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QUALITY CHARACTERISTICS OF MICROWAVE ASSISTED FLUIDIZED BED DRIED BUTTON MUSHROOMS (*Agaricusbisporus*)

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Abstract: Microwave assisted fluidized bed drying can greatly improve the quality characteristics of button mushroom (*Agaricusbisporus*) slices. The quality attributes such as colour, texture, rehydration ratio and sensory score of dehydrated mushrooms using microwave assisted fluidized bed drying were compared with fluidized bed and sun dried products. Microwave assisted fluidized bed dried mushrooms had better quality characteristics with high rehydration potential, better colour and softer texture than other drying techniques. The shrinkage and rehydration ratio of microwave assisted fluidized bed drying varied between 67.115%-69.12% and 3.12%-4.59%, respectively. Similarly, the hardness value and cohesiveness varied between 1.24-1.63 N and 0.19-0.49, respectively. L*, a* and b* values of dehydrated button mushroom were range between 76.1-78.8, -1.09-3.76 and 7.01-11.01, respectively. The microwave-fluidized dried mushrooms showed higher sensory score by sensory panel in terms of appearance, color and overall acceptability.

Key words: button mushrooms, microwave-fluidized bed drying, rehydration ratio, shrinkage, sensory score

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INTRODUCTION

Mushrooms are non-green edible fungi which comprise a large heterogeneous group having various shapes, sizes, appearance and edibility. It plays an importance role in human diet due to the presence of protein, non-starchy carbohydrates and dietary fiber, minerals and vitamins. Button mushroom (100g) contains 1.8g protein, 0.5g fat, 0.4g carbohydrate, 0.2g sugar and 0.2g starch^[1]. Button mushrooms are highly perishable as they contain moisture in the range of 6.75 to 18.9 kg/kg dry basis (87% to 95%, wet basis)^[2]. Low fat content, absence of cholesterol and high fiber content makes mushroom dietician's choice for heart patients and also inhibit aromatase activity and suppress breast cancer cell proliferation. The production of mushroom in India during the year 2013-14 was 25000 tones.

Nowadays button mushroom have enormous post harvest losses, estimated nearly as 20 to 30% of total production^[3]. So, there is a need to develop some processing techniques to reduce the post harvest losses.

Drying of button mushroom (*Agaricus bisporus*) is done by different methods viz. sun drying, tray and cabinet drying, fluidized/sprouted bed drying, microwave oven drying and freeze drying^[4].

The factors that affects drying rate are temperature, thickness of button mushroom, method of drying and moisture diffusivity. Sulphitation followed by drying is one of the pretreatment methods for button mushrooms. The drying method used in this study is microwave drying followed by fluidized bed drying technique. The microwave treatment helps for the instant loss of moisture from the sliced mushrooms while the later drying technique showed faster rate of drying with retaining the quality of the dried product. The quality evaluation of the dried mushroom was done based on shrinkage, rehydration ratio, colour, texture and sensory evaluation.

MATERIAL AND METHODS

The fresh button mushroom (4 cm size) without any defect was procured from Mushroom Research Centre, Pantnagar for the proposed study. It was washed thoroughly using potable water and soaked in 1.5% (Potassium metabisulphate) KMS solution for 15 min at room temperature for preservation. KMS preserves the natural colour of button mushroom and protects against bacteria. It was then blanched at 100°C with 3% common salt for 3 min in hot water to inactivate the enzymes and to retain the colour.

Microwave oven dryer: The drying apparatus used consisted of a microwave oven (Essential microwave oven fitted with National Magnetron with 800 Watts power and with 5 modes), which is operated at a 2450 MHz. The energy input was microprocessor controlled from 160W-800W.

Fluidized bed dryer: The fluidized bed dryer consist of a centrifugal blower, holding bin, heating coils, motor and thermostat control. The blower was centrifugal type with a capacity of 32m³/min, run by a 3 hp, 3 ϕ and 1400 rpm motor through a belt drive system. A sliding shutter was provided at the suction end to control the flow rate of air. Four fin type electrical heaters of 90 cm length were placed inside the drum. The thermostat at the discharge end measures the temperature of hot air and connected to the

main supply to control the power supply to the heater coils. Hot air of 40-75°C temperature at a flow rate of 9 to 32m³/min could be obtained in the dryer.

