



Quality Characteristics of Microwave-Vacuum Dried Button Mushrooms (*Agaricus Bisporus*)

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Abstract: Button mushroom (*Agaricus bisporus*) slices as well as whole mushrooms were dried by microwave-vacuum drying technique to a moisture content of around 6 % (d.b.). The dehydrated mushrooms were compared with hot-air dried products on the basis of different quality attributes such as colour, texture, rehydration ratio and sensory score. Statistical analysis of data revealed significant difference among the drying methods for all the attributes at $p \leq 0.05$. Microwave-vacuum dried mushrooms had significantly higher rehydration potential, lower density, better colour and softer texture than those obtained by air drying. The microwave-vacuum dried mushrooms were rated much better than air dried products by a sensory panel in terms of appearance, color and overall acceptability.

Keywords: *Button mushrooms; Microwave-vacuum drying; Rehydration ratio; Texture; Sensory score.*

INTRODUCTION

Mushrooms are extremely perishable in nature and may not be kept for more than one day after harvesting at ambient conditions. Various physiological and morphological changes occur after harvest, which make these mushrooms unacceptable for consumption. Among different varieties, the button mushroom (*Agaricus bisporus*) is the most widely cultivated and consumed mushroom in the world and it contributes

around 40% of the total world production of mushroom.

Drying is one of the important preservation methods employed for storage of mushrooms and dehydrated mushrooms are valuable ingredients in a variety of food formulations such as instant soups, sauces, snacks, pizzas, and meat and rice dishes. In recent years, much attention has been paid to the quality of foods during drying and several new methods have

been proposed in the technology of food dehydration. The methods of drying as well as physiological changes that occur in foods during drying affect the quality of the dehydrated products. More specifically, the duration and temperature of the drying process are the important factors affecting the properties such as colour, texture, density, porosity and sorption characteristics of the dehydrated materials (Yang and Atallah, 1985; Krokida *et al.*, 1998). Several methods of drying button mushrooms have been proposed in literature (Komonowsky *et al.*, 1970; Van Arsdell *et al.*, 1973; Gromley & O'Riordion, 1976; Mudahar & Bains, 1982; Pruthi *et al.*, 1984; Yapar *et al.*, 1990; Riaz *et al.*, 1991; Riva *et al.*, 1991; Suguna *et al.*, 1995; Gothandapani *et al.*, 1997; Seyhan & Evranzu, 2000; Torringa *et al.*, 2001; and Martinez-Soto *et al.*, 2001). As mushrooms are very sensitive to temperature, choosing the right drying method can be the key for producing high quality dehydrated mushrooms.

Conventional air drying is one of the most frequently used methods for mushroom dehydration, which involves thermal and/or chemical pretreatment and drying at temperature maintained between 50 and 70 °C. Due to long drying time and overheating of surface during hot air drying, the problems of darkening in colour, loss in flavour and decrease in rehydration ability occur. Freeze drying produces a high quality product, but being an expensive process, its application for mushroom drying is limited. Recently, microwave-vacuum drying (MVD) has been proposed as an alternative to dry heat-sensitive products since it can combine the advantages of drying at reduced temperature to those of microwave drying (Drouzas and Schubert, 1996; Yongsawatdigul and Gunasekaran, 1996b; Lin *et al.* 1998; Durance and Wang, 2002; Cui *et al.*, 2003; Giri and Prasad, 2006). The low temperature and fast mass transfer conferred by vacuum combined with rapid energy transfer by microwave heating generates very rapid, low temperature drying and thus it has the potential to improve energy efficiency and product quality.

The acceptance of a dehydrated product by consumers depends on important characteristics of the product such as structural, textural, sensory, microbiological and rehydration properties (Karathonos *et al.*, 1996). Hence, the objective of this study was to compare the quality attributes such as colour, texture, rehydration ratio, density, ascorbic acid content, and sensory score

of microwave-vacuum dried button mushrooms with conventional air dried products.

MATERIALS AND METHODS

Fresh button mushrooms (*Agaricus bisporus*) were obtained and kept in cold storage at 5-7 °C. Prior to drying experiments, mushrooms were thoroughly washed to remove the dirt. Moisture content of the mushrooms was determined in a vacuum oven maintained at 70°C and at a pressure of 100 mm Hg for around 16 hours when the constant sample weight was obtained (Ranganna, 1986). The initial moisture content of mushrooms ranged between 92 and 93 % (w.b.). Slices of desired thickness were obtained by carefully cutting the mushrooms vertically with a vegetable slicer. The slices from middle portions with characteristics mushroom shape were used for drying experiments without any pretreatments.

