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ORIGINAL RESEARCH PAPER

Study on the Dehydration Properties of Mushroom (*Calocybe indica*) under Different Pretreatment Conditions and Drying Mechanisms

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Abstract

This research studies the effect of different pretreatment conditions on dehydration characteristic of milky white mushroom (Calocybe indica). Mushroom samples were dried using three different methods (cabinet drying, solar drying and sun drying) with different pretreatments such as blanching (85° for 1 min), sulfiting (0.3% KMS for 10 min) and blanching and sulfiting and untreated. After dehydration, differently pretreated products from each drying mechanisms were analyzed for proximate composition, drying rate, rehydration properties, and sensory qualities. Among different pretreatments in all three drying mechanisms (cabinet, sun and solar), sulfited samples showed the best result in terms of nutrients retention such as crude protein (23.17 g/100 g, 22.57 g/100 g, 21.91 g/100 g), crude fat (5.01 g/100 g, 4.47 g/100 g, 4.21 g/100 g) and crude fibre (13.62 g/100g, 13.11 g/100g, 12.04 g/100 g) respectively. Blanched and sulfited samples showed satisfactory results on drying time (8 h, 9 h, 10 h) to reach constant moisture level, rehydration ratio (3.16, 2.54, 2.81), rehydration coefficient (0.47, 0.41, 0.42), and percent water in rehydrated mushroom (69.62%, 62.45%, 65.55%) respectively. Likewise, among different drying mechanisms, cabinet dried sample was found to be superior in terms of nutrients retention (crude protein 23.17 g/100 g; crude fat 5.01 g/100 g; and crude fibre 13.62 g/100 g), drying time (8 h) and rehydration properties (rehydration ratio 3.16; rehydration coefficient 0.47; and percent water in rehydration mushroom 69.2%).

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Introduction

Mushrooms are spore-bearing fleshy organ which are considered as a valuable ingredient of gourmet cuisine and has high nutritional and functional properties (Maray et al., 2018). One of the potential edible mushroom varieties is milky white mushroom (*Calocyble indica*) (Srivastava and Kumar, 2002).

Calocybe indica has been reported as third commercially cultivated mushroom after button and oyster mushrooms in India (Arumuganathan et al., 2008). It is also known as "Summer Mushroom" due to its successful cultivation during summer and possess unique nutritional and medicinal values, characteristic aroma and taste (Subbiah and Balan, 2015). Krishnamoorthy (2003) reported that *C. indica* contains 32.3% protein and around 41% crude fibre (on dry basis) along with essential minerals and vitamins. In a study, reported by Alam et al. (2008) the nutrient content of fresh mushroom ((*Calocyble indica*) g/100g was found to be 87% moisture, 2.75% protein, 0.65% lipid, 1.63% fibre, 1.28% ash and 6.8% carbohydrate. The milky white mushroom is rich in protein, minerals, devoid of starch or low in calories and carbohydrates (Kaur et al., 2011). These are ideal foods for diabetic and heart patient and those who do not want to put on weight (FAO, 1970)

Thin-layer drying experiments were conducted at drying air temperatures of 55, 65 and 75 °C and dry air velocities of 1 and 1.5 ms^{-1} (Akpinar and Bicer, 2005). Convective air drying at different air temperatures (50, 60 and 70 °C) was performed to compare the drying rate and rehydration properties of microwave-vacuum drying with conventional method (Giri and Prasad, 2007). Like fruits and vegetables, all mushrooms including *C. indica* are highly perishable in nature with extremely low shelf life as they possess moisture in the range of 87% to 91.1% (on wet basis). Due to high moisture content and high respiration rate, quality deterioration takes place if fresh mushrooms are not immediately processed. Therefore, the harvested mushroom needs immediate processing to the form of more stable product is important to meet the market demand and supply throughout the year. Mushroom can be preserved by different method such as dehydration, canning, bottling, freeze drying, pickling, irradiation etc. (Bhal, 1994).

Efficient preservation methods may extend shelf life and diversify the product for consumers. Of the different processing methods, drying of mushroom can be effective method of processing for small scale as well as large scale mushroom grower due to ease of processing and cost effectiveness by reducing bulk quantity, hence facilitates transportation, handling and storage (Arora et al., 2003). Although sun drying is considered to be economical, mechanical drying such as cabinet drier, solar drier, hot-air oven, etc. speeds up the process, reduces nutrient loss, ensures safer drying temperatures and produces superior product compared to sun drying (Arumuganathan et al., 2008). Furthermore, pretreatments of mushrooms before drying in one form or other such as washing in water, potassium metabisulphite (KMS), sugar, salt etc. either alone or in combination helps in checking enzymatic browning, stabilizing color, enhancing flavor retention and maintaining textural properties (Sharma and Bhat, 2018). Since *C. indica* retains fresh look and does not turn brown or dark black like that of button mushrooms, is very much cost effective to cultivate and incomparable productivity as well as shelf life to any other cultivated mushrooms in the world, it could play an important role in satisfying the growing market demands for edible mushrooms in near future (Chandra and Samsher, 2006). Khanal (1992) reported that, the rehydration coefficient is affected by pretreatment operations for the dehydration of tomato.

