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Study of drying characteristics of button mushroom (*Agricus bisporus*)

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SUMMARY : Dehydration of button mushrooms (*Agricus bisporus*) were carried out with various pretreatments like blanching, socking in different combination of sodium metabisulphite, potassium metabisulphite, citric acid, sugar and sodium chloride in fluidized bed dryer. The dehydration experiments were carried out at different temperature of 40, 45, 50 and 55^{0}C. The moisture loss data and drying characteristics such as drying rate, diffusivity, moisture ratio, during the drying process were determined. The qualities of dehydrated mushroom slices were evaluated on the basis of colour, appearance, rehydration ratio and veil opening by sensory evolution. The diffusion coefficient evaluated were 1.03 x 10^{-8} m^2/s to 9.64 x 10^{-9} m^2/s in tray and fluidized bed dryer, respectively. The sample treated with combination of potassium metabisuphate, citric acid, sugar and NaCl at 55^{0}C temperature were better accepted by consumer panel. The minimum and maximum rehydration ratio was found 1.90 to 2.61, respectively.

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Mushrooms are rich source of proteins, minerals and vitamins including riboflavin, niacin, folic acid, thiamine, pyrodoxine and ascorbic acid. They have been recognised as the alternative source of good quality protein per unit area and time from the worthless agrowastes. Mushrooms have traditionally been used for the medicinal and tonic properties and cosmetic products. Antitumor effects have been reported by the extracts of various edible mushrooms. Compounds extracted from white button mushroom (*Agaricus bisporus)* have been reported to have antifungal and antibacterial properties (Busswell and Chang, 1993). The high proteins, sterols, micro-elements and low caloric contents make mushrooms ideal for prevention of cardiovascular diseases (Poongkodi and Sakthisekaran, 1995). Today mushrooms are being cultivated in more than 100 countries with an estimated total production around 5 million tonnes. Out of 2000 varieties of prime edible mushrooms, about 80 have been grown experimentally and 4 to 5 species produced on industrial scale throughout the world (Chang and Miles, 1991). There are about 20 varieties of mushrooms being cultivated throughout the world as food. The production of mushroom is increasing at a fast rate from 4000 tonnes in 1985-86 to 30,000 tonnes in 1996-97 (Rama and John, 2000). Present production of mushroom in India is about 50,000 tonnes (Suman and Sharma, 2005). Although many species of mushrooms are edible, most popular ones are white button mushroom (*Agaricus bisporus*), paddy straw mushroom (*Volvariella* spp.), oyster mushroom (*Pleurotus* spp.) and Shitake (*Lentinus edodes*). In India the first three mushrooms can be artificially cultivated in different parts, depending on the suitability of season (Khader and Pandye, 1981). Mushroom (edible fungi) is the most priced commodity among vegetables. The market for mushrooms continues to grow due to interest in their culinary, nutritional and health benefits. Mushrooms are highly perishable and start deteriorating immediately after harvest. They develop brown colour on the surface of the caps due to enzymatic action of phenol oxidase and they quickly become soft at a high temperature. The rate of respiration of the freshly harvested mushroom is high, in comparison to other horticultural crops and this result in shorter shelf life.

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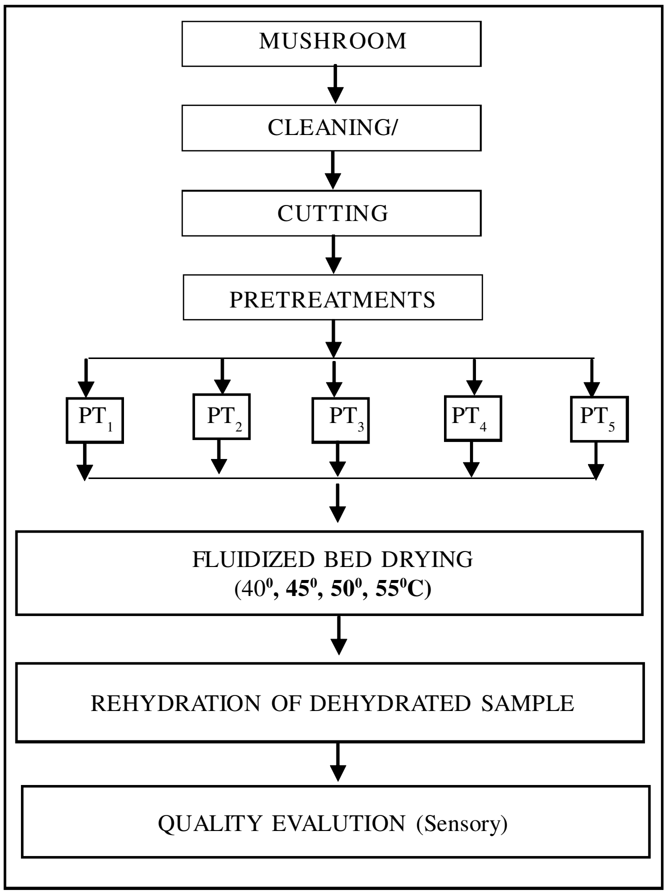
EXPERIMENTAL METHODS