Drying methods

Mushroom slices of 7.5 mm thickness as well as whole button mushrooms were dried to a final moisture content of about 6% using microwave-vacuum drying and hot-air drying method. Typical drying conditions have been chosen for each method as follows:

Microwave-vacuum drying: The laboratory microwave-vacuum drying system used in the study consisted of a microwave oven (IFB make, Model - Electron) having a rated capacity of 600W at 2.45GHz. The oven was modified to give variable power output (from 0 to 600 W) by incorporating a 230V AC variac in the circuit (Sharma and Prasad, 2001; Giri and Prasad, 2006). A container made of polycarbonate with provision to spread mushroom samples in a perforated teflon plate was placed inside the microwave oven cavity. A vacuum pump with a pressure-regulating valve was connected to the container for maintaining the desire level of vacuum inside it. The extent of vacuum in the container was monitored with a vacuum gauge. An airtight condenser was also used in the vacuum line for condensing the water vapour released from the drying samples during drying. Microwave-vacuum drying was carried out at a microwave power level of 200W and system pressure of 6.5 kPa, which was found as an optimum condition for button mushrooms in a previous study (Giri and Prasad, 2007).

Hot air drying: Air-drying was conducted at 60°C air temperature which is recommended for drying of button mushrooms by many previous researchers (Crues and Mark, 1942; Bano and Rajarathnam, 1988; Pruthi *et al.* 1984). The air velocity was kept constant at 1.5 m/s during drying. A laboratory cross flow type hot air dryer, available at the Drying Laboratory of Post Harvest Technology Centre of the Institute, was used for air-drying of mushrooms. The various components of the drying setup were: air supplying unit, air heating unit, drying unit and power supply and control unit.

Quality evaluation of dehydrated button mushrooms

Colour of fresh and dehydrated mushroom slices was measured with a Hunter Lab Colour meter (D25, DP-9000). Hunter L, a, and b colour scale was selected for all measurements. Sample slices were kept on the specimen port (95 mm diameter) so as to cover the full exposed area of the port to the light. All measurements were replicated thrice and the mean readings were taken. Hunter L-value and colour difference (ΔE) as described by equation 1 were used to describe the colour of dehydrated mushroom:

$$\Delta E = [(L-L^*)^2 + (a-a^*)^2 + (b-b^*)^2]^{0.5} \quad (1)$$

ΔE indicates the degree of overall colour change of a sample in comparison to colour values of an ideal sample having colour values of L^* , a^* and b^* . Fresh mushroom slices were taken as ideal sample in this case having L^* , a^* and b^* values of 80.6, 4.3 and 17.2 respectively.

Hardness of dried samples was measured in a texture analyzer (Texture Technologies corp., Stable Microsystems Ltd, UK, Model TA.XT-2i) fitted with a 25kg load cell. A 75 mm diameter compression platen (P/75) was used to compress the dehydrated mushroom slices to 30% of their original thickness. The pre-speed as well as post-speed of the probe was fixed at 1 mm/s and the test speed was 2 mm/s during compression. A typical plot of force vs. time is shown in Fig. 1. The hardness value (H) was expressed as the peak force (N) in the first compression and the mean hardness value of 5 replicates was taken.

Rehydration ratio of dried button mushrooms was determined by immersing 5 gm dried samples in distilled water at 100°C temperature. The water was drained and the samples weighed at every 2 min intervals until constant weight was attained. Triplicate samples were used. Rehydration ratio was defined as the ratio of weight of rehydrated samples to the dry weight of the sample.