Experimental procedure: After chemical pretreatment in KMS and sodium chloride, button mushroom pieces were dried in microwave oven dryer and fluidized bed dryer. The drying was carried out at different operating conditions of the dryer viz. drying time in microwave oven dryer, temperature and air velocity of fluidized bed dryer. The sun drying is also carried out simultaneously for the similar pretreated button mushrooms.

Shrinkage measurement: The button mushrooms were chopped into four equal pieces and its weight and bulk volume were measured. The same experiment was conducted for dried sample. Volumetric changes after dehydration of button mushroom pieces was measured by the liquid displacement method using liquid toluene. Shrinkage was expressed in terms of percentage change in the volume of the original sample.

$$\text{Shrinkage} = \frac{V_0 - V_t}{V_0} \times 100 \quad (1)$$

Where:

V_0 [ml] Initial volume,

V_t [ml] Final volume.

Rehydration ratio: Rehydration ratio (RR), a measure of rehydration characteristics of dried mushroom slices was determined by immersing 5 g of dried samples in distilled water at 30 and 100°C temperatures. The water was drained and the samples weighed at every 30 min intervals for those immersed at 30°C and at every 2 min intervals for those at 100°C. Triplicate samples were used. Rehydration ratio was defined as the ratio of weight of rehydrated samples to the dry weight of the sample

Textural Measurement: The textural properties of rehydrated button mushroom were determined according to the procedures outlined in the ASTM methods using a texture analyzer (Model TA.HD plus, United Kingdom) [5]. Samples were fixed on the plate of the equipment and probe P/75 was moved perpendicularly to the mushroom surface at a constant speed and the force-deformation were determined.

Color Measurement: For the measurement of colour of samples combination of digital camera, computer and Adobe Photoshop 7.0 software provides a less expensive and more versatile way to determine colour parameters of food products than traditional colour measuring equipments and also good colour of sample depends upon the intensity of light and distance between sample and camera. This colour measuring technique involves setting up a lighting system, high resolution digital camera to capture images of food samples [6].

The sample was placed under the source of light at minimum distance and intensity of light over the sample should be uniform for good quality colour. Digital camera (Sony 13 mega pixels) was used to capture the image of sample. The L*, a*, b* values of samples were measured by using Adobe Photoshop 7.0 software.

RESULTS AND DISCUSSION

The optimized drying conditions for drying under microwave assisted fluidized bed drying and other drying methods viz., fluidized and suns drying are presented in Table.1.

The drying is carried out in microwave followed with fluidized bed drying, separate fluidized bed drying and sun drying. The optimization of drying parameters drying temperature, time and air velocity of mechanical dryers was done based on rate of moisture removal rate and quality of dried product.

Table.1. Optimized drying parameter for drying of button mushroom

S.No	Drying conditions	Microwave with fluidized bed dryer	Fluidized bed dryer	Sun drying
1.	Drying temperature (°C)	40	50	27 to 31*
2.	Air velocity (m/s)	3.2	3.2	-
3.	Drying time (min)	2.7 and 60 to 65	210	5760
4.	Moisture content% (d.b)	8 to 9	8 to 9	23

*Sun drying was carried out from 9 AM to 4 PM

Quality evaluation of button mushroom: The quality evaluation of dried button mushrooms under optimized conditions of the three drying types is evaluated. The shrinkage, rehydration ratio, texture, colour and sensory analysis were done for the dried product and results are discussed below. The effect of drying parameters on the quality of the dried mushroom have been analyzed statistically using regression equation with modeling equation that fit to the curve and also analyzed graphically.

Shrinkage: Dried product usually shows the shrinkage due to the removal of moisture content. Dried product always contracted in size compared to the original material [7][8]. Volumetric shrinkage is a major parameter that affects the drying rate due to change in surface area. Hence to determine the volumetric shrinkage is essential.

