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Effect of Hot Air, Microwave and Freeze Drying on Drying Characteristics of Button Mushroom Slices (*Agaricus bisporus*)

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Authors' contributions

This work was carried out in collaboration among all authors. Author MM designed the conceptualization of the study, performed the statistical analysis and wrote the second draft of the manuscript. Author GB corrected the manuscript, check the plagiarism and format the manuscript. Authors AN, PKD, SP and AS done the experimental work, analysed the experimental data. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Button mushrooms, rich in vitamins and minerals, are very highly perishable and therefore, it has been very necessary to develop a value-added product. The aim of the research work is to study the effects of blanching on air-dried, microwave oven dried, and freeze dried mushroom samples and also to study the characterization of dried samples.
Place and Duration of Study: Department of Agricultural Engineering, School of Agricultural and Bio-Engineering, Centurion University of Technology & Management, between February 2021 to June 2021
Methodology: Three different drying techniques like hot air, microwave, and freeze drying were taken to study the drying effect on dried mushroom slices. The quality parameters like dehydration and rehydration potential, density, ascorbic acid, color, and organoleptic properties were studied.
Results: The rehydration ratio of freeze dried mushroom samples were high having low density than the other dried samples. Less color deterioration was also found in freeze drying. Moreover, ascorbic acid, color, texture, and overall acceptability of sensory analysis were found to be

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maximum in freeze dried samples. The freeze dried product was found to be attractive in flavour and texture and got highest score in sensory analysis.

Conclusion: The freeze drying can be an effective drying method to dry fresh mushroom compared to hot air and microwave drying.

Keywords: Mushroom; air drying; microwave drying; freeze drying; dehydration; rehydration; nutritional properties.

1. INTRODUCTION

Button mushroom, *Agaricus bisporus* rich in several nutrients is highly perishable in nature. Therefore, it is consumed or processed immediately after harvesting. The consumption of mushrooms has several benefits like it strengthens the human body [1]. It is rich in vitamins like vitamin D, vitamin B-6, thiamine, riboflavin, niacin, and biotin, minerals, carbohydrates, proteins (19-35%), amino acids especially lysine and leucine, and fat content (2-8%) which is very less. Besides these, it is also a rich source of copper, zinc, potassium, phosphorous, and selenium. It recovers human diseases like diabetes, hypertension, obesity, atherosclerosis, etc [2,3].

Dehydration is relatively cost-effective and one of the oldest methods than other approaches of preservation. The drying rate depends on several factors like a method of drying, thickness of the food product, moisture content, temperature, etc. The most important factors like temperature and time are associated with the drying. These factors can affect the sensory parameters like color, flavour, texture, appearance and nutritional value of food products [4]. Microwave drying and freeze drying are one the advanced technologies which preserve nutritional properties. In Microwave drying, the factors like microwave power and pressure can improve the texture, structure of food products compared to other techniques [5,6].

Freeze drying is one of the advanced and best methods to dehydrate food products with high quality. In this drying method, moisture is removed from the foods at low temperature that means in the frozen state and high vacuum. The freeze-drying method is gaining much attention having several advantages. This method retains the nutrients, original color, aroma, etc. Moreoer, it reduces the loss of volatile compounds. The dried product obtained by this method can be stored in any air-tight container. Having lightweight, the dried products can be stored for a longer storage shelf life period. The entire process consists of primary and secondary drying including pre-treating, freezing, freeze-drying, and packaging. In the pre-treating phase, several steps of unit operations are included like selecting the food materials, washing, slicing, blanching, filling the trays, etc. In the freezing phase, the treated or control food products are put in freezing section [7]. Wang et al., in 2018 [7] reported the effect of hot water blanching on freeze drying processing of apple slices which retain the hardness, color and shape of the samples. Fan et al., in 2020 [8] studied the ultrasonic effect on freeze dried carrot slices by traditional and infrared freeze drying technologies. He found that there was no significant difference in color, texture and sensory properties between freeze dried and infrared freeze dried samples.