The ascorbic acid content in the fresh and dried mushroom slices was determined by 2,6-dichlorophenol-indophenol visual titration method (Ranganna, 1986). The reagents used were 3% HPO_3 (meta-phosphoric acid) solution, ascorbic acid standard containing 0.1 mg of L-ascorbic acid in 1 ml of 3% HPO_3 , and the dye solution containing 50 mg of 2,6-dichlorophenol-indophenol in 200 ml of distilled water. The dye was standardized first by titrating a mixture of HPO_3 and ascorbic acid standard (5 ml each) with dye solution and the dye factor was expressed as 0.5/titre. The sample extract was prepared by blending 1 g of sample with 10 ml HPO_3 solution and an aliquot of 5 ml of the extract was titrated with the dye solution. The ascorbic acid content of the sample was calculated by the following formula (equation 2) and was expressed as mg/g dry matter.

$$\text{Ascorbic acid, mg/ 100g} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume of extract} \times 100}{\text{aliquot of extract} \times \text{wt. of sample taken}} \quad (2)$$

Bulk density of dried mushroom slices was measured by gently filling them in a container of known volume (diameter 127 mm) and taking the weight in a digital top pan balance. The weight of the filled samples was divided by the known volume of the container to give the bulk density of the samples.

The sensory evaluation of dried mushroom samples was carried out by a panel of 10 untrained judges using the hedonic rating test. The hedonic rating test is usually used to measure the consumer acceptability of food products (Ranganna, 1986). The panelists were given a specimen evaluation card for sensory evaluation and asked to rate the acceptability of each sample based on the quality attributes of color, appearance, texture and aroma/ flavor. The acceptability rating of the products was done on a scale of 9 points, ranging from “like extremely” to “dislike extremely”. Individual scores of each panel members for overall acceptability of different products were averaged to the nearest whole number and represented as the sensory score of the products.

RESULTS AND DISCUSSION

The different quality attributes of dehydrated mushrooms are presented in Table 1. One way analysis of variance (Tukey's Honestly Significant Difference Test) was conducted to compare the mean values and to find whether any significant difference exists among

the two methods with reference to these quality attributes. Different letters in the same row for a particular attributes in Table 1 indicates a significant difference among the methods of drying at $p \leq 0.01$.

Table 1. Quality parameters of dehydrated mushrooms

Properties	AD	MVD	
		Sliced	Whole
Rehydration ratio	2.48 ± 0.08 ^a	3.64 ± 0.085 ^b	3.24 ± 0.074 ^b
Hardness, N	126.42 ± 8.5 ^a	96.33 ± 5.08 ^b	108.50 ± 6.54 ^a
Colour (L-value)	47.8 ± 1.75 ^a	54.44 ± 1.82 ^b	58.72 ± 2.14 ^c
Colour difference (ΔE)	34.97 ± 1.75 ^a	26.87 ± 1.33 ^b	23.22 ± 0.97 ^b
Sensory score	4.4 ± 0.55 ^a	7.4 ± 0.9 ^b	8.00 ± 1.05 ^b
Bulk Density, kg/m ³	150 ± 6.64 ^a	102 ± 3.44 ^b	88.47 ± 5.87 ^c
Vitamin C, mg/ 100 g	8.27 ± 0.32 ^a	13.10 ± 0.18 ^b	15.64 ± 0.22 ^b

AD – Air dried; MVD – Microwave vacuum dried

Rehydration ratio

The dehydrated mushroom slices obtained (Fig. 2) were rehydrated in boiling water. The rehydration stabilized in about 10 min at 100°C water temperature and the rehydration ratio was in the range of 2.5 to 4.3 for different drying methods (Fig. 3).

As observed in Table 1, there was significant difference among the drying methods (Tukey's HSD test) at $p \leq 0.01$ and the rehydration ratio of

microwave-vacuum dried mushrooms was significantly greater than air dried sample. MVD has been shown to produce samples with greater rehydration capacity than other drying methods, because the internal structure of the product remains quite undistorted. Therefore, MVD products tended to have a porous and non-shrunken structure with excellent rehydration capacity.