The average shrinkage varied from between 67.11 to 69.12%. It was lower in case of 2.5 min drying in microwave oven dryer. The shrinkage of button mushroom was 79 and 75% in case of sun drying and fluidized bed drying respectively. Higher shrinkage was seen in sun drying and fluidized bed drying than microwave assisted fluidized bed dehydration. Similar result was reported by ^[9] button mushroom pieces dried by using vacuum drying. They concluded that over drying time and loss drying has more shrinkage than average drying time.

Shrinkage of button mushroom decreased from 67.9 to 65.8% with increasing air velocity (3.2 m/s) in fluidized bed drying keeping other variables (time and temperature) at optimum point. The graph Fig. 1. Presented below shows interactive effect of air velocity and temperature on shrinkage of button mushroom. Minimum shrinkage was obtained at optimum point of air velocity (3.2 m/s) at 42°C temperature while maximum shrinkage was obtained at air velocity (1.8 m/s) at 52°C temperature. From Fig. 2, at quadratic level, it is clear that the shrinkage of button mushroom decreased from 66.4 to 64.98 and increased from 64.98 to 67.2 with increasing drying time (3 min) in microwave oven dryer keeping variable (temperature and air velocity) at optimum point. The rehydration property is important for the better market value and consumer acceptability of the dried mushrooms. It was analyzed in terms of the ability of the dehydrated button mushroom to regain the original product characteristics. Rehydration kinetics was studied for a period of 5 min at 100°C temperature. The result of rehydration ration was statistically analyzed using regression analysis. Second order mathematical model (Eq.6.) was fitted into the rehydration ratio data to analyze the effect of variables.

Fresh sample had moisture content of about 90.33% and it decreased with increase in temperature. The average rehydration ratio varied between 3.12 to 4.59. Similar result was found by^[10]. Rehydration ratio was higher in the case of 2.5 min drying in microwave oven dryer and it was 2.12 and 2.52 for sun drying and fluidized bed drying respectively. It was significantly lower in case of sun drying and fluidized bed drying than microwave assisted fluidized bed dehydration. This is attributing to less shrinkage of dried material. ^[10]Reported that the rehydration ratio of button mushroom dried using freeze drying was 3.416 and for microwave finish drying rehydration ratio was 2.850.

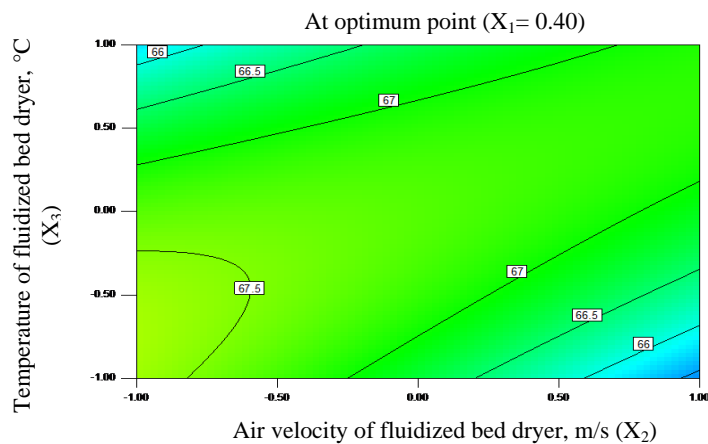


Figure 1. Temperature versus air velocity of fluidized bed dryer at interactive level

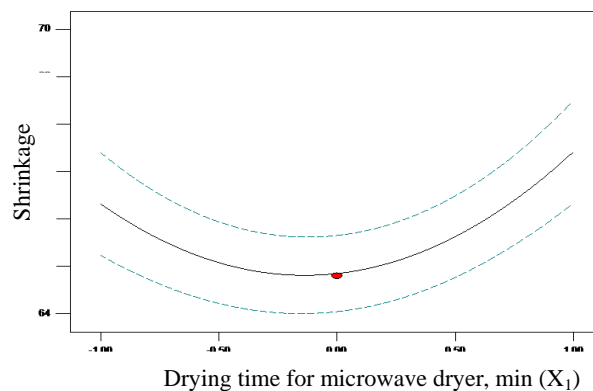


Figure 2. Shrinkage versus drying time for microwave dryer at quadratic level
Rehydration ratio

Total effect of individual parameter on rehydration ratio was calculated using the sequential sum of squares. It was observed that drying time for microwave oven dryer affected Rehydration ratio significantly at 1% level of significance, air velocity of fluidized bed dryer at 5% level of significance and temperature of the fluidized bed dryer affect 10% level of significance. Similar result was obtained by [11].