The aim of the present research work are to study the effects of blanching on air-dried, microwave oven dried, and freeze dried mushroom samples and also to study the characterization of dried samples.

2. MATERIALS AND METHODS

2.1 Collection of Raw Material

Raw and freshly harvested button mushrooms were collected from the Mushroom Unit, Centurion University of Management, R. Sitapur, Paralakhemundi, Odisha, India. Before starting the experiment, the mushrooms were cleaned thoroughly with clean tap water and then cut into slices. The collected mushrooms having head size diameter 5 mm were selected for doing the experimental work (Fig. 1). The pieces obtained were weighed and the average moisture content of raw mushroom samples was evaluated by the oven drying method [9]. The initial moisture content of the raw button mushroom samples was found to be 14.34 ± 0.1% to 13.28 ± 0.1% on a dry basis (d. b.). Moisture content was then calculated using the following equation:

$$X_t = \frac{m_t - m_d}{m_d}$$

Where,

X_t is the moisture content of mushroom sample at drying time t (min) on dry basis (g/g, d.b.)
m_t is the weight of mushroom sample at drying time t (min)
m_d is the dry matter weight of mushroom sample.

2.2 Three Different Treatment Methods

The prepared sliced and blanched mushroom samples were taken for three different treatments. Three different drying methods (pre-treatment) such as air drying, microwave drying, and freeze drying were selected to conduct the drying experiments for the present research work (Fig. 2a and Fig. 2b). Before drying, the samples were water blanched at 90°C for 7 minutes. One kg of blanched mushrooms was made for air drying, microwave drying and oven drying. During the drying process, when the dryer temperature reached a steady-state condition, the cut mushroom slices were distributed uniformly into the tray. 100 g of sample was weighed and taken for the experiment. When the drying process was completed, the final moisture content of the dried product was measured and then packed in LDPE pouches after cooling and then sealed properly. Three replications of the experiment were taken to get accurate data. For microwave drying, a domestic microwave oven (Morphy Richard, 2450 MHz) was used for conducting the experiment [10]. For hot air drying, the temperature was taken for the experiment was 70°C whereas, for freeze-drying, the chamber and condenser temperature was set at 20°C and -55°C, respectively.

2.3 Theoretical Consideration

2.3.1 Determination of moisture content

Moisture content is one of the most important factors that affect the characteristics of the food product. The optimum moisture content obtained in food ingredients maintained the factors like color, flavour, taste, appearance but also extends the shelf life of that product [11]. The moisture content of fresh raw sliced mushrooms was determined by a hot air oven at a temperature of 104°C for 24 hours. This is a time-consuming procedure but is precise and reliable.

(a) (b) (c)

Fig. 1. Images of mushroom sample preparation (a) cut mushroom slices (b) Hot air oven for moisture determination (c) dried moisture after hot air oven drying

(a) (b)

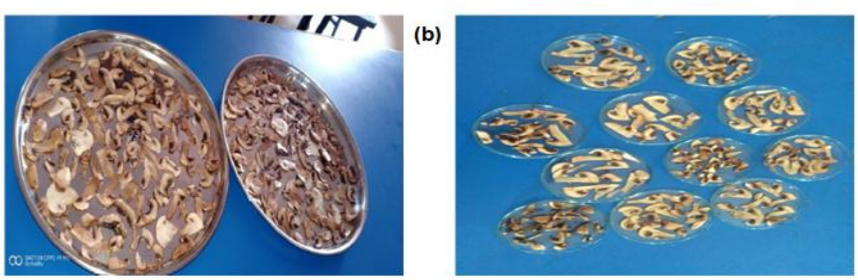


Fig. 2. (a) Prepared samples for air drying and freeze drying (b) Prepared sample for microwave drying

