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Research article

Effect of Drying Kinetics on the Quality of the Green Capsicum

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ABSTRACT

The effect of power (Watt) of microwave assistance drying on consumption of energy, drying efficiency and kinetic studies in green capsicum (Capsicum annum) was studied. For describing green capsicum drying behavior two mathematical models (Lewis model and Parabolic model) are used. Based on their root mean square error, χ2 and R2, values of predicted and experimental moisture content to models are compared. The drying time of green capsicum was decreased from 47 minutes to 22 minutes due to increasing power of microwave from 180 Watt to 900 Watt. The drying process was showing a falling rate period. In Lewis model the result shown most appropriate model for the study. For co-relation of moisture content with effective moisture diffusivity a third-order relationship was found. The effective moisture diffusivity of Green Capsicum samples increased as the moisture content decreased. Over the microwave power spectrum tested, the effective diffusivity ranged from 1.5 X 1012 m2/sec to 4.3 X 108 m2/sec, with an energy activation of 31.74 W/g. As microwave power and moisture content increased, so did energy efficiency.

Keywords: Green Capsicum (Capsicum annum), Drying kinetics, Microwave drying, Lewis model

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INTRODUCTION

Capsicum (Capsicum annum) contains antioxidants, proteins, dietary fiber, vitamin C and provitamin A compounds such as capsaicinoids, alkaloids, flavonoids and phenolic compounds (1). Capsicum is a perishable vegetable, so it cannot be stored at room temperature for a long time. Drying is an essential operation to extend the self-life of green capsicum after harvesting. By drying processes, microbiological action, physicochemical changes that lead to spoilage during storage are inhibited by removing moisture (2, 3).

Modern drying aims to reduce the energy utilization and provide excellence and least in economic inputs. Water is removed from capsicum by microwave drying technique for low drying time, foremost low energy consumption and superior quality of the dried product. The microwave's drying time is less due to the rapid energy absorbed by water holding capacity capsicum. However, there are few troubles with the microwave drying technique such as uneven distribution and non-uniform heating of microwave field. Quality deterioration and overheating can take place (4). The kinetics study of drying used to describe heat and mass transfer phenomenon. It is influenced by drying conditions, materials characteristics to be dried, types of the dryer, etc. Kinetics models of drying are necessary for product quality improvement and process optimization.

This study aims to determine the effect of different powers (180W, 600W, 900W) on capsicum by two thin-layer drying models: the Lewis model and the parabolic model. Equilibrium moisture ratio had a crucial character on the normalized drying curve. It was determined for green capsicum at each microwave power (180W, 600W, 900W). The kinetic models were compared on the basis of (R^2) coefficients, and model fit was analyzed by root mean square error (RMSE) value (5).

SEM has been very appealing to food scientists compared to light microscopy because it can study both surface and extrinsic property. That has a brode range of magnification and is very quick (6). This research aimed to compare the effect of microwave power levels (180W, 600W, 900W) on drying kinetics by Lewis and the Parabolic model on capsicum powder. Colour characteristic during storage (90 days) was observed on green capsicum and microwave dried capsicum.

MATERIALS AND METHODS

Raw materials

The fresh capsicums (Capsicum annum) were purchased from Kolkata, India's local market, during July-September.

Methods

The fresh capsicums were collected and thoroughly washed with water. The whole capsicum was blanched using hot water at 90o C for 3 min7 and then cooled in child water (0-4º C) and drained excess water on a perforated tray before drying. The capsicum was cut into approximately 2 cm × 2 cm size. It was then dried using microwave drying methods (MWD). The microwave drying process is done at 900 W, 600 W, 180 W. All the dried capsicum samples were taken when the moisture content was constant, approximately 3-5 %. Dried samples were made into the fine powder by kitchen mixture and stored in the refrigerator at 4º C for further analysis.

Moisture ratio

Two drying models used at three different microwave powers are shown. In Eq. (1), moisture ratio (MR) was determined by this equation:

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

Where:

Mt – Moisture content (g water/g dry matter) at any certain time (min);

M0 – Primary moisture content (g water/g dry matter);

Me– Equilibrium moisture content (g water/g dry matter);

The values of me are considered as small compared to Mt or M0, especially for microwave drying. Thus, Eq. (1) can be simplified to MR= Mt/M0.

The drying rate (DR)

The following formula calculated the drying rate (DR):

$$DR = \frac{M_t - M_{t+\Delta t}}{\Delta t} \quad \text{……….. (2)}$$

Where: M t+Δt – moisture content at time t+Δt (g water/ g dry matter);

t– Time (min)

Mathematical modeling (8, 9)

Two thin layer drying models are mentioned and examined in the research to quantify the capsicum's moisture removal behaviour and drying kinetics.

