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RESEARCH ARTICLE

Studies on the drying of oyster mushrooms (*Pleurotus sajor-caju*) and its utilization in mushroom-incorporated cookies

Ritika[1], Krishan Kumar[1,2]*, Sanyukta[1], Manjot Kaur[1], Navjot Kaur[1], Duyi Samyor[2], Naseer Ahmed[1], Mohd Aaqib Sheikh[1]

[1]Department of Food Technology, Dr Khem Singh Gill Akal College of Agriculture, Eternal University, Sirmour-173101, Himachal Pradesh, India
[2]Department of Food Technology, Rajiv Gandhi University, Doimukh 791112, Arunachal Pradesh, India

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ABSTRACT

The present investigation was carried out to study the drying of oyster mushrooms by involving two methods, namely hot-air oven drying and vacuum drying, after different pre-treatments. There was a decrease in browning of mushrooms dried after blanching and steeping in anti-browning agents such as citric acid (0.5%) and ascorbic acid (0.5%). The browning was observed to be lowest in vacuum-dried mushrooms compared to hot-air oven-dried mushrooms. Therefore, the mushrooms dried by vacuum drying techniques, pre-treated with citric acid (0.5%) and ascorbic acid (0.5%) solutions after blanching, were utilized for the preparation of mushroom powder for incorporation in cookies. The cookies were prepared by incorporating mushroom powder at 5%, 10%, and 15% by replacing wheat flour and were subjected to organoleptic evaluation by a semi-trained panel. The cookies were moderately acceptable, having an organoleptic score of more than 7.0 as per a 9-point hedonic rating scale. However, the cookies containing a higher level of mushroom powder (15%) scored slightly lower (having an overall score of less than 7) compared to other formulations. These products can provide significant support against protein-energy malnutrition (PEM), obesity, cardiovascular diseases, diabetes, and other lifestyle disorders that have a wide prevalence in different sections of society.

Keywords: Cookies, hot air oven drying, organoleptic evaluation, oyster mushroom, vacuum oven drying.

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INTRODUCTION

The edible mushrooms have widely been utilized as human foods and have been admired for texture, flavor, as well as some medicinal and nutritional aspects (Manzi et al., 2001). There are around 38,000 mushroom varieties known to exist. However, about 100 of these are considered edible. In India, mainly three species viz., white button, oyster or dhingri, and paddy straw mushrooms are commercially cultivated on a large scale (Chandra and Samsher, 2005).

* *For correspondence*: K. Kumar (Email: krishan.kumar@rgu.ac.in)

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Nowadays, mushrooms are being relished throughout the world as food and medicine. Researcher reports disclose that mushrooms, being a complete food source, are rich in proteins, vitamins, fats, dietary fibers, carbohydrates, and minerals (Alam et al., 2009). Oyster mushrooms (*Pleurotus spp*), also known as 'dhingri' or 'abalone', rank second among the important cultivated mushrooms in the world (Miles and Chang, 1997). These mushrooms have popularly been consumed by people all over the world due to their appreciated taste, flavor, and high nutritional and medicinal value (Deepalakshmi and Sankaran, 2014). *Pleurotus species* were first cultivated on logs as it is a wood-digesting fungus. After cultivation of the edible mushroom *Pleurotus sojor-caju*, various spent agro-residues obtained were used in anaerobic digesters for the production of biogas (Bisaria et al., 1990).

Under natural conditions, the oyster mushroom is grown on living trees as a parasite or dead woody branches of trees as a primary decomposer and saprophyte. Because of its tongue-shaped pileus with an eccentric lateral stripe, this group got the common name 'oyster mushrooms'. It possesses a very pleasant flavor and taste and is a highly perishable commodity. The off-seasonal use of mushrooms can be achieved by adopting appropriate post-harvest technology to process the fruiting bodies into novel value-added products. Various value-added products have been developed from *Pleurotus* mushrooms (Kumar, 2020).

Oyster mushrooms have been reported as an edible and potential resource of medicinal and nutritional components by a large number of researchers. The protein content of this mushroom is higher than other foods because of the presence of all nine essential amino acids, and these can be used as a substitute for a meat diet (Kakon et al., 2012). The presence of a large number of bioactive components such as β-glucan, ascorbic acid, lectins, phenolic components, antioxidants, and polysaccharide-protein complex makes them suitable to be used as an ingredient for nutritional enrichment of mushroom-based functional foods (Kumar, 2020).

Because of high proteins and low calories, they are the number one diet to be recommended to heart patients. These contain lysine and tryptophan, two essential amino acids deficient in cereals (Bahl, 2002). There is a large production of these mushrooms during their season, but a major portion of their produce perishes due to a lack of processing techniques. So, there is an immense need for the development of processing technologies for such nutritious but highly perishable foods.