Procedure for the experiment:

– The procured mushrooms were washed and cleaned thoroughly

– The mushrooms were cut in the form of slices of 0.5 cm thicknesses
– Various treatments of sodium metabisulphite, potassium metabisulphite citric acid, sugar and sodium chloride were given to mushroom slices.
– The pre-treated mushrooms were dehydrated at different temperatures and dehydration characteristics were studied.
– The rehydration of dehydrated samples was done.
– The quality of dehydrated and re-dehydrated samples of mushrooms was evaluated by sensory evaluation.



Pre-treatments :

The following pretreatments (PT) were applied to mushroom quarters:

PT_1 Blanching in boiling water for 3 min and steeping in solution of 0.5 per cent sodium metabisulphite ($NaHso_3$) + 0.25 per cent citric acid (CA)at room temperature for 15 min.

PT_2 Blanching in boiling water for 3 min and steeping in solution of 1.0 per cent potassium metabisulphite (KMS) ($KHSO_3$) +0.25 per cent CA at RT for 15 min.

PT_3 Blanching in boiling water for 3 min and steeping in solution of 0.1 per cent $KHSO_3$ +0.2 per cent CA+ 6 per cent sugar+ 3 per cent NaCl at RT for 15 min.

PT_4 Steeping in solution of 0.5 per cent $KHSO_3$ at RT for 15 min.; no blanching

PT_5 Steeping in solution of 0.1 per cent $KHSO_3$ +0.2 per cent CA+ 6 per cent sugar+ 3 per cent Nacl at RT for 15 min; no blanching.

Dehydration :

For drying of mushroom fluidized bed dryer and tray dryer were used. The details of the drying equipment and technique describe below.

Fluidized bed dryer :

The fluidized bed drying technique holds an important position among modern drying methods. The principle of operation of fluidized bed dryer is to provide sufficient air pressure to fluidize a thin bed of sample, giving an excellent air contact. It is provided with centrifugal blower equipped with 0.25hp motor having capacity 2.8 m/s with 120mm static pressure head. It consisted of one heater of 500 watts filled in insulated box. The temperature (40^0to300^0C) was controlled by thermostatic switch. The airflow rate was controlled by the butterfly valve.

Dehydration characteristics :

Initial moister content :

Initial moisture content of sample was determine by hot air over drying method as recommended by Association of Analytical Chemist (AOAC). The moisture content in per cent was calculated using equation,

$$Mw \frac{W_1 - W_2}{W_1} x100$$

where,

Mw – Moisture content of sample (% wb)
W_1 – Initial weight of sample (g)

Overall drying rate:

The overall drying rate was computed by using following equation.

$$(\Delta m/\Delta t) = \frac{Mi\text{-}Mf}{Dt}$$

where,

Mi - Initial moisture content (%) db
M_f - Final moisture content (%) db
Dt - Total drying time (min)
$(\Delta m/\Delta t)$ - Overall drying rate, per cent moisture / min.

Diffusivity :

In drying diffusivity is used to indicate the flow of moisture or moisture out of material. In falling rate of drying, moisture is transfer mainly by molecular diffusion and water is transported by diffusion from interior to surface of material. The falling rate period of biological material is best described by Fick's diffusion model as:

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

where,

D = Diffusion coefficient, m^2 /s, M is the moisture content, X is the distance 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 :

$$\frac{M - M_e}{M_o - M_e} = \frac{8}{\pi^2}\sum_{n=0}^{8}\frac{1}{(2n+1)}\exp\left[-(2n+1)^2\pi^2\frac{Dt}{L^2}\right]$$

Simplifying this by taking the first term of the series solution and assuming that M_e =0, gives:

$$MR = \frac{M - M_e}{M_o - M_e} = \frac{8}{\pi^2}\exp\left[-\pi^2\frac{Dt}{L^2}\right]$$

