvest process and food engineering Department of G.B.Pant University of Agriculture &Technology. The schematic diagram of the Microwave is shown in Figure 1 the Microwave basically consists of an electric heater & cooling fan, temperature was controlled by the temperature sensor automatically. Microwave frequency was 2450 MHz and power was kept160 W for all drying experiments.

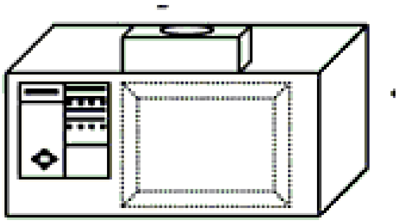

Figure 1: Schematic diagram of microwave oven.

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Drying experiments

Fresh beet root (*Beta vulgaris L.*) were obtained from a farm in Pantnagar, and stored at 3-4°C for about one day for equilibration of moisture and then used for the experiments. The initial and final moisture contents of the sample were determined according to the standard oven drying method. The initial moisture content of beetroot for all samples was found to be 483.772-654.717 (%, db). Experiments were performed at 100 to 150°C The sample, was cut uniformly with the help of stainless steel square chopper. Weight loss of samples was measured by means of weighing balance after 10 minute interval. The drying process was stopped when the moisture content decreased to 8.48-9.369% (w.b.) from an initial value of 89.53 ± 0.5% (w.b.). The product was cooled for 15 minutes after drying, and kept in desiccators. Drying tests were replicated three times at each temperature, and averages are reported.

Mathematical modeling of drying curves

Drying curves were fitted with two moisture ratio models, namely, the generalized exponential model and the Page model. Simplifying the general series solution of Fick's second law generally leads to these models. It consistently over predicts the drying rate during the early stages, and under predicts it during the later stages of drying. The Page model is an empirical modification of the simple exponential model to overcome its shortcomings. It was successfully used to describe the drying characteristics of a variety of biological materials such as red chilli, pigeon pea and carrot [4]. The model is given as

$$\frac{M - M_e}{M_o - M_e} = \exp\left(-kt^y\right)$$

Where k and y are constants in the model. The regression analysis was performed using the Statistical computer program. The goodness of fit of the tested mathematical models to the experimental data was evaluated from the coefficient of determination (R2). The generalized exponential model was used to describe drying of mint leaves and mulberry [5]. This can be written as Generalized Exponential Model

$$\frac{M - M_e}{M_o - M_e} = a\exp\left(-kt\right)$$

Where M is the moisture content (kg water/kg dry matter), M_e is the equilibrium moisture content (kg water/ kg dry matter), M_0 is the initial moisture content (kg water/kg dry matter), a and k are constants in the model.