Second order predictive quadratic equation for Rehydration ratio (%) is given below:

$$Y = 4.34 - 0.039X_1 - 0.027X_2 - 0.18X_3 + 0.34X_1X_2 - 0.030X_1X_3 + 0.0074X_2X_3 - 0.74X_1^2 - 1.10X_2^2 + 0.15X_3^2 \quad (2)$$

Where:

- Y [-] Rehydration ratio,
 X_1 [s] Drying time for microwave oven dryer,
 X_2 [m/s] Air velocity of fluidized bed dryer,
 X_3 [°C] Temperature of the fluidized bed dryer.

The interactive effect of air velocity and drying time on rehydration ratio of button mushroom. Maximum rehydration ratio was obtained at optimum point of drying time (2.5 min) at 3.2 m/s air velocity while minimum rehydration ratio was obtained at drying time 2 and 3 min in microwave oven dryer. It decreased from 3.49 to 4.5 and gradually decreased from 4.5 to 4.2 with increasing drying time in microwave oven dryer keeping other variables (air velocity and temperature) at optimum point.

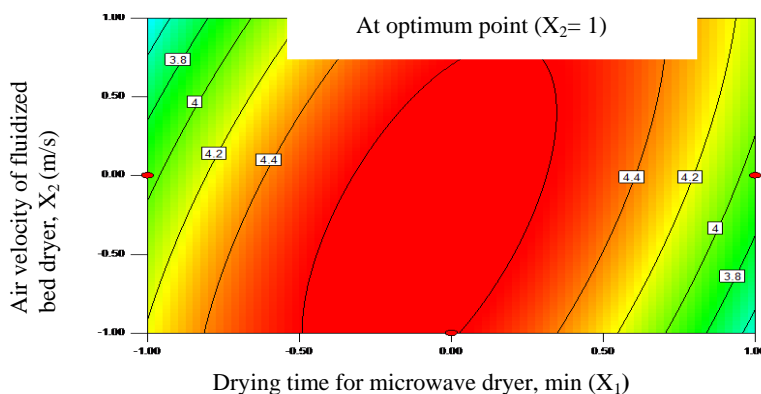


Figure 3. Rehydration ratio versus temperature of fluidized bed dryer at linear level

Texture characteristics: Texture characteristics of rehydrated button mushroom pieces were studied in terms of hardness and cohesiveness. Texture of button mushroom pieces was measured using Texture analyzer. The hardness value varied between 1.24 N to 1.63 N and cohesiveness varied from 0.19 to 0.49 for microwave assisted fluidized bed drying.^[12] Observed the same trend of hardness and cohesiveness for rehydrated button mushroom. Hardness was 2.56 and 2.13 and cohesiveness was 0.07 and 0.10 in case of sun drying and fluidized bed drying respectively. The hardness was higher and cohesiveness was less in case of sun drying and fluidized bed drying than microwave assisted fluidized bed dehydration. It was also observed that hardness was increased and cohesiveness was decreased with increase in drying time and temperature.

It was observed that drying time for microwave oven dryer affected Hardness significantly at 1% level of significance, air velocity of fluidized bed dryer and temperature of the fluidized bed dryer affect 10% level of significance. Similar result

was obtained by ^[13]. In the present study, effect of three variables on Hardness was observed.

The graph Fig.4. below indicates that hardness of rehydrated button mushroom is increased from 1.38 to 1.29 and increased from 1.29 to 1.63 with increasing in drying time in microwave oven dryer keeping other variables (air velocity and temperature) at optimum point. It also increases with increase in air velocity in fluidized bed dryer keeping at optimum point.