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 = Diffusion coefficient, m^2 /s

If ln(MR) versus time is plotted, then it would result in a straight line and the slop of the straight line could be used to predict the diffusivity

Rehydration ratio

The rehydration ratio (Ranganna, 1986) was computed by using following equation:

$$RR = \frac{WR}{WD}$$

where,

WR - Drained weight of reconstitute slice g

WD - Weight of dried sample taken for reconstitute g

RR - Rehydration ratio

Sensory evaluation and veil opening :

The evaluation was done on the basis of 9-point Hedonic scale recommended by the Bureau of Indian standard (IS, 1971). A panel of 10 judges evaluated for colour, appearance and overall acceptability of dehydrated mushroom.

Statistical analysis :

The experimental drying data statistically analyzed in terms of reduction in moisture content and moisture ratio with drying time for drying data using analysis of variance (ANOVA).

EXPERIMENTAL FINDINGS AND ANALYSIS

The results of the present study as well as relevant discussions have been presented under following sub heads:

Fluidized bed drying of mushroom slices :

The primarily processed button mushroom slices were pre-treated with chemicals.. The slices were dehydrated in the fluidized bed dryer with drying air temperature 40,45,50 and 550C. The velocity of the drying air was kept constant.

The initial weight of the samples and the weight after 15 minutes interval were recorded for initial period of one and half hour. Subsequently the weight was recorded after every 30 minutes interval till the constant weight was observed. It was found that final moisture content was in the range 11-12 per cent (w.b.) for various drying experiments.

Air drying curves for mushroom slices :

The pretreated sliced mushrooms were dried at 40, 45, 50,550C in the fluidized bed dryer. The weights of the mushroom slices at different interval of drying were recorded and moisture content of the slices was determined by mass balance equation. The variation in moisture content for different air drying temperature is also presented in Fig.1 for PT_3

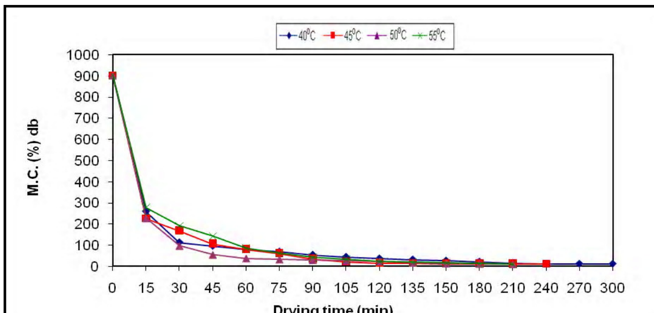


Fig. 1 : Variation in M.C. (%) db of 0.5 cm thick mushroom slices treated with PT_3 at different temperature of drying air

It can also seen that maximum moisture removal took place in initial period of drying for all the pretreatments. It can be seen that in all the experiments more than 40 per cent reduction in moisture took place in the initial period of 1 h of drying.

Drying rate curves for mushroom slices:

The drying rates of mushroom slices were determined by mass balance equation during the fluid bed drying experiment. It can be seen that the initial drying rate was different for different temperature for a particular treatment but as the drying was continuous, the curves followed the similar pattern and overlap each other. It may be due to very small variation in the value of drying rate. It can be seen from the Fig 2 that in some of the experiments at low temperature (40 and 45^{0}C) of drying air, the rate of drying did not follow the systematic pattern which may due to variation in relative humidity of ambient air which effect the drying potential of air.

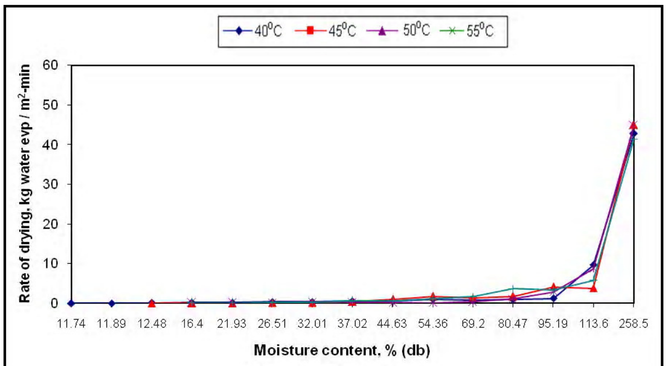


Fig. 2 : Variation in drying rate of mushroom slices treated with PT_3 at different temperature of drying air

Diffusivity of water in mushroom slices :

The moisture loss data during the air drying were analyzed and moisture ratios at various time interval of drying were determined. The calculated data were statistically analyzed and regression equations were predicted. It can be seen from Fig. 3 that ln (MR) versus time follow straight line equation with negative slope. It can also be observed that for a particular treatment, the variation in ln (MR) depended on the temperature of drying air. However, in the later part of drying the curves did not follow the straight line. The diffusivity during the air drying for various pre-treatments, temperatures of drying air were calculated by comparing the slope of curve with standard equations. The slope of curves and intercept of straight line were determined, the predicted equations and value of diffusivity with coefficient of determination are presented in Table 1.