2.3.2 Determination of rehydration ratio

The rehydration capacity of dried sliced mushroom samples was evaluated by the method followed by Mudahar and Bains [12]. Twenty grams of dried mushroom samples were immersed in 300 ml of water maintaining the temperature of 30 °C and 100 °C. For 30 °C rehydration temperature, different rehydration times i.e. 20, 50, 80, 110, 140, and 170 min, and for 100 °C temperature, different times i.e. 1, 3, 5, 7, 9, and 11 min are fixed. After draining out the samples from water, the surface moisture was removed by using tissue paper, and then the weight of all samples was measured using a weighing balance. After getting the weight of the rehydrated sample, the rehydration ratio was calculated which was given as below:

$$\text{Rehydration ratio (RR)} = \frac{\text{Weight of rehydrated sample (g)}}{\text{Weight of dried sample (g)}}$$

2.3.3 Measurement of ascorbic acid

The ascorbic acid content of different treated dried mushroom samples was determined by the titration method followed by Rama and John [13]. For this measurement, a two-gram freeze-dried mushroom sample was taken and made into powder for each treatment. A solution was prepared by taking 10 ml of 3 % metaphosphoric acid with 2 g of powder sample. The solution was kept in an incubator shaker at 30°C and rpm of 120 for 30 min. The prepared solution was filtered and from this filtered solution, 5 ml of aliquot was titrated against the dye (indicator) which reduces the sample to a colorless solution.

$$Amount\ of\ ascorbic\ content\ \left(\frac{mg}{100g}\right) = \frac{500 \times V_2 \times 25 \times 100}{V_1 \times 5 \times 5}$$

Where, 500 = µg of standard ascorbic acid taken for titration; V_1= Volume of dye consumed by 500 µg of standard ascorbic acid; V_2 = Volume of dye consumed by 5 mL of test sample; 25 = Corresponds to the total volume of extract; 100= Ascorbic acid content /100g of the sample; 5 = Weight of the sample taken for extraction; and 5 = Volume of the test sample taken for titration.

2.4 Sensory Analysis

For the sensory analysis, the parameters like color, texture, aroma, appearance, and overall acceptability were taken. The sensory analysis of dehydrated and rehydrated samples was done by a 9-point hedonic scale (9 denoted as like very much to 1 as dislike very much) with the help of 7 trained judge panels. The panellists were asked to analyse and marked the sensory attributes of all samples. Before testing all the samples, the panellists were asked to rinse their mouths properly.

3. RESULTS AND DISCUSSION

3.1 Effect of Hot Air, Microwave, and Freeze Drying on Blanched Mushroom Sample

The dehydration rate of all blanched samples for treatment methods was shown in Fig. 3. The initial moisture content of raw mushroom samples was found to be 92.57% wet basis (w.b.). Comparing all the drying methods, in microwave drying, the samples were dried very rapidly only in 30 minutes and the final moisture content was reached 10.28 % wb from the initial moisture content i.e. 92.57% wb Microwave drying was found to be a very faster drying process compared to air and freeze drying. It only took 30 minutes while air and freeze-drying took 28 and 24 hours, respectively to reach final moisture content up to 10 %. In the hot air drying method, after 4 hours of the drying period, the moisture content of processed dried and blanched samples was found to be 84.53 % wb. It took one day and extra four hours to completely dry and reached a final moisture content of 10.67 % wb. But in freeze-drying, after 4 hours of the drying period, the moisture content was found to be 62.25 % wb and it took 24 hours to reach a final moisture content of 10.12 % wb. In both hot air and freeze drying methods, the moisture content of blanched mushroom samples was found to be decreased up to 28 and 24 of the drying period, respectively. In microwave drying, the drying rate is very fast therefore, the drying time was set up to 30 minutes. After 5 min, 15 min, and 30 min, the moisture content of the blanched sample was decreased to 78.35 % wb, 55.42 % wb, and 10.28 % wb, respectively. But, the drying rate was found to be very fast in MD compared to AD and FD that means mass transfer within the food is very rapid. In this case, heat generates in food due to microwave volumetric heating and creates a larger vapour pressure between the centre and surface of the food products. Because of this vapour pressure within the microwave chamber, the mushroom samples got to expand, the structure changed and it became puff [14]. Therefore, the density of the dehydrated mushroom samples was observed to be lower than air-dried blanched sample (Fig. 4). Comparing all the treatments, the air-drying method was found to be less acceptable because, from the data analysis, it resulted that by hot air drying the texture, color and flavor were affected by high temperature and long drying time. In microwave drying the effect was found to be significant but less than freeze drying because in this drying method, by vacuum and rapid energy the microwave heating creates a very rapid and low-temperature drying due to which the color and nutrient of dried mushroom sliced products are retained. Comparing all the above-discussed moisture content data of all drying methods, in AD the moisture content was found to be high compared to MD and FD. Therefore, the density of blanched samples of AD was found to be highest compared to MD and FD (Figure 4). In FD mushroom samples, the density was found to be very less because of sublimation and voids. In FD, the drying process allows ice in a frozen state to sublimate. In this process, the freeze-dried samples structures and texture were also found to be retained.