A. Lewis Model: MR= exp (–kt)

B. Parabolic Model: MR= a+ bt+ Ct2

T is the drying time in minutes, and a, b, c are the parabolic Model parameters.

MR is the moisture ratio.

K is the parameter of the Lewis model.

The coefficient of determination (R2), reduced chi-square (χ2) and root mean square error were the statistical parameters used to analyse the models that best explained the difference in the moisture ratio values of dried samples (RMSE). The greater the goodness of fit, the lower the χ2 and RMSE values are, and the higher the R2 value is.

$$\chi^2 = \frac{\sum_{i=1}^{N}(MR_{\exp.i} - MR_{\text{pre}.i})^2}{N - z} \quad \text{………… (3)}$$

$$\text{RMSE} = \left[\frac{1}{N}\sum_{i=1}^{N}(MR_{\text{pre}.i} - MR_{\exp.i})^2\right]^{1/2} \quad \text{………… (4)}$$

MRexp, i, MRpre, I – experimental and predicted value, N – number of observations; z – constants.

Diffusivity analysis

The effective diffusion coefficient D_{eff} is used in quantitative analysis of drying characteristics. Fick's second law can be used to calculate the effective moisture diffusivity, Eq. (5)[10].

$$\frac{\partial X}{\partial t} = D_{\text{eff}}\nabla^2 X \quad \text{……………. (5)}$$

Deff is the effective moisture diffusivity (m2/s), and X is the material moisture content (g water / g dry matter).

The capsicum sample is dried in two phases: a constant rate phase and a dropping rate phase. Effective moisture diffusion phenomenon could indicate the methods of moisture movement inside hygroscopic powder samples during the falling rate time[11]. The Fick's Law was used to calculate the effective moisture diffusivity.

$$MR = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\exp\left(-\frac{(2n+1)^2\pi^2 D_{\text{eff}}t}{4L^2}\right) \quad \text{… (6)}$$

Where: Deff – effective moisture diffusivity (m2/s);

t – Time (s);

L – half-thickness of samples (m);

n – Positive integer

For long drying times, only the first term in Eq. (6) is significant, and the equation simplifies to:

$$MR = \frac{8}{\pi^2}\exp\left(-\frac{\pi^2 D_{\text{eff}}t}{4L^2}\right) \quad \text{……. (7)}$$

Equation (7) can be written in a logarithmic form as follows

$$\ln(MR) = \ln\left(\frac{8}{\pi^2}\right) - \left(\frac{\pi^2 D_{\text{eff}}\ t}{4L^2}\right) \quad \text{…… (8)}$$

Deff was evaluated by plotting experimental drying data in ln (MR) versus drying time in Eq. (8). The plot produces a straight

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line with the slope as follows:

$$\text{Slope} = \left(\frac{\pi^2 D_{eff}}{4L^2}\right) \quad \ldots\ldots\ldots\ldots (9)$$

Computation of activation energy

Temperature is calculated by the modified form of Arrhenius equation[12] the equation is given as follows:

$$D_{eff} = D_0 \exp\left(-\frac{E_a m}{P}\right) \quad \ldots\ldots\ldots\ldots\ldots (10)$$

Where: Deff is the effective moisture diffusivity

Ea – Activation energy (W/kg);

P – Microwave power (W);

m – Sample weight (kg).

D0- Pre exponential factor of Arrhenius equation (m2/s)

Colour

Hunter Lab colour measurement device (Color Flex 45/ 0, D 65, 10° observer; Hunter Associates Laboratory Inc. Reston, VA) was used to investigate the colour of Capsicum at three different microwave power levels. The instrument was calibrated using a white standard plate (L*=93.49; a* =-1.07; b*=10.6). Dried samples were placed in optical glass cells that were 3.5 cm long and 6 cm wide. L* lightness (0; black to 100; white), a* redness (; green to +; red), and b* yellowness (; blue to +; yellow) values were used to express the results

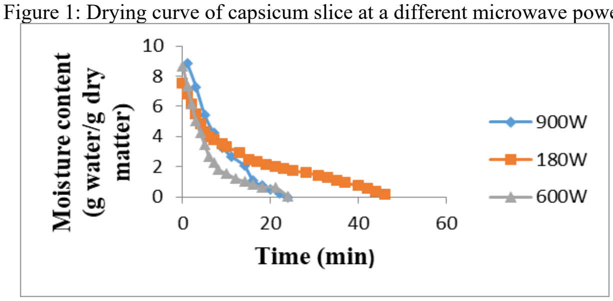
RESULTS AND DISCUSSION

Effect of the power level of microwave assistance drying of capsicum

Due to increasing power level of microwave the drying time of capsicum was reduced significantly. The mass transfer rate of dried capsicum was quick during microwave assistance heating, i.e., the microwave penetrated inside the capsicum directly. The heat was produced within the capsicums, resulting in rapid and uniform heating across the entire capsicum, resulting in a vapour pressure differential between the product's centre and surface, allowing for rapid water transport and evaporation. Free water is much more available than bound water since it can be heated and extracted.

