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Changes in ascorbic acid content, colour (L-value) and water activity (a_w) during air-drying of osmosed *Agaricus bisporus* slices

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ABSTRACT : The effect of different drying conditions on total drying time, ascorbic acid content, colour and water activity of osmo-dehydrated button mushroom slices were investigated at 45, 55, 65, 75 and 85^{0}C drying temperature and 1.0, 1.5 and 2.0 m/s air velocities. The retention of ascorbic acid was found to be increased with decrease in drying temperature from 85 to 65^{0}C and it decreased with further decrease in drying air temperature to 45^{0}C. Similarly, with respect to individual effect of velocity, the sample dried with lower velocity (1.0 m/s) recorded highest ascorbic acid (27.24 mg/100 g dm). As the temperature increased, L-value of colour was increased from 45^{0}C to 65^{0}C, means sample became lighter in colour and thereafter decreased at 75^{0}C. The sample dried with 2.0 m/s drying air velocity was found significantly superior with better colour (49.91). Sample with lowest water activity (0.228) was one dried at 85^{0}C drying temperature and 2.0 m/s drying air velocity and was significantly superior over the sample dried by all other combinations of temperature and velocity.

KEY WORDS : Temperature, Air-velocity, Ascorbic acid, Colour (L-value), Water activity

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Mushrooms can be treated as a healthy and nutritive food, supplying good amount of protein, minerals and vitamins. Cultivation of mushroom has now become a household name in almost all regions in India. Button mushroom is grown in cool/hilly regions (17-18^{0}C) of the country like Himachal Pradesh, Kashmir, Uttrakhand, Ooty hills, Dargiling hills and Gangtok (Sikkim) seasonally/all the year round. Mushrooms can be regarded as the vegetable of the future. A supplementary food, mushrooms are ideally suited for the Indian diet. Consumption of food is directly related to the quality. Quality commonly thought of as a degree of excellence, is one of the major positioning tool of the producer for marketability and for consumers satisfaction. Important attributes identified with food are nutritional value and colour. Nutritional value and colour are two major quality attributes of dehydrated products most important to consumers, and in general severe browning or discolouration and low nutrition levels reduce quality. Colour is one of the most important qualities of acceptance for products, reflects sensation to the human eye. Colour is important to consumer as a mean of identification, as a method of judging quality and for its basic esthetic value. Dried products are usually darker in colour, but darker colour does not mean better quality. The aim of this study was to evaluate the effect of drying temperature and air-velocity on total drying time, vitamin C (ascorbic acid) retention and colour (L-value) content of osmosed button mushroom (*Agaricus bisporus*).

METHODOLOGY

The preliminary experiment for mass transport data of button mushroom (*Agaricus bisporus*) were performed for fixing the levels of input variables for further experimentation. Based on the results of preliminary investigations on water loss and salt gain, brine to sample ratio was taken as constant at 5:1 level, which was also suggested by various researchers for various fruits and vegetables (Kar and Gupta, 2001; Pokharkar and Prasad, 2002; Pisalkar *et al*., 2011). The ranges of rest three input parameters such as solution temperature (35-55^{0}C); brine concentration (10-20%) and duration of osmosis (30-60 min) were fixed and optimized on the basis of targeted salt gain.

The optimum salt gain was decided on the basis of consumer's taste panel. However, high solid gain affects the products quality and sensory characteristics. When high levels of solids are incorporated into the products (mushroom slices) during the osmotic dehydration significant sensory

alterations can occur and the final product may present a taste that is very different from fresh sample, thus affecting the overall acceptability. Fifteen judges were given the mushroom samples having the various levels of salt gain. The judges were asked to taste the samples and give the marks according to hedonic rating test ranging from like extremely (score-9) to dislike extremely (score-1).

Numerical multi response optimization technique was carried out for the process parameters of the osmotic dehydration of mushroom sample. In order to optimize the process parameters for osmotic dehydration process by numerical optimization which finds a point that maximizes the desirability function; equal importance of '3' was given to all the three process parameters and two responses. The goal setting begins at a random starting point and proceeds up the steepest slope on the response surface for a maximum value of water loss and targeted value of salt gain.

Osmo-dehydrated products at the optimum process conditions (solution temperature = 45°C, brine concentration = 17% and duration of osmosis = 48 min) were further dried at temperature of 45, 55, 65, 75 and 85°C with air velocities of 1.0, 1.5 and 2.0 m/s.

RESULTS AND DISCUSSION

As per two independent variables (drying temperature and air velocity) having five levels of drying temperature and three levels of air velocity, total fifteen experiments were performed as enumerated in Table 1 for total drying time, Table 2 for ascorbic acid retention, Table 3 for colour (L-value) and Table 4 for water activity.