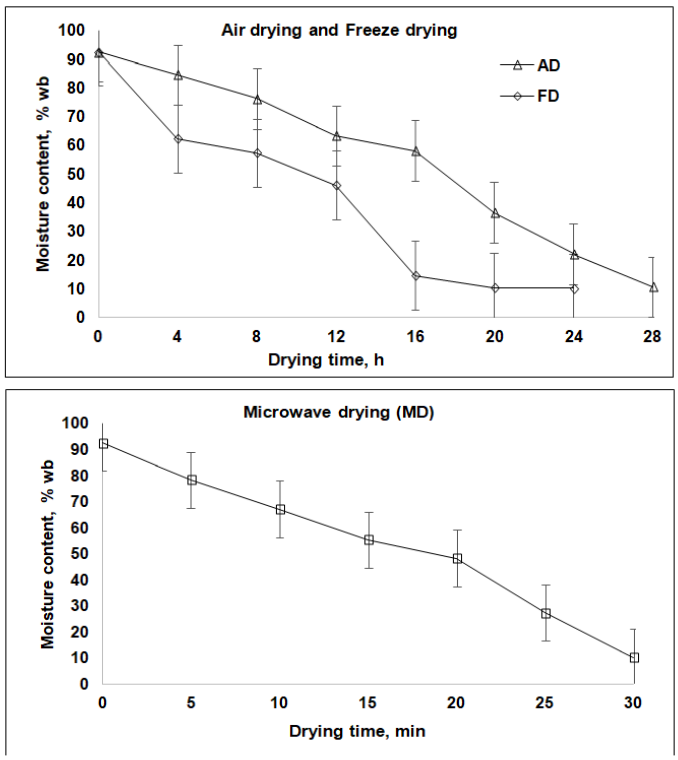


Fig. 3. Dehydration curves of air dried (AD), microwave dried (MD), and freeze dried (FD) mushroom slices

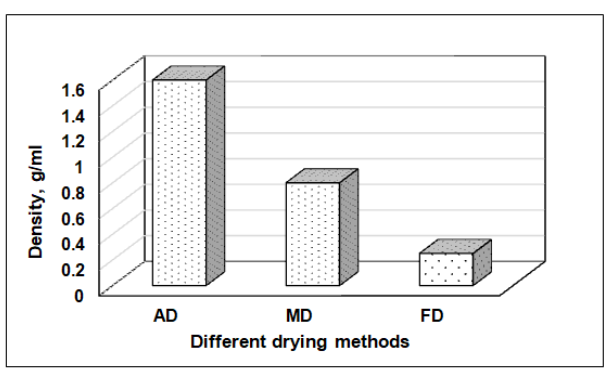


Fig. 4. Density of air dried (AD), microwave dried (MD), and freeze dried (FD) mushroom slices