Due to the higher moisture diffusion, the material's moisture content was very high during the initial drying phase, resulting in higher microwave absorption and higher drying rates. The loss of moisture in the product caused a decrease in microwave power absorption as the drying progressed, resulting in a decrease in the drying rate. The microwave drying process reduced the moisture content of capsicum from 8.847 g/g of d.b to 0.257 g water /g of d.b in 22 min, 7.546 g water/g of d.b to 0.1487 g water/g of d.b in 46 min and 8.68 g water/g of d.b to 0.052g water/g of d.b in 27 min at 900W, 180W and 600W. Drying curves of capsicum slice at different microwave shown in fig 1.

Figure 1: Drying curve of capsicum slice at a different microwave power



The drying rate curves for capsicum were given in fig 2.and it was observed that depending on the drying conditions, drying rates is varies from 0.053 kg/kg d.b.min to 1.97 kg/kg d.b.min for the microwave power levels between 180W, 600 W and 900W, respectively. As the power level of microwave increased, the drying rate of the sample was increased. This implies that at high voltage, heat and mass transfer and water loss is greater. The drying rates were elevated at the beginning l of the process then reduce the moisture content in the capsicum. A decrease in drying rate may be attributed to a decrease in capsicum porosity as a result of shrinkage, which increased resistance to water movement.

Figure 2: Drying rate curves for capsicum slice at a different microwave power

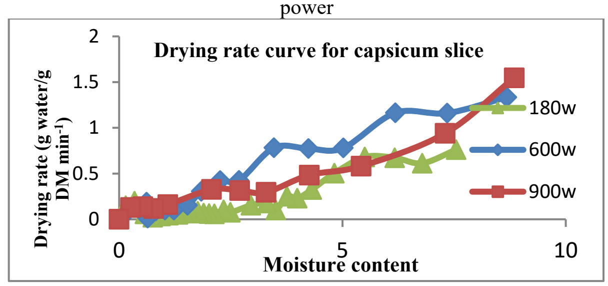
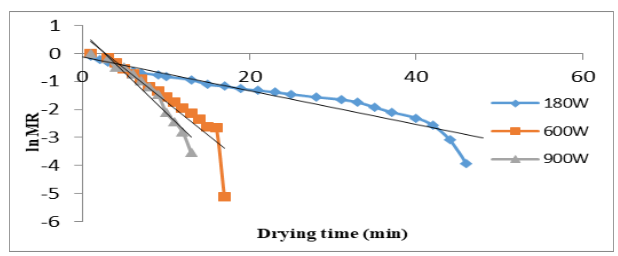


Figure 3: Drying rate curves for capsicum slice at a different microwave power



Effective moisture diffusivity

The ln (MR) graph against drying time for capsicum slices dried at 180, 600, and 900 W is shown in Fig 3. Effective moisture diffusivity is found to range between 1.5 × 10-7 m2/sec to 4.3 × 10-8 m2/s at microwave power of 180–900 W.

It is seen that Deff values increased significantly with increasing power microwave due as a result of the increasing temperature of the samples, which raised the vapour pressure The highest effective moisture diffusivity was obtained when drying at 900 W, and the lowest value was obtained when drying at 180 W.W14. This was reported that the Deff value of agriculture product range is 10-12 m2/sec to 10-8 m2/sec.

Figure 4: Effective moisture diffusivity versus microwave power

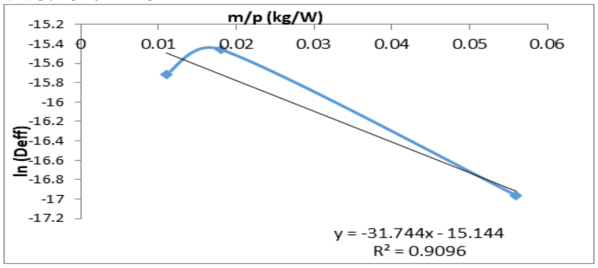
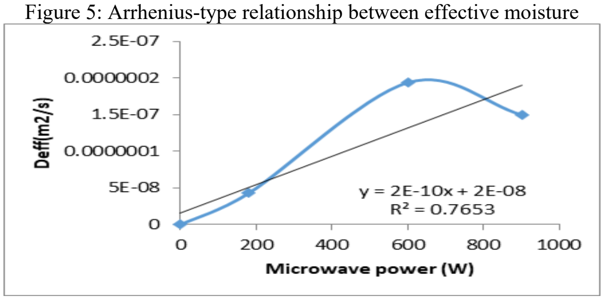