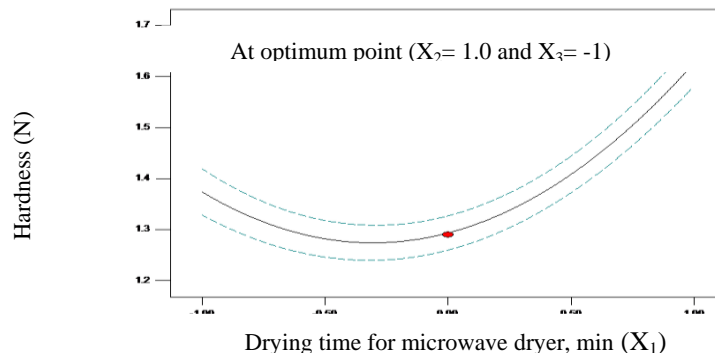


Figure 4. Hardness versus drying time for microwave dryer at linear level

The cohesiveness of rehydrated button mushroom increased from 0.32 to 0.46, decreased from 0.46 to 0.18 with increasing in drying time in microwave keeping other variables (air velocity and temperature) at optimum point. It increased from 0.39 to 0.41 and start decreasing from 0.41 with increasing air velocity of fluidized bed dryer keeping other variables (drying time and temperature) at optimum point.

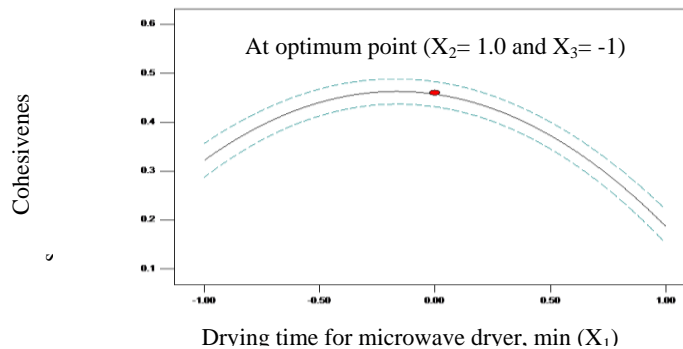


Figure 5. Cohesiveness versus drying time for microwave dryer at linear level

Colour characteristics: The colour of dried button mushroom indicates its quality of consumer acceptability pieces were measured in terms of L^* value (darkness/brightness), a^* value (greenness/redness) and b^* value (blueness/yellowness). L^* , a^* and b^* values of fresh button mushroom pieces was 85.2, 0.5 and 9.11. L^* , a^* and b^* values of dehydrated button mushroom were range between 76.1 to 78.8, -1.09 to 3.76 and 7.01 to 11.01 respectively. Similar result was found by ^[14]. The L^* , a^* and b^* of button

mushroom was 70.3, -1.20 and 8.02 in case of fluidized bed drying but L^* was 72.8, a^* was -1.29 and b^* was 7.56 in sun drying. The sun dried product was dark than fluidized bed dried than microwave assisted fluidized bed dehydration.

The below figures give a clear difference in colour of sliced dried button mushrooms using different drying technique.

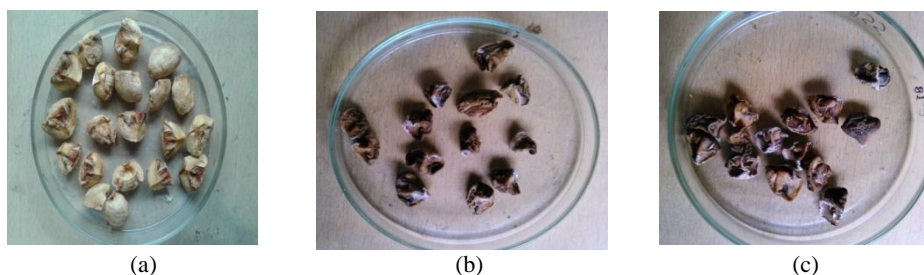


Figure 6. Dried sliced button mushroom (a) Microwave assisted fluidized bed dehydrated button mushroom; (b) Sun dried button mushroom; (c) Fluidized bed dried button mushroom

The L^* value decreased from 78.6 to 77.6 with increase drying time in microwave oven dryer keeping other variables (air velocity and temperature) at optimum point.