Drying mushrooms is widely practiced to make them available in off-seasons. Also, dehydration has been found to be an effective method of extending the shelf-life of mushrooms. The mushroom powder can be utilized for the development of value-added products such as bakery products (Rai and Arumuganathan, 2008). Keeping in view the nutritional and health benefits of oyster mushrooms, the present investigation was planned to study the effect of various drying techniques on the physicochemical characteristics, and mushrooms obtained from the best drying technique were converted to mushroom powder and utilized for the development of cookies by incorporating wheat flour in different proportions.

MATERIALS AND METHODS

Materials

The good quality mushrooms of *Pleurotus sojor-caju* variety were purchased from the Directorate of Mushroom Research, Solan. The raw materials needed to make the processed goods were obtained from the neighborhood market. Ultrapure grade chemicals, obtained from reputable suppliers like BDH chemicals, Qualigens, Merck India, Hi-Media, and Sigma, were employed in the current studies. The baking ingredients, which included hydrogenated vegetable oil, crystal sugar, food-grade NaCl, and wheat flour of standard manufacturers, were purchased from the neighborhood market.

Methods

Physico-chemical analysis

The air-oven drying method, as outlined by AOAC (1990), was used to determine the moisture content. The ash content, crude fiber, crude fat, and crude proteins were estimated according to the methodology described by Ranganna (1986). The amount of carbohydrates was calculated by the difference after determining the moisture, proteins, fat, ash, and crude fiber. The calorific

value was estimated using the Atwater factors of 4.0, 9.10, and 4.2 Kcal/g for each component, i.e., crude protein (N×6.25), fats, and carbohydrates, respectively (WHO 1973). The Atomic Absorption Spectrometer (Agilent Technology, CA, USA; AA240FS) was utilized to ascertain the mineral contents (AOAC 1990). The modified colorimetric method of Vaintraub and Lapteva (1988) was followed for the phytic acid assay.

The total phenolic content was ascertained using the Folin-Ciocalteu reagent, following the slightly modified version of Ainsworth and Gillespie (2007), and values were expressed as mg Gallic Acid Equivalent (GAE) per 100 g. A semi-trained panel of fifteen members evaluated the organoleptic properties in terms of color, appearance, texture, aroma, and taste on a 9-point hedonic rating scale (Ranganna 1986).

Drying of mushrooms

Mushrooms were dried using two methods, namely hot-air oven drying and vacuum drying, after different pre-treatments. After cleaning, the mushrooms were cut into slices. The 100 g slices were weighed and treated separately as follows:

1. Control without any treatment
2. Blanching in 400 ml boiling water (100°C) for 3 minutes
3. Blanching in 400 ml boiling water (100°C) for 3 minutes, followed by steeping in 0.5% ascorbic acid and 0.5% citric acid solutions for 30 minutes.

Three replicates of the pre-treated 100 g slices were spread over aluminum trays. During hot-air oven drying, the temperature was initially maintained at 60°C for 5 hours and then at 50°C for the remainder of the drying period. In the case of vacuum drying, the temperature was maintained at 60°C until the mushrooms were completely dried.

Preparation of mushroom-incorporated cookies

The mushrooms were dried using vacuum drying techniques that were pre-treated with citric acid (0.5%) and ascorbic acid (0.5%) solutions after blanching. These dried mushrooms were then used to prepare mushroom powder for incorporation into cookies. Various blends were made for making the cookies. The mushroom powder was substituted at levels of 5, 10, 15, and 20% to replace wheat flour. The traditional creamery method was used to prepare the cookies, using ingredients such as wheat flour or blend (100 g), hydrogenated vegetable oil (35 g), sugar (35 g), glucose (1 g), skimmed milk powder (1 g), ammonium bicarbonate (1 g), sodium bicarbonate (1 g), vanillin (0.05 g), and water (15-18 ml). Control cookies were made from wheat flour and other ingredients for comparison. The sugar was ground in a grinder to a fine powder, and the sugar, fat, and vanillin were mixed for 2-3 minutes. This mixture was then added to a mixture of wheat flour, SMP, glucose, common salt, and oat flour. To make the dough, sodium bicarbonate and ammonium bicarbonate were dissolved in water, and this water was used to prepare the dough. Using a wooden rolling pin, the prepared dough was sheeted onto an aluminum platform until it reached a consistent thickness of 2.5 mm. The sheet was divided into equal pieces using a round cutter with a diameter of 48 mm, and these pieces were then placed evenly on a baking tray. The tray was placed in the baking oven (SANCO) and baked for 7-8 minutes at 205°C. After reaching room temperature, the cookies were packed into 100-gauge polypropylene pouches and heat-sealed.

Statistical analysis

Each experiment was conducted in triplicate, and the mean ± standard deviation was used to represent the findings. The IBM SPSS Statistics Developer software, version 16.0, was used to compute means using an embedded one-way analysis of variance (ANOVA). Significant differences were taken into consideration at a significance level of $p \leq 0.05\%$.