Figure 5: Arrhenius-type relationship between effective moisture



The following equation defines the effect of microwave power on effective moisture diffusivity

Deff = 2 × 10–10 x – 2 × 10–8 (R2 =0.765)....... (11)

Activation energy

The slope of the Arrhenius plot, ln (Deff) versus mass/microwave power (m/p), can be used to calculate the activation energy (Eq. 10). The slope of the line is (–Ea), and the intercept is (D0). The results show Eq. (12). The effect of sample weight/microwave power on Deff of samples with the following coefficients:

Deff = 2.65 × 10–8 exp (–31.74 m) /P (R2 = 0.9662)........... (12)

The estimated values of D0 and Ea from modified Arrhenius type exponential Eq. (12) are 2.65 × 10–8 m2/s and 31.74 g W/ g.

Models evaluation and results of statistical analysis

Two thin-layer drying models are used to explain microwave drying kinetics of capsicum, and these models are compared. For all experimental data, the Lewis model was found to be the most suitable. The model with the highest R2 and the lowest 2, AIC, BIC, and RMSE values was chosen as the best. The results of these models are represented in Table 1 and Table 2. The R2 values ranged from 0.9712 to 0.9956 for Lewis, and for parabolic, it is various from 0.9615 to 0.9817.χ2, and RMSE values for Lewis is varied from and 0.0086 to 0.03543, for parabolic 0.0475 to 0.5112 respectively. The microwave dried capsicum at 180W has the lowest Aikaike Criterion (AIC) and Bayesian-Schwartz Criterion (BIC) value and higher r2 value. When AIC and BIC are less, then the model was the best fit.

Colour characteristics in storage

The change in colour indicates that the dried green capsicum's consistency has deteriorated. Green capsicum L*, a*, and b* were L* 66.16, a* –11.370, and b* 28.33. When compared to fresh green capsicum, the L* and b* values of both dried samples decreased significantly. The dried capsicum's L* values, which indicate the product's lightness, ranged from 13.77 to 11.31. Because of the Maillard reaction triggered by a long drying period, the lowest L* value was determined for a dried product at 180 W. The differ¬ences in L* values found in the different power of dried capsicum power. For microwave drying, the highest -a* value was observed at 900 W drying. It's likely that the short drying period at this power output is to blame. As a result, the green colour of green capsicum is retained. At 900 W, the b* values for fresh and dried samples were found to be 28.130 and 12.83, respectively.

Table 1 and Table 2. Coefficients of the fitting statistics of various thin layer models at different drying powers

Model name	Lewis Model
Equation	MR= exp(–kt)
P(W)	180
	600
	900
Constants	K=0.02178
	K=0.05832
	K=0.06546
R^2	0.9956
	0.9637
	0.9712
RMSE	0.0086
	0.04625
	0.03546
Log lik	61.85
	12.82
	12.93
AIC	-163.52
	-91.60
	-61.85
BIC	-158.49
	-88.77
	-59.37
Σ	0.02287
	0.1065
	0.0932
X^2	0.00019
	0.00044
	0.0031

Model name	Parabolic Model
Equation	MR= a+ bt+ Ct^2
P(W)	180
	600
	900
Constants	a=1.043
	b= - 2.554
	c=2.723*10^{-4}
	a=0.8722
	b= -0.05
	c=0.0016
	a=0.9475
	b= -0.075
	c=0.0031
R^2	0.9615
	0.9817
	0.9717
RMSE	0.0475
	0.5113
	0.4912
Log lik	85.76
	49.802
	34.8186
AIC	-119.6
	-21.6
	-21.537
BIC	-117.1
	-20.23
	-20.72
Σ	0.0095
	0.0097
	0.01897
X^2	0.0037
	0.0051
	0.0029

