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RESEARCH PAPER

Effective microwave drying characteristics of ginger (*Zingiber officinale*)

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SUMMARY : Ginger rhizomes and slices were dehydrated in a microwave dryer at 1.0, 1.5, 2.0 and 2.5 kW power levels and their drying characteristics such as rate of drying, diffusion rate, re-hydration ratio were studied. The qualities of dehydrated samples were evaluated on the basis of colour and ascorbic acid content. The entire drying process took place in the falling rate period. Drying curves were constructed using non-dimensional moisture ratio (MR) and time. The effective moisture diffusivity was determined by Fickian method using uni-dimensional moisture movements and values ranged from 1.2982×10^{-10} to $1.2678 \times 10^{-9} m^2/s$ within the power levels (1.0 to 2.5 kW) were studied. The samples dehydrated at 2kW showed highest retention of ascorbic acid with superior quality.

Key Words : Ginger, Ascorbic acid, Moisture diffusivity, Rehydration ratio, Drying rate

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Ginger is the most important and export oriented spice in India with largest share of 32.75 per cent of world production. However, they contain large quantity of water (approximately 85.6 per cent) and therefore suffer considerable weight loss during transportation and storage. This in the turn causes serious economic losses, due to reduction in weight and quality. Among various methods employed for preservation of ginger, drying is one of the oldest most cost effective means of preservation of foods in all varieties (Mujumdar, 2000). The present study was conducted to generate information on dehydration characteristics and effect of microwave drying of ginger.

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EXPERIMENTAL METHODS

The fresh ginger rhizomes were procured in bulk from the local market of Udaipur in the state of Rajasthan (India) which were, then washed under running water to remove adhering impurities. The ginger rhizomes were hand peeled, cut into slices (5$\pm$1 mm thickness) with a sharp stainless steel knife in the direction perpendicular to the vertical axis. Three measurements were made on each slice for ensuring proper thickness.

Microwave drying of ginger rhizomes and slices:

The ginger rhizomes and slices were dehydrated in the microwave dryer at 1.0, 1.5, 2.0 and 2.5kW. The initial mass of the samples and the mass after every 5 min during first 30 min, 10 min during second 60 min, 15 min during third 60 min drying were recorded. Subsequently the masses were recorded after every 20 minutes interval till the constant mass was observed. The moisture contents of the samples during drying were predicted by mass balance calculations. The initial moisture contents of the samples were determined by air oven method as suggested by Ranganna (2002). All the experiments were conducted in triplicate and the average of these data were used for further analysis. The drying characteristic curves were drawn, between moisture content v/s time and ln (MR) v/s time.

Moisture diffusivity:

In drying, diffusivity is used to indicate the rapidness of flow of moisture or moisture out of material. In falling rate period of drying, moisture is transferred mainly by molecular diffusion. Diffusivity is influenced by shrinkage, case hardening during drying, moisture content and temperature of material (Singh, 2001; Karim and Hawaldar, 2005).

The falling rate period in drying of biological materials is best described by simplified mathematical Fick's second law diffusion as given below:

$$\frac{\delta M}{\delta t} = D\frac{\delta^2 M}{\delta X^2}$$

where, D is moisture diffusivity, m2 /s, M is the moisture content, X is the distance form from the centre line and t is the time elapse during the drying. Assuming uniform initial moisture distribution and negligible external resistance, the solution of above mentioned equation as proposed by Crank (1975) is

$$MR = \frac{M - M_e}{M_0 - M_e} = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}\exp\left[\frac{-(2n+1)^2\pi^2 D_{eff} t}{L^2}\right]$$

where,

MR = Moisture ratio, dimensionless

M_e = Equilibrium moisture content, g water /g dry matter

M_o = Initial moisture content, g water /g dry matter

M = Moisture content at time (t), g water /g dry matter

L = Thickness of the slab, m

t = Time, s

D = Moisture diffusivity, m^2/s

Rearranging the above mentioned equations as

$$\ln[MR] = -0.21 - \left(\frac{\pi^2 D_{eff} t}{L^2}\right)$$

If the ln(MR) versus time is plotted, then it will result in a straight line with negative slope and the slope of the line can be used to predict the moisture diffusivity.