The drying kinetics of mushroom is complex phenomenon and only limited research is carried out to study drying characteristic of mushrooms and data was reported on moisture loss and drying rates. However, there is a huge gap in systematic studies on drying kinetics of milky white mushroom (Arumuganathan et al., 2008). This study has been carried out to find appropriate drying mechanisms and pre-treatment conditions for the dehydration of milky white mushroom. The different parameters under study are pre-treatments, its effect on drying characteristics and rehydration properties.

Materials

Good quality milky white mushroom (*Calocybe indica)* variety were purchased from Urlabari-6, Manglabare of Morang district, Nepal. The fresh samples were taken in batches because of perishability. 1 kg of milky white mushroom samples was picked from farm, stored under refrigeration at 4±1°C overnight and used for cabinet drying the next day. Similar process was followed for solar and sun drying.

Methods

The mushrooms samples collected at a particular stage of maturity were sorted and washed to remove dust, foreign matters and damaged parts. The sorted mushrooms were sliced into two to four halves as the part of preliminary preparations. The average size of mushroom was made about 3.0 cm×3.0 cm×5.0 cm with SS knife (Walde et al., 2006) followed by different pretreatments and drying mechanisms. The different drying methods used are cabinet drying, solar drying and sun drying. The different pretreatments in each drying methods are fresh (no treatment), blanching (at 85°C for 1 min), sulfiting (in 0.3% KMS for 10 min) and blanching and sulfiting.

Drying of milky white mushroom

The samples viz. fresh, blanched, sulfited, blanched and sulfited were weighed, placed in stainless steel trays and were dehydrated at 60±2°C in cabinet dryer and at temperature around 27±1°C under sun until the weight of dried mushroom were constant. The temperature of solar dryer was 40±2°C. The samples from each dehydrating process were weighed at an interval of 1 h until three concurrent readings and the effects of different pretreatment on the drying characteristics were studied.

Drying curve fitting

The different drying rate curves of differently pretreated samples were plotted against moisture content (dry basis) and time for each drying mechanisms to study the drying characteristics of milky white mushroom from the data recorded during the dehydration (Brennan, 2006). These curves can be used to describe the drying characteristics of mushroom.

Packaging

The dried samples were packed in LDPE (low density polyethylene) bags with water vapor transmission rate (WVTR) of 16-23 $g/m^2/24$ h at 36°C, 90% RH for 1 mil film (low density polyethylene) bags and heat sealed using impulse heat sealer electric sealing and stored at room temperature (25±1°C). The finished product was used further for analysis.

Determination of proximate composition of raw and dehydrated milky white mushroom

Moisture content, crude fat, crude protein, crude fibre, total ash and total carbohydrate content of raw and cabinet dried, solar dried and sun-dried mushroom samples were determined by using a method as per Ranganna (1986).

Determination of rehydration ratio (RR), rehydration coefficient (RC) and % water in rehydrated mushroom (PWRM)

The rehydration ratio of dried mushroom pieces was determined by rehydration test. The dehydrated samples of 5 g each were placed in glass beakers, 100 ml of water was added and heated at 45°C for 60 min. The excess water was drained off through bloating paper and drained samples were weighed. The rehydration ratio, rehydration coefficient and percent water in rehydrated material of milky white mushroom samples were computed using following equation (Srivastava and Kumar, 2002).

Rehydration ratio = c/d

where, c= drained weight of rehydrated samples, g
d= weight of dehydration samples taken for rehydration test, g

Rehydration coefficient =

$$\frac{\text{drained wt. of rehydrated material} - \text{dry matter content in dehydrated sample}}{\text{drained weight of rehydrated material}}$$

Percent water in rehydrated material =

$$\frac{\text{wt. of rehydrated sample} - \text{wt. of dehydrated sample taken}}{\text{wt. of dehydrated sample taken}} \times 100$$

Data analysis

All experiments were performed in triplicates and values are expressed as mean ± standard deviation. The data analysis was done statistically by Genstat discovery edition 3 for one-way and two-way ANOVA. The drying data were fitted using the Microsoft office 2003 for coefficient of determination of various models. The differences between data were compared using least significance difference (LSD) at 5% level of significance.