3.2 Rehydration Effect

The blanched mushroom slices dried by air drying, microwave and freeze drying were taken for rehydration at 30°C and 100°C (Fig. 5). Comparing all the drying process, the highest rehydration ratio was obtained in freeze dried samples than microwave and air dried samples because of having porous structure. The reason behind these result also depends on the density (Figure 4) of the samples. The freeze dried samples had high rehydration ratio because these samples had less density and had a higher capacity to absorb water. When the water temperature is increased the rehydration ratio was found to be less at 100°C than 30°C. At the beginning stage of rehydration of all samples, higher rehydration rate was occurred and in FD, it was found to be maximum than others. During the rehydration process of freeze dried samples, up to 30 minutes the moisture uptake was found to be more rapid and then significantly increased to a constant point. From the rehydration data analysis, it was resulted that the blanched samples dried by freeze drying can be rehydrated successfully by cooking or boiling method.

3.3 Color of Dehydrated Mushroom Samples

The color of both dehydrated and rehydrated mushroom samples obtained by air, microwave and freeze drying methods were identified by visual method. In comparison, mushroom slices by air drying was found to be darker than others. The reason behind these changes that in hot air drying, the samples got exposure to direct heat during drying and became darker. Because of this, the texture of also got affected. But in freeze dried product, because of below temperature drying, the color and texture of the mushroom samples did not affected. Similarly, in all rehydrated samples, the color of freeze dried rehydrated samples did not affected than others.

3.4 Measurement of Ascorbic Acid

The initial ascorbic acid content of 100 g of mushroom samples was found to be 10.12 mg whereas in blanched samples it was 4.65 mg before taking to drying (Fig. 6). The blanching treatment was followed to inactive the enzyme and during this blanching process some ascorbic acid content is lost [15]. The ascorbic content of air dried, microwave dried and freeze dried was found to be 3.45 mg, 3.75 mg and 4.22 mg per 100 g of sample. The lowest ascorbic acid content was found in air drying method. In this method, some ascorbic acid content was lost because of heat treatment [16]. In freeze drying method, it was found to be maximum because of freezing effect within the chamber and low temperature. After blanching, the ascorbic acid content was further reduced due to the drying effect on the sample. Comparing all the samples, the ascorbic acid was found to be better retained when it was subjected to freeze drying.

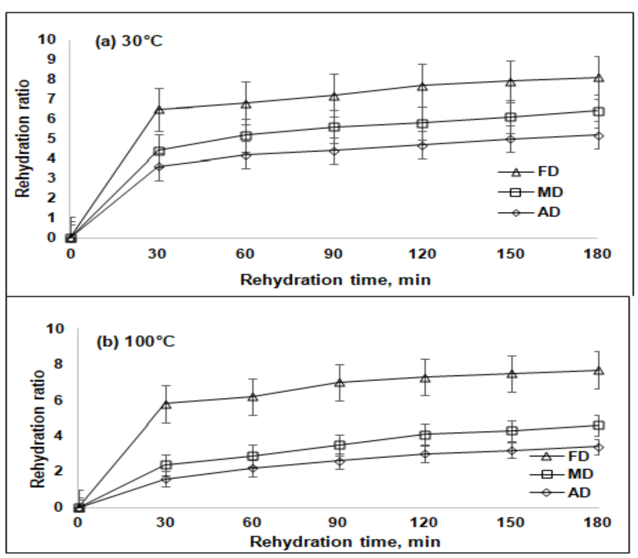
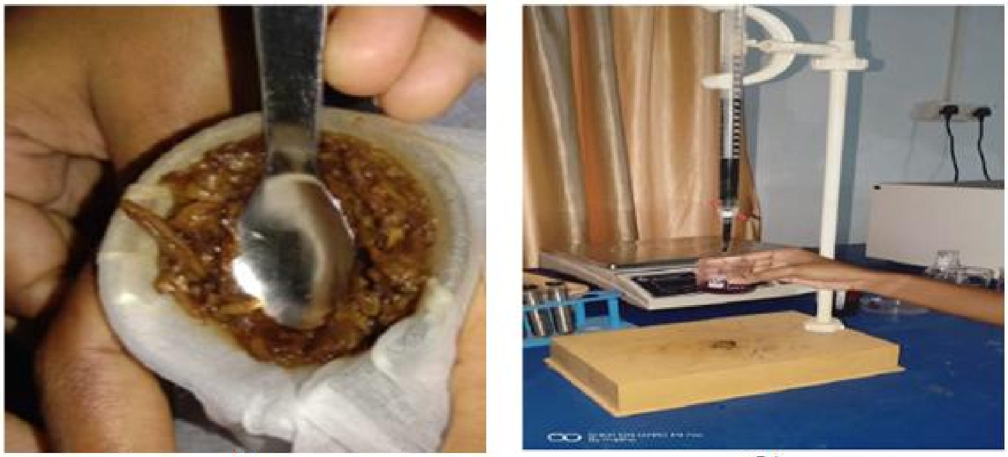