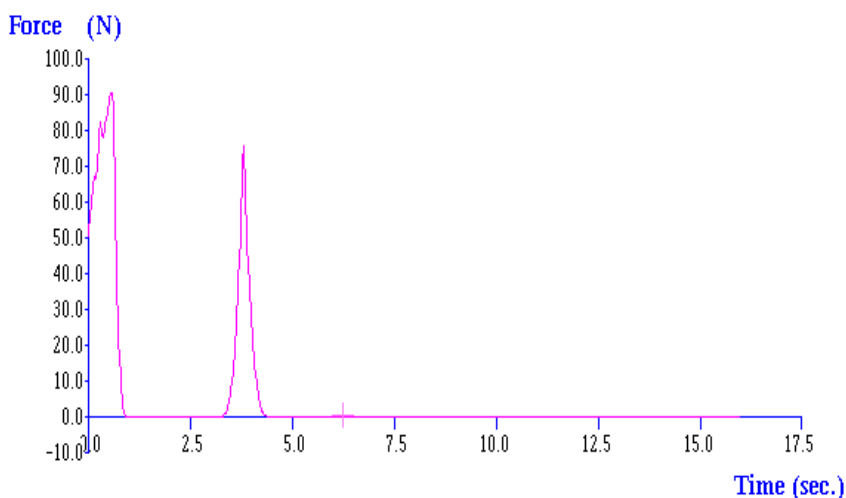


Fig. 1. A typical texture profile analysis curve for dehydrated mushroom

Hardness

The hardness of the samples dried by two different methods is shown in Fig. 4. The force required to break MVD and AD mushroom slices were 96 and 126 N respectively, indicating that less case hardening occurred with MVD mushrooms. During air drying, liquid diffuses to the surface of the mushroom from

the interior and carries solutes with it. As the surface moisture evaporates, solutes concentrate and precipitate leaving a hard and dry skin and hence a tough product. Less case hardening occurred with microwave-vacuum drying as heat was generated within the product, resulting *in situ* vaporization of water which was able to rapidly diffuse out of the tissue, without carrying dissolved solutes with it (Lin et al., 1998).

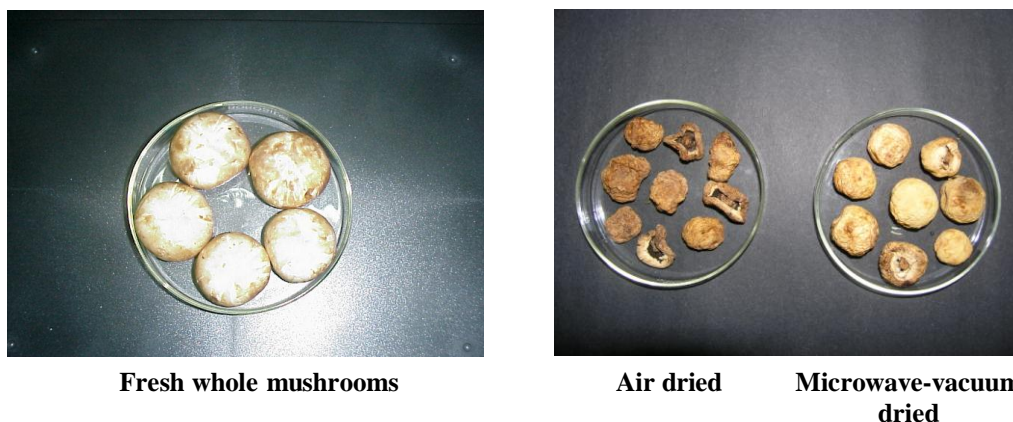


Fig 2. Fresh and dehydrated whole buton mushrooms

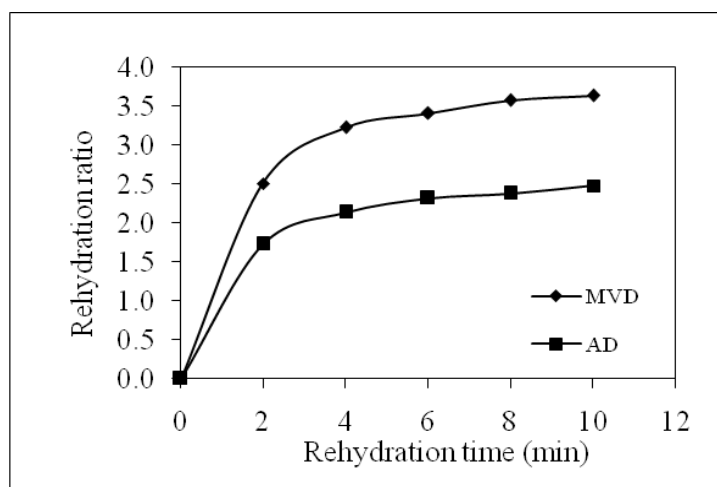


Fig 3. Rehydration ratios with time of rehydration of mushrooms dried by various methods

Colour

The Hunter colour parameter (L) and colour difference (ΔE) of dehydrated mushroom slices are presented in Table 1. Mean colour values of dehydrated mushrooms were compared to those of fresh mushroom slice, which was used as standards for

determination of the colour difference (ΔE). The L-values of the dehydrated samples were found significantly lower than fresh one, indicating occurrence of browning reaction during drying. Significant differences in colour values between drying methods was observed and AD mushroom slices were darker than

MVD samples (Fig. 2). The main cause of colour change during drying is enzymatic and non-enzymatic browning reactions (Maillard reaction), which depend on temperature and duration of heat treatment (Chua *et al.*, 2002). Hence drying at lower temperature (as in case of MVD) gave better colour products than AD. A similar observation was also reported in literature (Abbatemarco and Ramaswamy, 1994).