Results and Discussion

Proximate composition of fresh milky white mushroom

The moisture content, crude protein, crude fat, crude fibre, total ash and carbohydrate content of raw milky white mushroom was found to be 85.6, 3.12, 1.02, 1.28, 1.24 and 7.73 g/100 g of fresh edible portion as in average of three batches which is within the range reported by Alam et al. (2008). The proximate composition of fresh milky white mushroom is shown in Table 1.

Proximate composition of dehydrated fresh milk white mushroom

The influence of pretreatments on the proximate composition of cabinet drier dried, solar dried and sun dried milky white mushroom is shown in Table 2.

Table 1
Proximate composition of fresh milky white mushroom (% wet basis)

Parameters	*Content (g/100 g)*
Moisture content	85.60 ± 1.60
Crude protein	3.12 ± 0.10
Crude fibre	1.28 ± 0.19
Total ash	1.24 ± 0.14
Carbohydrate	7.73 ± 1.68

Note. Values are the mean of triplicates and values in the parentheses are the standard deviation

In case of cabinet dryer-dried mushroom samples, blanched sample retained least moisture content. Protein, fat and crude fibre content was higher in sulfited sample. Blanched sample contained higher amount of total ash whereas, amount of carbohydrate was higher in blanched and sulfited sample.

In case of solar-dried mushroom samples, blanched and sulfited sample retained least moisture content. Protein, fat and crude fibre content was higher in sulfited sample. Blanched sample contained higher amount of total ash whereas, amount of carbohydrate was higher in blanched and sulfited sample.

Table 2
Proximate composition (dry basis) of cabinet dried milky white mushroom

Drying methods	*Parameters*	*Pretreatments*			
		A	B	C	D
Cabinet drying	**Moisture content**	4.94 ± 0.692[a]	3.47 ± 0.139[b]	4.153 ± 0.117[c]	3.815 ± 0.153[d]
	Crude protein	22.85 ± 0.140[a]	21.19 ± 0.160[b]	23.17 ± 0.075[c]	21.583 ± 0.245[d]
	Crude fat	4.81 ± 0.273[a]	3.99 ± 0.025[b]	5.01 ± 0.115[a]	4.32 ± 0.237[b]
	Crude fibre	13.16 ± 0.040[a]	12.82 ± 0.078[b]	13.62 ± 0.230[c]	13.04 ± 0.086[ab]
	Total ash	8.01 ± 0.458[a]	9.94 ± 0.064[b]	6.26 ± 0.056[c]	7.55 ± 0.087[d]
	Carbohydrate	51.17 ± 0.136[a]	52.36 ± 0.280[b]	51.94 ± 0.142[c]	53.52 ± 0.030[d]
Solar drying	**Moisture content**	4.43 ± 0.065[a]	4.41 ± 0.074[b]	3.33 ± 0.047[c]	3.04 ± 0.110[d]
	Crude protein	21.52 ± 0.130[a]	20.85 ± 0.315[b]	22.57 ± 0.265[c]	21.15 ± 0.055[ab]
	Crude fat	4.14 ± 0.065[a]	3.51 ± 0.560[b]	4.47 ± 0.191[a]	4.07 ± 0.056[a]
	Crude fibre	12.44 ± 0.120[a]	12.04 ± 0.072[b]	13.11 ± 0.119[c]	12.19 ± 0.060[b]
	Total ash	10.66 ± 0.202[ac]	11.05 ± 0.197[a]	8.53 ± 0.290[b]	10.27 ± 0.270[c]
	Carbohydrate	51.24 ± 0.100[a]	52.32 ± 0.094[b]	51.64 ± 0.140[c]	52.55 ± 0.317[d]
Sun drying	**Moisture content**	4.43 ± 0.036[a]	3.26 ± 0.045[b]	4.68 ± 0.051[c]	3.14 ± 0.045[d]
	Crude protein	20.73 ± 0.211[a]	19.85 ± 0.34[b]	21.91 ± 0.111[c]	20.08 ± 0.081[b]
	Crude fat	4.13 ± 0.04[a]	3.64 ± 0.476[b]	4.21 ± 0.021[a]	4.11 ± 0.020[a]
	Crude fibre	11.41 ± 0.077[a]	11.14 ± 0.058[b]	12.04 ± 0.065[c]	11.24 ± 0.065[b]
	Total ash	10.70 ±0.332[ac]	11.04 ±0.064[a]	6.26 ±0.056[b]	7.55 ± 0.087[c]
	Carbohydrate	52.56 ± 0.135[a]	54.33 ± 0.652[b]	53.37 ± 0.290[c]	53.61 ± 0.216[c]

Note. Values are the mean of triplicates and values in the parentheses are the standard deviation. Values with same superscript are not significantly different.
Abbreviation. A= Fresh, B=Blanched, C= Sulfited, and D= Blanched and Sulfited

In case of sun-dried mushroom samples, blanched and sulfited sample retained least moisture content. Protein, fat and crude fibre content was higher in sulfited sample. Blanched sample contained higher amount of total ash as well as carbohydrate.