Table 3. Colour characteristics during storage

Day	Microwave Power		
	600W		
	L*	a*	b*
0	13.77±0.68	0.42±0.02	15.68±0.78
15	12.98±0.62	0.68±0.03	15.89±0.79
30	12.19±0.60	0.81±0.04	16.11±0.80
45	11.84±0.59	0.97±0.04	16.71±0.83
60	11.58±0.57	1.09±0.05	16.84±0.84
75	11.48±0.57	1.18±0.05	16.93±0.84
90	11.31±0.56	1.22±0.06	17.04±0.85
		900W	
0	7.48±0.37	4.89±0.24	10.27±0.51
15	7.09±0.35	5.24±0.26	10.79±0.53
30	6.67±0.33	5.92±0.38	11.19±0.55
45	6.04±0.3	6.28±0.31	11.31±0.56
60	5.52±0.27	6.49±0.32	11.53±0.57
75	4.08±0.20	6.57±0.32	12.02±0.60
90	3.97±0.19	6.64±0.33	12.83±0.64
		180W	
0	3.04±0.15	2.44±0.12	3.97±0.19
15	2.46±0.12	2.86±0.14	4.41±0.22
30	2.04±0.10	3.14±0.15	4.87±0.24
45	1.46±0.07	3.49±0.17	4.92±0.26
60	1.12±0.05	3.89±0.19	5.17±0.25
75	1.03±0.05	4.47±0.22	5.42±0.27
90	0.88±0.044	4.97±0.24	5.81±0.29

CONCLUSION

The effect of microwave powers (180, 600 and 900 W) on capsicum by microwave drying was investigated. As the microwave power level was increased, the capsicum's drying rate was increased, and drying time was inversely proportional to the microwave power level. Lewis and Parabolic drying model justifies the drying kinetics by low RMSE value, and R2 and best fit were observed on Lewis model on capsicum drying. Effective moisture diffusivity was between 1.5 × 10-7 m2/sec to 4.3 × 10-8 m2/s at microwave power of 180W to 900W. Experimental and predicted moisture ratio values correlated well. Colour characteristics in storage prove the highest -a* value was observed at 900 W due to a short drying time; thus, greenness was preserved.

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REFERENCES

1. Materska M, Perucka I, 2005. Antioxidant activity of the main phenolic compounds isolated from hot pepper fruit (Capsicum annuum L), J of Agri Food Chem; 53:1750-56.
2. Doymaz I, Ismail O, 2011. Drying characteristics of sweet cherry, Food and Bioproducts Processing; 89: 31–8.
3. Vijayavenkataraman S, Iniyan S, Goic R, 2012. A review of solar drying technologies, Renewable & Sustainable Energy Review; 16: 2652–70.
4. Huang J, Zhang M, Adhikari B, Yang Z, 2016. Effect of microwave air spouted drying arranged in two and three stage s on the drying uniformity and quality of dehydrated carrot cubes, J of Food Eng; 177: 80-9.
5. Doymaz I, Kipcak SA, Piskin S, 2015. Microwave Drying of Green Bean Slices: Drying Kinetics and Physical Quality, Food Technology and Economy, Engineering and Physical Properties; 33 (4): 367–76.
6. Bingol D, Tekin N, Alkan M, 2010. Brilliant yellow dye adsorption onto sepiolite using a full factorial design, App Clay Sci; 50: 315-21.
7. Gupta RS, Dixit VP, Dobha MP, 2002. Hypocholesterolemic effect of the oleoresin of *capsicum annum* L, in gerbils (*Meriones hurrianae* Jerdon), J of Clinical Pharmacology; 13(3):273-75.
8. Hossain ME, Woods JL, Bala BK, 2007. Single-layer drying characteristics and colour kinetics of red chilli, Int J of Food Sci and Tech; 42: 1367–75.
9. Tunde-Akintunde TY, Ogunlakin GO, 2013. Mathematical modeling of drying of pretreated and untreated pumpkin, J of Food Sci and Tech; 50: 705–13.
10. Harahsheh M, Muhtase A, Magee T, 2009. Microwave drying kinetics of tomato pomace: Effect of osmotic dehydration, Chem Eng and Proces; 48:524–31.
11. Rayaguru K, Routray W, 2011. Microwave drying kinetics and quality characteristics of aromatic Pandanus amaryllifolius leaves, Int Food Res J; 18(3): 1035-42.
12. Dadali G, Apar DK, Ozbek B, 2007. Estimation of effective moisture diffusivity of okra for microwave drying, Drying Technology; 43: 1443–51.
13. Mahdhaoui B, Mechlouch RF, Mahjoubi A, Ben BA, 2014. Microwave drying kinetics of olive fruit (*Olea European* L), Int Food Res J; 21(1): 67-72.
14. Zogzas NP, Maroulis ZB, Marinos-Kouris D, 1996. Moisture diffusivity data compilation in foodstuffs, Drying Technology; 14: 2225–53.

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