Sensory score

Sensory evaluation of the dried mushroom slices was carried out to obtain preliminary information on consumer preference. MVD mushroom slices received significantly higher ratings than air-dried products for color, texture and overall acceptability, (Table 1). AD mushroom slices, on the other hand, received the lowest rating for all the attributes evaluated.

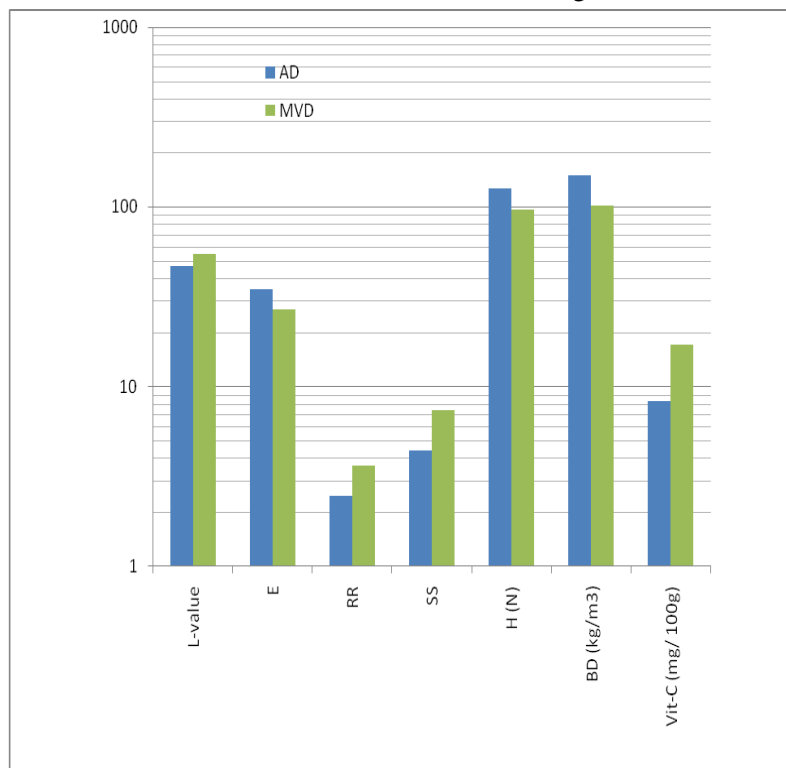


Fig 4. Quality attributes of dehydrated button mushrooms (AD - air dried; MVD - microwave-vacuum dried)

Ascorbic acid (Vitamin C) content

The average initial ascorbic acid content of fresh samples was about 24.5 mg/100g solid weight and all dehydrated mushrooms tended to lose some ascorbic acid during the drying process (Table 1). Only 8 mg/100g solid, which represents 33% of the vitamin C in the fresh mushroom, was retained in the AD mushroom slices. The percentage of retention of ascorbic acid was nearly 54% for MVD sliced mushrooms and 85 % for whole mushrooms. Generally, an increasing level of ascorbic acid

degradation is resulted from slower drying methods and due to oxidation of ascorbic acid in the presence of hot air (Schadle *et al.*, 1983, Nindo *et al.*, 2003). The relatively long drying time associated with the air drying method also contributed to the severe loss of vitamin C. No significant loss of vitamin C occurred during freeze drying because the temperature was very low during drying process. The above data indicated that microwave-vacuum drying can better retain vitamins than hot air drying and can be used for drying products which are especially sensitive to thermal damage and oxidation.

Bulk density

Bulk density was found greatly affected by the drying method. Specifically, microwave-vacuum dried had much lower bulk density than air dried products (Fig. 4). Formation of porous structures in FD and MVD products and the puffing effect during MVD might be the cause of lower density values in these products.

CONCLUSIONS

Microwave-vacuum dried mushrooms were found superior than the hot air dried products.

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