The statistical analysis showed significant effect of pretreatments on moisture content, crude protein, crude fat, crude fibre, total ash and carbohydrate among four different formulations of dehydrated mushroom samples in each drying mechanism at 5% level of significance. The values are within the range reported by Alam et al. (2008).

Drying rate curve

Drying rate curve of milky white mushroom dehydration under different mechanisms i.e., cabinet drier, solar and sun is shown in the Figure 1, 2 and 3 respectively.

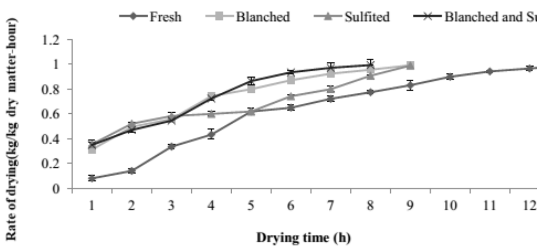

Figure 1 Drying rate curve for milky white mushroom dehydration in cabinet drier

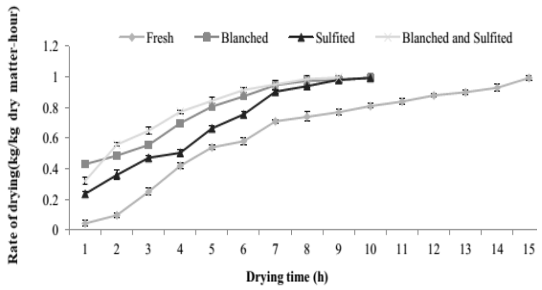

Figure 2 Drying rate curve for milky white mushroom dehydration in solar drier

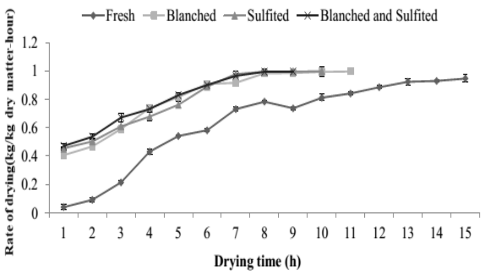

Figure 3 Drying rate curve for milky white mushroom dehydration in sun

From the graph (Figure 1, 2 and 3), it can be revealed that the drying rate is highest in case of blanched and sulfited sample while non treated sample has least drying rate in all three drying mechanisms. Also, we can see that there is no stationary rate period in the drying rate curve. The absence of the stationary rate period may be attributed to the fact that mushroom was laid on the tray in a thin layer and temperature and air velocity is sufficient to drag the moisture away, which is in accordance with the work of Akpinar and Bicer (2005) and Giri and Prasad (2007) in different fruits and vegetables dehydration.

The drying temperature of 60°C is sufficient to bring the minimum activation energy required to detach the moisture away from the surface of mushroom (Arumuganathan et al., 2008). Low temperature drying causes less structural damage, reduces protein denaturation and gives higher quality product.

Arumuganthan et al. (2008) found the drying time of 5 to 7 h for mushroom without any treatments. The longer drying period in case of cabinet drier dried untreated sample might be due to large pieces of mushroom, low air velocity and frequent load-shedding. While, in case of sun and solar dried samples, the relatively longer drying period of untreated milky white mushroom in present work may be due to the large pieces of mushroom, low air velocity, cloudy weather and uneven humidity.

Rehydration tests of dried milky white mushroom (rehydration ratio, rehydration coefficient and percent water in rehydrated mushroom)

The rehydration behavior was analyzed in terms of the ability of the dried mushroom pieces to regain their original moisture content. The rehydration ratios of dried samples in all three drying mechanisms (i.e., cabinet drier, solar and sun) was found to be maximum for blanched and sulfited samples followed by sulfited, fresh and blanched samples. The low RR in case of blanched sample may be due to rupturing of cells and tissue during blanching leading to decreased water absorbing capacity. In contrast to our result Singh *et al.,* (2008) found no or very little effect of pre-drying treatments on the rehydration of milky white mushrooms. The values of the RR of mushroom samples dried at different pretreatments under different mechanisms are showed in Table 3.