Results and Discussion

Influence of temperature

The effect of six temperatures on the drying curve of Beet root is

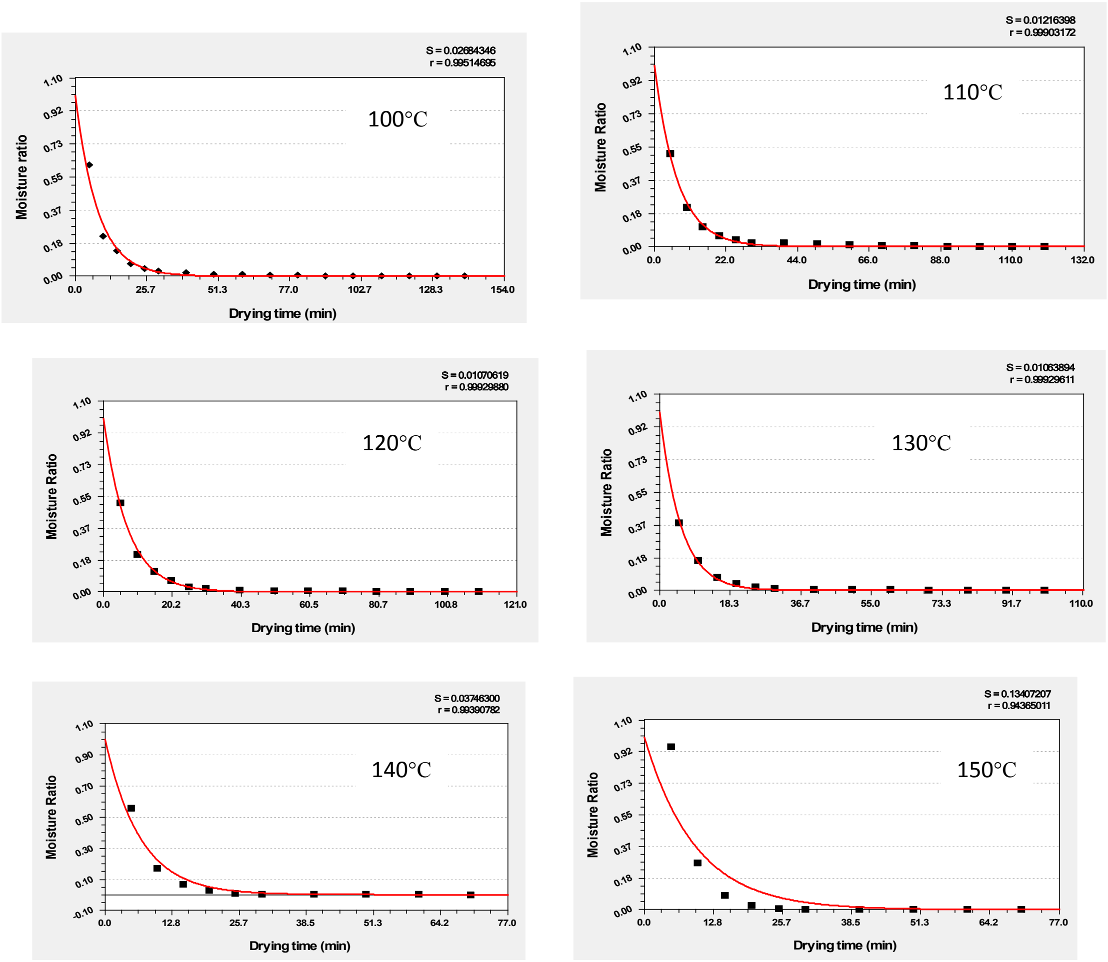

Figure 2: Variation of moisture ratio with drying time in Page's Model.

shown in Figures 2 and 3. It can be seen that there is no constant rate drying period in the drying of Beet root. All the drying in case of Beet root takes place in the falling rate period. This shows that diffusion is the dominant physical mechanism governing moisture movement in the samples. Similar results were obtained by for green bean, and for red chilli. It is obvious from Figures 2 and 3 that increasing the drying temperature caused an important increase in the drying rate, thus the drying time is decreased. The time required to reduce the moisture ratio to any given level was dependent on the drying condition, being highest at 100°C and lowest at 150°C. With drying, the time taken to reduce the moisture content of beet root from the initial 82.65-91.44% (w.b.) to a final 8.48-9.369% (w.b.) was 140, 120, 110, 100, 70, 70 min at 100, 110, 120, 130, 140, 150°C, respectively. The effect of drying air temperature was most dramatic with moisture ratio decreasing rapidly with increased temperature. Several investigators reported considerable increases in drying rates when higher temperatures were used for drying various vegetables such as carrot [4,6], garlic, and eggplant.

Evaluation of the models

These models were fitted to the experimental data in their nonlinear form with the help of Curve Expert statistical program determine the constant of models. The two models were compared on the basis of standard error of estimation (SEE) and coefficient of determination (R2). Coefficient of determination and standard error of estimation are given in Table 1 and model constant are tabulated in Table 1.

Table 2 shows that coefficient of determination R2, varied between 0.99929 and 0.94365 in case of page's model while that of generalized exponential model 0.99931-0.94942. It shows that both model had approx same value for R^2 in all experiment runs and similarly standard errors of estimate are same in both models. The experimental data are satisfactory for both models. Actual and predicted moisture ratio is shown in Figures 2 and 3.

Drying rate

The relationship between drying rate with time and moisture content are shown in Figure 4. The rate of drying as expected decreased continuously with the increase in time, being faster at higher temperature. Lot of variation was observed in the drying rate due to temperature increased in Microwave convection drying. The decrease in drying rate with the period of drying was non-linear.