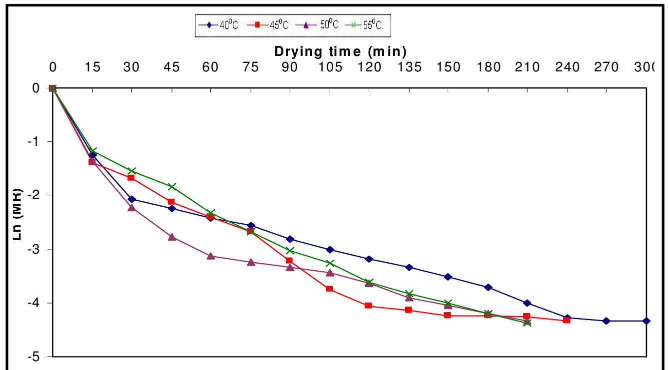


Fig. 3: Variation in Ln of MR of 0.5 cm thick mushroom slices treated with PT_3 at different temperature of drying air

Quality analysis of dehydrated button mushroom slices and veil opening:

The colour and appearance of dehydrated button mushroom slices were tested with the help of consumer

Table 1 : Predicted equations and diffusivity for PT_3 mushroom slices

Temp. (^{0}C)	Predicted equations	Diffusivity (m^2/s)	Rehydration ratio	Coefficient of determination
40	Y = (-) 0.0118 x – 1.4526	7.4 x 10^{-9}	2.02	R^2 = 0.84
45	Y = (-) 0.0166 x – 1.3085	1.05 x 10^{-8}	2.25	R^2 = 0.79
50	Y = (-) 0.0168 x – 1.4779	1.06 x 10^{-8}	2.61	R^2 = 0.79
55	Y = (-) 0.0197 x – 1.9211	1.25 x 10^{-8}	2.52	R^2 = 0.79

Table 2: Consumer panel acceptance of dehydrated mushroom slices and Veil opening

Sr. No.	Treatments	Temp.	Avg. score of panel	Comments	Veil opening
1.	PT_1	55	7	Like moderately	NVO
2.	PT_2	55	7	Like moderately	NVO
3.	PT_3	55	9	Like extremely	NVO
4.	PT_4	55	6	Like slightly	NVO
5.	PT_5	55	6	Like slightly	PVO
6.	PT_1	50	7	Like moderately	NVO
7.	PT_2	50	7	Like moderately	NVO
8.	PT_3	50	9	Like extremely	NVO
9.	PT_4	50	6	Like slightly	NVO
10.	PT_5	50	6	Like slightly	PVO

NVO – No veil opening PVO – Partial veil opening panel of 10 judges for all the samples (Table 2).It was found that the samples treated with PT_3 showed more acceptances when compared to dehydrated mushroom slices treated with PT_1, PT_2, PT_4 and PT_5.However, The veil opening of dehydrated button mushroom slices were evaluated by the judges. They observed that most of the de-hydrated samples had no veil opening and full well opening was totally absent in all the samples. However, some of the samples PT_5 had down partial veil opening.

Conclusion:

Following specific conclusions can be drawn from the study.

– The maximum moisture removal took place in initial period of drying for all the pretreatments including the all pretreated samples and in all the experiments more than 40 per cent reduction in moisture took place in the initial period of 1h in fluidized bed drying. It required approximately 7 and 5 h for completion of the drying

– The diffusion coefficient varied from 1.03 x 10^{-8} x 9.64 x 10^{-9} m^2/s in fluidized dryer, respectively. It also depends on the temperature of drying air.

– The samples pretreated with potassium metabisulphite + citric acid + sugar + NaCl (PT_3) showed more acceptance on the basis of colour and appearance and veil opening when compared to other pretreatments and was recommended.

– The minimum and maximum rehydration ratio 1.90 and 2.61 was obtained in fluidized bed drying experiments. There was not much difference in the rehydration ratio and coefficient of rehydration for all the samples.

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