Table 3
Rehydration ratio (RR), rehydration coefficient and percent water in rehydrated material of cabinet, solar and sun dried milky white mushroom

Drying methods	*Pretreatments*	*RR*	*RC*	*PWRM*
Cabinet drying	**Fresh**	2.87 ± 0.023^{c}	0.43 ± 0.003^{c}	66.46 ± 0.265^{c}
	Blanched	2.76 ± 0.010^{d}	0.41 ± 0.001^{d}	65.03 ± 0.130^{d}
	Sulfited	2.98 ± 0.026^{b}	0.45 ± 0.004^{b}	68.08 ± 0.285^{b}
	Blanched and sulfited	3.16 ± 0.040^{a}	0.47 ± 0.006^{a}	69.62 ± 0.350^{a}
Solar drying	**Fresh**	2.48 ± 0.005^{b}	0.37 ± 0.007^{c}	61.27 ± 0.155^{b}
	Blanched	2.42 ± 0.010^{c}	0.36 ± 0.001^{d}	60.03 ± 0.165^{c}
	Sulfited	2.50 ± 0.010^{b}	0.39 ± 0.004^{b}	61.55 ± 0.077^{b}
	Blanched and sulfited	2.54 ± 0.005^{a}	0.41 ± 0.008^{a}	62.45 ± 0.081^{a}
Sun drying	**Fresh**	2.43 ± 0.026^{c}	0.36 ± 0.004^{b}	60.69 ± 0.434^{b}
	Blanched	2.30 ± 0.015^{d}	0.34 ± 0.001^{c}	58.40 ± 0.274^{c}
	Sulfited	2.51 ± 0.026^{b}	0.37 ± 0.004^{b}	61.11 ± 0.299^{b}
	Blanched and sulfited	2.81 ± 0.020^{a}	0.42 ± 0.003^{a}	65.55 ± 0.258^{a}

Note. Values are the mean of triplicates and values in the parentheses are the standard deviation. Values with same superscript are not significantly different.

The rehydration coefficient of dried mushroom samples was found to be maximum for blanched and sulfited sample followed by sulfited, fresh and blanched sample respectively. The values of the RC of mushroom samples dried at different pretreatments under different mechanisms are showed in Table 3. There was significant difference in RC of Fresh and pretreated cabined drier dried and solar dried mushroom samples, while no any significant difference was observed in RC of fresh and sulfited sun dried mushroom samples at 5% level of significance.

The percent water in the rehydrated mushroom is the indicative of water absorption capacity of dehydrated mushroom. Generally, the more is the RR more the water in the rehydrated mushroom. The rupturing of cells and vacuoles during treatments may be the causative factor for different results of percent water in the rehydrated sample (Maray et al., 2018).

The results of percent water in the rehydrated material i.e., milky white mushroom samples treated differently under different mechanisms are shown in Table 3. The statistical analysis showed significant effect of pretreatments as well as drying mechanisms on RR, RC and PWRM of cabinet drier, solar and sun dried milky white mushroom samples at 5% level of significance and it is estimated that the cabinet drier dried blanched and sulfited sample showed maximum RR, RC and regained the maximum percent of water. The report in this study is in accordance with the findings of Khanal (1992), who reported that, the RR, RC and PWRM is affected by pretreatment operations. Pretreatment operations such as blanching and sulfiting minimized the cell rupture and disruption of cell walls during drying, which in turn facilitate in better rehydration.

Conclusion

From the research work, the drying time of 8.71 to 9.88 h seems to be sufficient to bring the product to stable moisture content i.e., less than 6% in cabinet dryer, solar and sun respectively. On the basis of chemical analysis, among differently pretreated samples in all three mechanisms, sulfited sample was found to be superior in terms of nutrient retention while the blanched and sulfited sample was found to be optimum on the basis of other drying characteristics like drying rate, RR, RC, and PWRM. Of the three drying mechanisms, cabinet drier dried samples were found to be optimum for the best quality product in terms of nutrient retention and dehydration properties. The product which was blanched and sulfited and dried in cabinet drier showed faster drying rate and better rehydration properties. This method has scope for commercialization.

Recommendations

Further study could be carried out to study the storage stability of dried mushroom using various packaging material and under other storage environments. Likewise, mathematical modeling of dehydration process at various temperatures, pre-treatments and various air velocities can be carried out. The retention of nutrients and vitamin C in blanched and sulfited mushroom samples under various blanching temperatures and time can also be studied.

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Compliance with Ethical Standards

Conflict of Interest

The authors declare no conflict of interest.

Ethical approval

The study did not involve any inhumane animal study.

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