Fig. 5. Rehydration curve of air dried (AD), microwave dried (MD), and freeze dried (FD) mushroom slices at (a) 30°C and (b) 100°C



(a) (b)

Fig. 6. Images of ascorbic acid determination (a) extraction of mushroom solution (b) Titration for ascorbic acid determination

Table 1. Sensory analysis of air dried, microwave dried and freeze dried mushroom slices

Different drying treatments	Color	Appearance	Texture	Flavor	Overall acceptability
AD	4.6±1.8^{a}	4.8±2.2^{a}	2.5±3.2^{a}	4.2±1.5^{a}	4.5±2.7^{a}
MD	7.8±2.0^{b}	7.9±1.8^{b}	6.3±2.6^{b}	6.9±2.2^{b}	7.2±3.2^{b}
FD	8.5±1.5^{b}	7.4±1.1^{c}	8.0±1.5^{c}	7.8±1.6^{b}	8.2±1.4^{c}

^{abc} Data are significantly different. Values are expressed in mean ±standard deviation

Table 2. Sensory analysis of rehydrated air dried, microwave dried and freeze dried mushroom slices

Different drying treatments	Color	Appearance	Texture	Flavor	Overall acceptability
AD	6.2±1.3^{a}	5.2±1.6^{a}	5.8±1.2^{a}	5.9±2.7^{ab}	6.0±0.8^{a}
MD	7.5±3.2^{b}	7.2±1.7^{b}	6.5±1.0^{a}	5.5±2.2^{a}	7.0±0.5^{a}
FD	7.8±2.9^{ab}	6.1±1.7^{c}	6.0±1.2^{a}	6.2±3.2^{b}	6.6±1.2^{a}

^{abc} Data are significantly different. Values are expressed in mean ±standard deviation

3.5 Sensory Evaluation

Sensory evaluation was done for both dehydrated and rehydrated samples following all the drying process. Both in dried and rehydrated samples, freeze dried samples got high rating than air and microwave treated samples. On the basis of panellists, in freeze dried samples, all the sensory parameters like color, texture, flavour, appearance and overall acceptability were rated as high than other samples (Table 1). Rehydrated freeze dried samples got highest score only in color parameter whereas in microwave samples, the rest parameters like appearance, texture, flavour and also overall acceptability got highest score when rehydrated (Table 2). There was no significant difference was found in texture and overall acceptability of rehydrated samples. In case of dehydrated samples, the freeze dried samples scored highest overall acceptability because of freezing process.