The drying process of a high moisture food consists of two drying rate periods: constant rate period and falling rate period. With regard to the drying curves falling rate period took place in all the drying

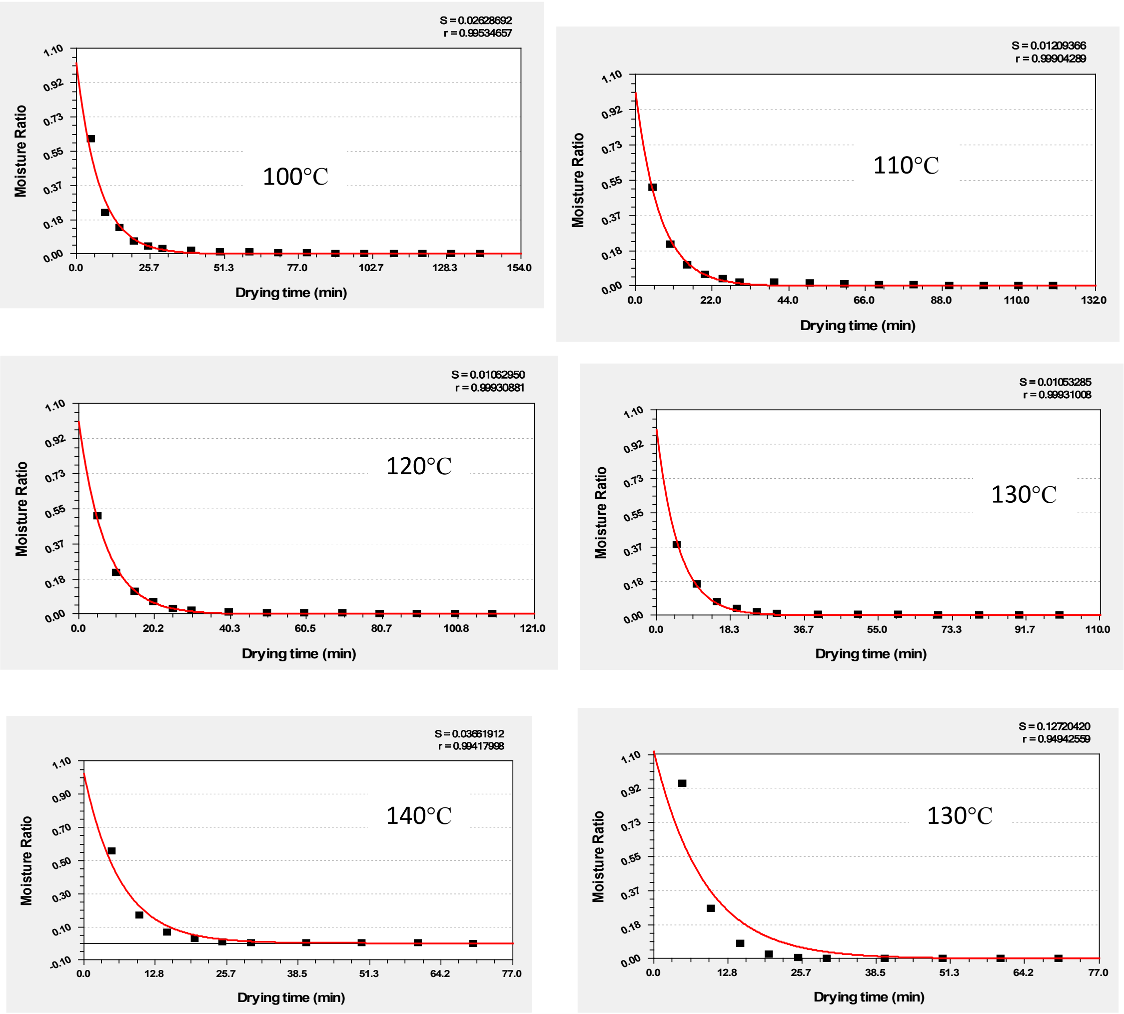

Figure 3: Variation of moisture ratio with drying time in Generalized Exponential Model.