Rehydration ratio:

Rehydration tests for dehydrated samples were carried out by immersing 5 g sample in 50 ml distilled water at 35°C in a 100 ml beaker kept in a hot water bath to maintain a water temperature of 35°C for 5 hr (Nsonzi and Ramaswamy, 1998). Dehydrated samples were evaluated for rehydration ratio, from the weight before and after the rehydration.

$$\text{Rehydration ratio } (RR) = \frac{C}{D}$$

where,

C = drained weight of rehydrated sample (g)

D = test weight of dehydrated samples (g)

Colour measurement:

Colour is important to consumer as a mean of identification, as a method of judging quality and for its basic esthetic value and food is no exemption. The overall objective of colour of the food is to make it appealing and recognizable. The most common technique to assess the colour is Hunter Lab Colorimeter (McGuire, 1992).

Ascorbic acid determination:

The ascorbic acid content in the fresh and dehydrated ginger samples were determined by titration method (Ranganna, 2002).

EXPERIMENTAL FINDINGS AND ANALYSIS

The present study was conducted to study drying characteristics and the effects of microwave drying on quality of dehydrated ginger rhizomes and slices. The moisture content of the fresh ginger was found 85.6 per cent (w. b.) which reduced to 6 per cent after microwave drying at four (1.0, 1.5, 2.0 and 2.5kW) different power levels.

Microwave drying of ginger rhizomes and slices:

The drying curve of ginger rhizomes and ginger slices during microwave drying process are presented in Fig. 1 (a and b). When Fig. 1(a and b) are examined it is noted that a marked decline was noted in the drying period of samples with the increasing microwave power level (Prabhanjan *et al.,* 1995; Soysal, 2004). This is due to the fact that higher energy power which leads to a larger driving force for heat transfer (Methakhup *et al.,* 2005). The drying rates were higher in the beginning of the drying processes and gradually reduced through the end of the drying process. This was because of more energy is absorbed by the moisture at the product surface initially, resulting in faster drying and with the product surface drying out subsequently, heat penetration through the dried layer decreased thus retarding the drying rates (Sharma *et al.,* 2005). The time required for the lowering of moisture content of samples to 6 per cent on wet basis varied between 400 to 105 min for ginger rhizomes and 270 to 90 min for ginger slices at 1.0, 1.5, 2.0 and 2.5 kW microwave power level.

The natural logarithms of moisture ratio (ln MR) were plotted against average (Fig. 2a and 2b). It was observed from the figure that the relationship was non-linear in nature for all drying conditions.

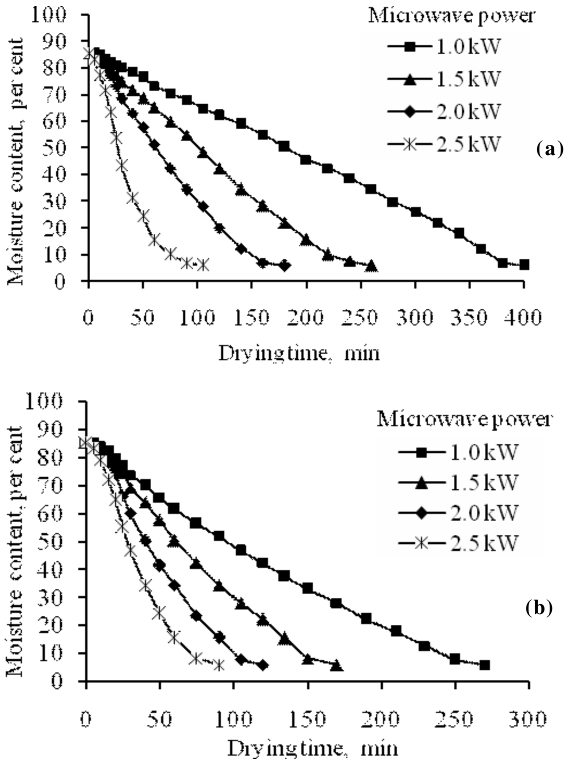

Fig. 1 : Variation in moisture content of ginger rhizomes (a) and slices (b) during microwave drying moisture diffusivity of samples