Drying time

The total drying time for convective drying of osmotically dehydrated mushroom sample is shown in Table 1. It can be seen that there was a wide variation in drying time from 270 to 780 min for the range of drying temperatures and air velocities taken for study. It can also be seen that minimum time in drying was observed for higher air temperature (85°C) and maximum time was recorded for low air temperature (45°C) for all air velocities. Drying time in general decreased with

Table 1 : Effect of temperature (T), velocity (V) and their interaction on total drying time

Temp.,°C \ Velocity, m/s	1.0	1.5	2.0	Mean
45	780	720	660	720
55	600	540	480	540
65	510	480	450	480
75	420	390	330	380
85	330	300	270	300
Mean	528	486	438	

Table 2 : Analysis of variance for the effect of process variables on the drying time

Source	DF	SS	MSS	F_{cal}	SE (m) ±	CD at 5%	C.V.%
T	4	931680	232920	6582.14**	1.9829	5.7270	1.23
V	2	60840	30420	859.65**	1.5359	4.4361	
T x V	8	5760	720	20.35**	3.4345	9.9195	
Error	30	1061.60	35.39				
Total	44						

** Indicate significance of value at P=0.01

Table 3 : Effect of temperature (T), velocity (V) and their interaction on ascorbic acid

Temp.,°C \ Velocity,m/s	1.0	1.5	2.0	Mean
45	27.45	26.49	25.31	26.41
55	28.12	27.02	26.09	27.07
65	28.83	27.45	26.71	27.66
75	27.33	25.88	24.21	25.80
85	24.48	23.29	22.14	23.30
Mean	27.24	26.02	24.89	

increase in drying temperature as well as increase in drying air velocity but the effect of temperature was more pronounced as compared to air velocity (Jain *et al*., 2011).

The ANOVA was carried out to study the effect of process variables *i.e.* temperature and velocity of drying air on drying time for drying of osmotically dehydrated mushroom samples and the same is presented in Table 2. It can be inferred from the table that drying temperature and air velocity both have significant effect at 1 per cent level on drying time during convective drying process, but influence of air velocity was not as high as drying temperature.

Second order regression model for total drying time was fitted to experimental data (Table 1). This model (Eqn. 1) shows the effect of drying temperature (T) and air velocity (V) on total drying time.

$$\text{Drying time} = 1850.251 - 27.107T - 151.501V + 0.114T^2 - 12.00V^2 + 1.500TV \quad R^2 = 0.98 \quad \text{.....(1)}$$

Ascorbic acid :

In the present study the ascorbic acid content of fresh mushroom sample was 105.29 mg/100 g dm, whereas ascorbic acid content of osmo-convectively dried mushroom sample ranged between 22.14 to 28.83 mg/100 g dm (Table 3). It revealed that in all the dried samples, the loss of ascorbic acid was greater than 75 per cent compared to fresh sample. Individual effect of temperature on ascorbic acid revealed that the retention of ascorbic acid was found to be increased with decrease in drying temperature from 85 to 65°C and it decreased with further decrease in drying air temperature to 45°C (Table 3). The loss of ascorbic acid at higher temperature (85°C) is maximum because it is thermo sensitive compound (Hawlader *et al.,* 2006) but comparative higher loss at lower temperature (45°C) might be due to long period of exposure (e.g. 660 to 780 min for 2.0 m/s to 1.0 m/s air velocity, respectively) required to dry the sample at 45°C. Similar results were quoted by Miranda *et al.* (2009). As regard to individual effect of temperature the sample dried with drying air temperature 65°C was found better and recorded significantly highest ascorbic acid (27.66 mg/100 g dm). Similarly, with respect to individual effect of velocity, the sample dried with lower velocity (1.0 m/s) recorded highest ascorbic acid (27.24 mg/100 g dm). As the velocity increased the ascorbic acid was found to be decreased slightly.

The ANOVA with respect to ascorbic acid is shown in Table 4. The table shows that the effects of temperature, air velocity, and their interaction on ascorbic acid were significant

Table 4 : Analysis of variance for two factor CRD for ascorbic acid

Source	DF	SS	MSS	F_{cal}	S.E. ±	C.D. at 5%	C.V.%
T	4	102.55	25.64	723.13**	0.0628	0.1813	0.72
V	2	41.44	20.72	584.35**	0.0486	0.1404	
T x V	8	1.44	0.18	5.07**	0.1087	0.3140	
Error	30	1.06	0.04				
Total	44						

** Indicate significance of value at P=0.01

Table 5 : Effect of temperature, velocity and their interaction on colour (L-value)

Temp., °C \ Velocity, m/s	1.0	1.5	2.0	Mean
45	40.84	42.80	44.31	42.65
55	47.11	49.44	50.37	48.97
65	56.35	57.79	60.99	58.37
75	49.66	52.65	53.87	52.06
85	38.71	39.11	40.02	39.28
Mean	46.53	48.35	49.91	

Table 6 Analysis of variance for two factor CRD for colour (L-value)

Source	DF	SS	MSS	F_{cal}	S.E. ±	C.D. at 5%	C.V.%
T	4	2553.83	563.46	324.11**	0.4395	1.269	2.72
V	2	118.96	59.18	34.21**	0.3404	0.983	
T x V	8	45.87	5.73	3.30**	0.7612	2.198	
Error	30	52.15	1.74				
Total	44						

**Indicate significance of value at P=0.01

at 1 per cent level of significance. Table 1 revealed that the sample with the highest retention of ascorbic acid (28.83 mg/ 100 g dm) was the one dried at 65°C temperature and 1.0 m/s drying air velocity and was significantly superior over all other samples.