4. CONCLUSIONS

In this study, the dehydration and rehydration characteristics of mushroom slices in hot air, microwave, and freeze drying at different drying time were investigated. The freshly harvested mushroom was analysed for moisture content and the initial moisture content was found to be 92.57% wb. The drying time in microwave, hot air and freeze drying was found to be 30 min, 28 hrs and 24 hrs, respectively. Comparing all the drying process, the highest rehydration ratio was obtained in freeze dried samples compared to microwave and hot air dried samples. The ascorbic content of hot air, microwave and freeze dried was found to be 3.45 mg, 3.75 mg and 4.22 mg per 100 g of sample, respectively. The freeze dried samples got highest sensory score compared to other dried samples. Therefore, the freeze drying can be an effective drying method to dry fresh mushroom compared to hot air and microwave drying based upon the colour, texture, ascorbic acid and other nutritional values. The freeze dried mushroom products can be stored for a longer storage period having excellent quality because of less microbial attack. In future studies, the research work has to be conducted using freeze dried samples having better retention quality for processing of value added products. This will be helpful to enlarge the efficiency of this technology to industrial scale.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Chang ST, Miles PG. Mushroom cultivation, nutritional value, medicinal effect and environmental impact, 2nd Ed. CRC Press LLC. USA;2004
2. Kaul TN. Biology and conservation of Mushrooms. New Delhi, India: Oxford and IBH publishing Co. Pvt. Ltd. 2001;117-145.
3. Dhamodharan G, Mirunalini, S. A novel medicinal characterization of *Agaricus bisporus* (white button mushroom). Pharmacology. 2010;2:456-463.
4. Alzamora SM, Castro MA, Vidales SL, Nieto AB, Salvatori D. The role of tissue microstructure in the textural characteristics of minimally processed fruits, Minimally processed fruits and vegetables. 2000;153-169.
5. Ibrahium M, Hegazy A. Effect of replacement of wheat flour with mushroom powder and sweet potato flour on nutritional composition and sensory characteristics of biscuits. Current Science International. 2014;3:26-33.
6. Eskandari-Nojedehi M, Jafarizadeh-Malmiri H, Rahbar-Shahrouzi J. Hydrothermal green synthesis of gold nanoparticles using mushroom (*Agaricus bisporus*) extract: physicochemical characteristics and antifungal activity studies. Green Processing and Synthesis. 2017;7(1):38-47.
7. Wang HO, Fu QQ, Chen SJ, Hu ZC, Xie HX. Effect of hot-water blanching pretreatment on drying characteristics and product qualities for the novel integrated freeze-drying of apple slices. Journal of Food Quality;2018.
8. Fan D, Chitrakar B, Ju R, Zhang M. Effect of ultrasonic pretreatment on the properties of freeze-dried carrot slices by traditional and infrared freeze-drying technologies. Drying Technology. 2021;39(9):1176-1183.
9. AOAC. Official methods of analysis. Association of Official Analytical Chemists Inc. 15th edn. Arlington, Virginia, USA;1990.
10. Jiang N, Liu C, Li D, Zhou Y. Effect of blanching on the dielectric properties and microwave vacuum drying behavior of *Agaricus bisporus* slices. Innovative Food Science and Emerging Technologies. 2015;30:89–97.
11. Yang CST, Atallah WA. Effect of four drying methods on the quality of intermediate moisture lowbush blueberries. Journal of Food Science. 1985;50:1233-1237.
12. Mudahar GS, Bains GS. Pretreatment effect on quality of dehydrated *Agaricus bisporus* mushroom. Indian Food Packer. 1982;28:19-22.
13. Rama V, John PJ. Effects of methods of drying and pre-treatments on quality of dehydrated mushroom. Indian Food Packer. 2000;54:59-64.
14. Giri KS, Prasad S. Studied drying kinetics and rehydration characteristics of microwave-vacuum and convective hot-air dried mushrooms. Journal of Food Engineering. 2007;78(2):512-521.

15. Ramesh MN, Wolf W, Tevini D, Bognar A. Microwave blanching of vegetables. J. Food Sci. 2002;67: 390–398.

16. Zhuk YUT, Tsapalova IE. Effect of heat drying on the quality of dried mushroom. Konservnaya -iOvoshchesushil _naya-Promyshlennost. 1973;12:30-31.

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