Sample	Page's model		Generalized exponential model	
	*R^2	**SEE	*R^2	**SEE
1	0.99514	0.02684	0.99536	0.02628
2	0.99903	0.01216	0.99904	0.01209
3	0.99929	0.01070	0.99930	0.01062
4	0.99929	0.01063	0.99931	0.01053
5	0.99390	0.03746	0.99417	0.03661
6	0.94365	0.13407	0.94942	0.12720

1-100°C, 2-110°C, 3-120°C, 4-130°C, 5-140°C , 6-150°C
*Coefficient of Determination
**Standard Error of Estimation

Table 1: Statistical results obtained from the selected models.

Sample	Page's model		Generalized exponential model	
	^{1}k	^{1}Y	^{2}K	^{2}A
1	1.19632	1.02765	1.02071	1.27652
2	1.05142	1.35408	1.00472	1.42954
3	1.05111	1.347802	1.00447	1.42214
4	1.16743	1.575620	1.14832	1.83189
5	1.05167	1.377680	1.02298	1.52932
6	1.05167	1.00278	1.11598	1.140536

1- 100°C, 2-110°C, 3-120°C, 4-130°C, 5-140°C , 6-150°C
^{1} Page's model constant
^{2} Generalized exponential model constant

Table 2: Regression coefficient for drying models.

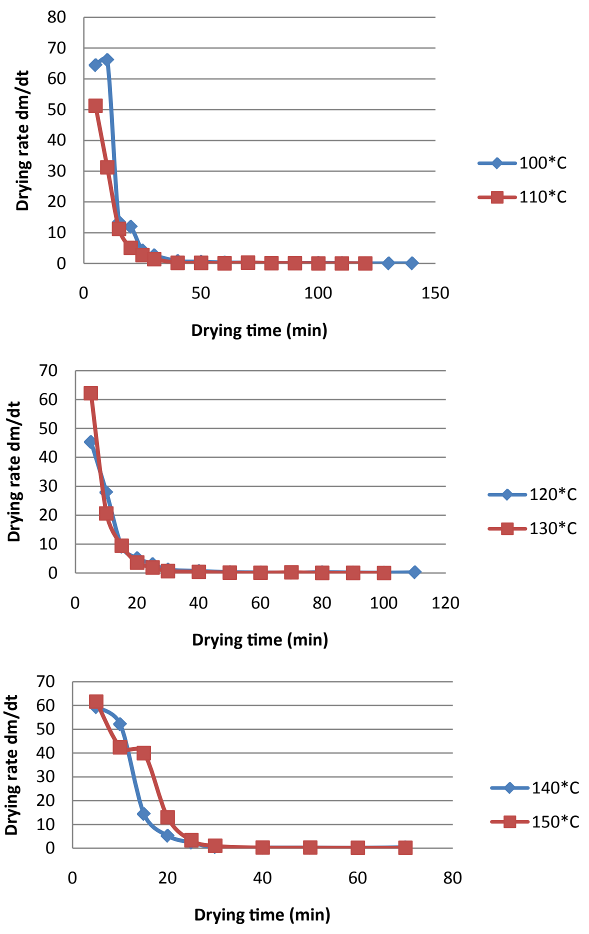

Figure 4: Variation of drying rate with moisture content.

processes of Beet root. Similar patterns have been observed in drying of quercus [7] and also similar pattern observed in drying of potato [8].

Conclusion

Microwave convection drying can greatly reduce the drying time of food materials with internal resistance to mass transfer. In the present preliminary study, beetroot (*Beta vulgaris L.*) has been dried by five different temperature levels, in all temperature levels; moisture is lost in good extent. Both the Generalized exponential and Page models can be used to describe the drying behavior, both fitted well in the experimental data the Page model showed a better fit than the simple exponential model. But the microwave convection drying proved better than the other method in terms of reduced drying time and lower final moisture content, as per the results obtained. The future research on food drying will inevitably focus on lower energy costs, less reliance on fossil fuels, and reduced greenhouse gas emissions.

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Nomenclature

a, k, y: constants of models
M: moisture content, kg water/kg dry matter
Me: equilibrium moisture content, kg water/kg dry matter
M0: initial moisture content, kg water/kg dry
R2: coefficient of determination
T: temperature (C)
T: drying time, min

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