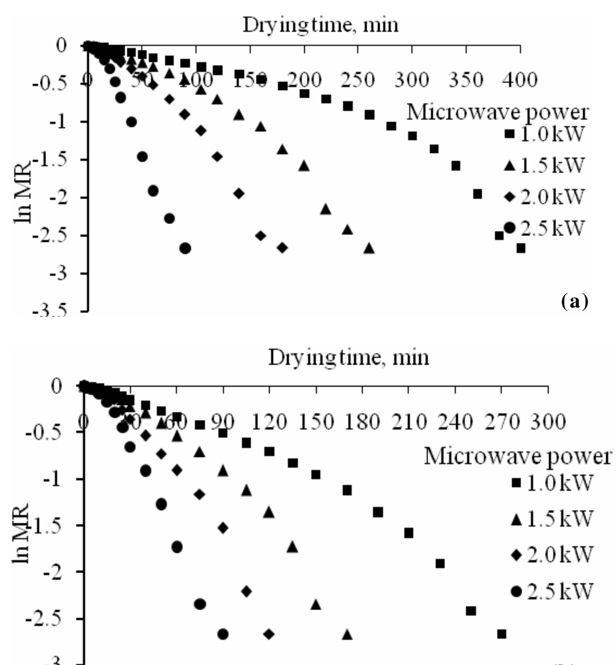

Fig. 2 : Variation in ln(MR) with drying time at different microwave power levels for ginger rhizomes (a) and slices (b)

The average effective moisture diffusivity $(D_{eff})_{avg}$ values were found in range of 1.2171×10^{-8} to 8.1139×10^{-9} for ginger rhizomes and 1.01424×10^{-9} to 5.0712×10^{-10} m^2/s for ginger slices. These values of diffusivities were in the range obtained by the other research worker (Doymaz *et al.*, 2006; Vega Galvez *et al.*, 2007).

Quality analysis:

Qualities of the dehydrated ginger rhizomes and slices were evaluated on the basis of colour and ascorbic acid content.

Colour parameter:

L* value represents lightness index of the product. Table1 shows that the greatest loss in brightness was observed at 2.5 kW power level, whereas higher values were obtained in the power levels of 1.5 kW (32.69 for ginger slices) and 2 kW (17.93 for ginger rhizomes). These results are consistent with those of Chua and Chou (2005) for carrot and Sharma *et al.* (2005) for garlic.

Ascorbic acid retention:

Reduction in the ascorbic acid levels of the samples subjected to microwave drying was recorded (Table 1) depending on time. Ascorbic acid values gave the lowest results (0.26 mg/100 g for ginger rhizomes and 0.23 mg/ 100 g for ginger slices) at the power level of 2.5kW. This could be possibly due to the exposure of product to high power level which could have affect ascorbic acid concentration. Similar, microwave cooking treatment of broccoli was realized in a study by Zhang and Hamauzu (2004).

Rehydration studies:

Rehydration capacity is an important parameter to evaluate the quality of dried products. Table 1 represents as microwave power increased rehydration ratio also increased maximum to 2.85 for ginger rhizomes and 2.94 for ginger slices at 2.5 kW. This is due to cellular and structural changes during drying process. This result agreed to Giri and Prasad (2007) in

Table 1 : Effect of drying methods on quality attributes of dried samples

Sample	Power level (kW)	Rehydration ratio	Colour (L-value)	Ascorbic acid (mg/100g)
Ginger	1.0	2.03	14.62	0.80
rhizomes	1.5	2.41	13.67	0.71
	2.0	2.64	17.93	0.81
	2.5	2.85	1.16	0.26
Ginger	1.0	2.37	32.28	0.73
slices	1.5	2.55	32.69	0.731
	2.0	2.62	31.66	0.31
	2.5	2.94	25.96	0.23

which an improvement in rehydration of dried mushroom by microwave vacuum drying was observed over hot air drying.

Conclusion:

Microwave drying of ginger slices occurred in the falling rate period and no constant rate period of drying was observed. It might be possible to dry ginger sample by combine microwave-hot air drying technique. The drying technique was more efficient than that conventional hot air drying for ginger which resulted in saving of time up to greater extent. Good quality dried ginger samples were obtained by microwave drying technique.

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