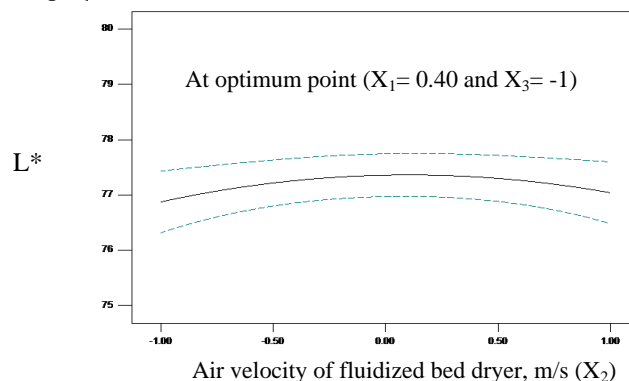


Figure 7. L^* versus air velocity of fluidized bed dryer at quadratic level

The value of a^* increased from -0.07 to 2.09 with increasing in microwave dryer and fluidized bed dryer other variables at optimum point. The b^* value increased from 7.8 to 10.98 and decreased from 10.98 to 10.70 in microwave dryer and increased from 9.48 to 10.97 in fluidized bed dryer, this may be significantly influenced by optimum drying temperature^[15].

CONCLUSION

Button mushroom is highly perishable in nature; therefore, its shelf life needs to be extended to use it during off season. It has a very high level of moisture content hence it needs preservation. Dehydration is the most important method for preservation of button

mushroom with an ultimate aim of improving storability by reducing its moisture content. Removal of water from button mushroom prevents microbial growth and thus makes storage without refrigeration possible. Microwave assisted fluidized bed drying of mushroom was much faster than fluidized bed and sun drying. Particularly towards the end of the drying process

Result of the study shows that microwave assisted fluidized bed dried mushroom created a more porous dehydrated product, shrinkage slightly reduced then rehydrated more quickly. The hardness was lower and cohesiveness was higher for microwave assisted fluidized bed dried. The drying time range from 60 to 65 min for microwave assisted fluidized bed drying whereas 210 min for separate fluidized bed was drying and 4 days for sun drying to dry the button mushroom up to 23.00% moisture content (d.b.). The shrinkage and rehydration ratio of microwave assisted fluidized bed dried mushroom varied from 67.11 to 69.12%. and 3.12 to 4.59. whereas shrinkage of button mushroom was 79 and 75% in case of sun drying and fluidized bed drying respectively. The rehydration ratio for sun drying and fluidized bed drying 2.12 and 2.52 respectively. It is concluded that the quality of the dried button mushroom was high in case of microwave assisted fluidized bed dryer.

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KVALITATIVNE KARAKTERISTIKE MIKROTALASNOG SUŠENJA PEČURKI U FLUIDIZOVANOM SLOJU (*Agaricusbisporus*)

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Sažetak: Mikrotalasno sušenje u fluidizovanom sloju može značajno da unapredi kvalitet pečurki (*Agaricusbisporus*). Kvalitativne osobine kao što su boja, tekstura, odnos rehidracije i ukus dehidriranih pečurki su poređene sa pečurkama sušenim na suncu. Mikrotalasno sušenje je dalo bolji kvalitet sa velikim potencijalom rehidracije, lepšom bojom i mekšom teksturom nego druge tehnike sušenja. Skupljanje i odnos rehidracije bili su 67.115% - 69.12% i 3.12% - 4.59%, redom. Slično, tvrdoća i kohezija su iznosili 1.24 - 1.63 N i 0.19 - 0.49, redom. L*, a* i b* vrednosti dehidriranih pečurki su iznosile 76.1 - 78.8, -1.09 - +3.76 and 7.01 - 11.01, redom.

Ključne reči: pečurke, mikrotalasno sušenje u fluidizovanom sloju, odnos rehidracije, skupljanje

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