Second order regression model was found best fitted to the experimental data (Table 3). This model [Eqn. (2)] shows the effect of drying temperature (T) and air velocity (V) on ascorbic acid.

$$\text{Ascorbic acid} = 8.126 + 0.762T - 1.873V - 0.006T^2 + 0.164V^2 - 0.015TV \quad R^2 = 0.98 \quad \text{.....(2)}$$

Colour (L-value) :

Colour is often used as an indication of quality and freshness for food products. Hence, it has become important for food processors to be able to evaluate and grade their products based on colour.

The colour of dried mushroom product was measured in terms of L-value (brightness/darkness) and shown in Table 5. The L-value of fresh mushroom sample was about 39.84. The L-values of osmo-convectively dried mushroom sample at various experimental conditions ranged from 38.71 to 60.99 (Table 5). As the temperature increased, L-value of colour was increased from 45°C to 65°C, means sample became lighter in colour and thereafter decreased at 75°C (Table 5) which may be due to discolouring the sample slightly because of elevated temperature. The drying air temperature 65°C was found better and recorded significantly highest colour (L-value = 58.37). Similar results were quoted by Shrivastava and Dutta (1999), Singh *et al*. (2007) and Murumkar *et al*. (2006). Increase in velocity also resulted in increased colour (L-value) slightly. The sample dried with 2.0 m/s drying air velocity was found significantly superior in recording better colour (L-value = 49.91).

From Table 6 it can be seen that temperature, air velocity and their interactions were significant at 1 per cent level of significance. The sample with highest L-value (60.99) was the one dried at 65°C temperature and 2.0 m/s air velocity and was significantly superior over rest of the samples dried with all other combinations of temperature and velocity (Table 5).

Second order regression model for colour (L-value) was fitted to the experimental data (Table 5). This model [Eqn. (3)] shows the effect of drying temperature (T) and air velocity (V) on colour (L-value).

$$\text{Colour (L-value)} = -113.874 + 5.021T + 7.188V - 0.039T^2 - 0.540V^2 - 0.034TV \quad R^2 = 0.91 \quad \text{.....(3)}$$

Water activity :

The water activity of fresh mushroom sample was 0.911 whereas water activities of osmo-convectively dried samples with all combinations of temperatures and velocities ranged between 0.228 and 0.418 (Table 7). As regards to individual effect of temperature, it revealed that as the temperature increased water activity decreased significantly. The sample dried at 85°C drying air temperature was having significantly lowest (0.238) water activity. Similarly as air velocity increased water activity decreased significantly but the rate was comparatively less. The sample dried with 2.0 m/s air velocity shown significantly lowest (0.228) water activity.

The ANOVA for water activity is presented in Table 8. From this table, it can be seen for temperature, air velocity and their interaction that the effect of drying temperature, air

Table 7 : Effect of temperature, velocity and their interaction on water activity

Temp.,°C \ Velocity, m/s	1.0	1.5	2.0	Mean
45	0.418	0.411	0.401	0.410
55	0.381	0.374	0.362	0.372
65	0.342	0.334	0.321	0.332
75	0.294	0.287	0.274	0.285
85	0.249	0.239	0.228	0.238
Mean	0.336	0.329	0.317	

Table 8 : Analysis of variance for two factor CRD for water activity

Source	DF	SS	MSS	F_{cal}	S.E.±	C.D. at 5%	C.V.%
T	4	0.1668	0.0417	49133.05**	0.0003	0.0009	0.28
V	2	0.0029	0.0015	1720.60**	0.0002	0.0007	
T x V	8	0.0000	0.0000	3.65**	0.0005	0.0015	
Error	30	0.0000	0.0000				
Total	44						

** Indicate significance of value at P=0.01

velocity, and their interactions were significant on water activity at 1 per cent level of significance. Table 7 revealed that the sample with lowest water activity (0.228) was one dried at 85°C drying air temperature and 2.0 m/s drying air velocity and was significantly superior over the sample dried by all other combinations of temperature and velocity.

The model that fits well to the experimental data was second order regression model Eqn. (4). This model shows the effect of drying temperature and air velocity on water activity (a_w).

Water activity (a_w) = 0.540 - 0.002T + 0.010V - 0.00002T^2 .....(4)
- 0.008V^2 - 0.00009VT R^2 = 0.99

Conclusion :

It was concluded that the drying time in general decreased with increase in drying temperature as well as increase in drying air velocity but the effect of air temperature was more pronounced as compared to air velocity.

It was found that in all the dried samples, the loss of ascorbic acid was greater than 75 per cent compared to fresh sample.

The sample with highest L-value (60.99) was the one dried at 65°C temperature and 2.0 m/s air velocity and was significantly superior over rest of the samples dried with all other combinations of temperature and velocity.

It was also found that water activity decreased significantly as the temperature increased.

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