RESULTS AND DISCUSSION

Physicochemical characteristics of fresh oyster mushroom

Data pertaining to the physical parameters of fresh oyster mushrooms are presented in Table 1. The physical parameters, such as the length and weight of fresh oyster mushrooms, were determined. The data shows that the value for stipe length was 3.67 cm and the mean weight of the fruiting body of the mushroom was 17.73 g.

Table 1: Physico-chemical characteristics of fresh oyster mushroom

Parameters	Mean value
Stipe length (cm)	3.67±0.51
Weight (g)	17.73±1.17
Moisture (%)	86.18±0.67
Protein (%)	4.52±0.28
Ash (%)	1.27±0.16
Fat (%)	0.29±0.02
Fibre (%)	1.23±0.04
Total carbohydrates	6.50±0.30
Calorific value (Kcal/100g)	48.05±2.09

Values in the table are presented as mean±SD

The chemical composition of fresh oyster mushrooms is presented in Table 1. The parameters such as moisture, ash, fat, fiber, protein content, and carbohydrates of fresh oyster mushrooms were estimated using standard procedures.

Fig. 1: Fresh oyster mushroom (*Pleurotus ostreatus* L.)

The fresh oyster mushroom contained 86.18% moisture, 1.23% crude fiber content, 0.29% crude fat, 4.52% crude protein, and 1.27% ash content, whereas carbohydrates and calorific values were found to be 6.50% and 48.05 Kcal/100g, respectively (Fig.1).

Physico-chemical characteristics of oyster mushroom dried by hot-air oven technique

The chemical composition of oyster mushrooms dried in a hot-air oven, subjected to different pre-treatments, namely untreated and hot air dried (UHD), blanched hot air dried (BHD), and blanched, treated with anti-browning agents and hot air oven-dried (BTHD), is presented in Table 2. The parameters, such as moisture, fat, fiber, protein, ash, carbohydrates, and mineral content,

were estimated using standard procedures. The moisture content of hot-air oven-dried mushrooms ranged between 7.41% (UHD) and 8.77% (BTHD).

Table 2: Physico-chemical characteristics of hot-air oven-dried oyster mushroom

Parameters	UHD	BHD	BTHD
Moisture (%)	7.41±0.17^{c}	8.29±0.11^{b}	8.77±0.12^{a}
Fat (%)	2.06±0.07^{a}	0.93±0.06^{b}	0.81±0.06^{b}
Fiber (%)	8.89±0.29^{a}	5.36±0.05^{b}	5.19±0.10^{b}
Protein (%)	24.90±0.09^{a}	21.90±0.20^{b}	21.33±0.15^{c}
Ash (%)	8.66±0.49^{a}	5.98±0.28^{b}	4.85±0.06^{c}
Carbohydrates (%)	48.08±0.98^{b}	58.19±0.47^{a}	58.41±0.51^{a}
Calorific value (Kcal/100g)	320.33±3.13^{c}	340.49±0.70^{a}	337.98±1.00^{b}
Browning (OD values)	0.33±0.01^{a}	0.23±0.01^{a}	0.15±0.01^{b}
Total Phenolic components (mg GAE/100g)	33.80±0.61^{a}	27.91±0.03^{b}	11.96±0.03^{c}
Phytic Acid (%)	0.29±0.02^{a}	0.26±0.02^{a}	0.18±0.01^{b}
Cu (mg/100g)	1.76±0.36^{a}	1.36±0.11^{ab}	1.23±0.16^{b}
Fe (mg/100g)	7.86±0.13^{a}	6.60±0.32^{b}	6.44±0.33^{b}
Zn (mg/100g)	6.78±0.19^{a}	5.49±0.28^{b}	5.13±0.24^{b}
Mn (mg/100g)	0.92±0.06^{a}	0.77±0.11^{ab}	0.67±0.08^{b}

Values in the table are presented as mean±SD. Values within rows sharing the same letters are not significantly different according to Duncan's LSD post-hoc analysis at P≤0.05. UHD - Untreated Hot air oven dried, BHD - Blanched+ Hot air oven dried, BTHD - Blanched + treated + Hot air oven dried.

Crude fat contents ranged between 0.81 (BTHD) and 2.06% (UHD). The UHD mushrooms contained the highest fiber content (8.89%), and BTHD the lowest (5.19%). Crude protein contents ranged between 21.33 (BTHD) and 24.90% (UHD). The values for ash content were highest for UHD-dried mushrooms (8.66%) and lowest for BTHD-dried mushrooms (4.85%). Carbohydrate contents ranged from 48.08% (UHD) to 58.41% (BTHD). Similar results were obtained by Tiram (2013) during the nutritional evaluation of oyster mushrooms (*Pleurotus sajor-caju*) dried by different drying techniques. Nadew et al. (2024) reported about 27.8% protein and 50.2% carbohydrates in dried oyster mushrooms. They further reported that potassium and sodium were the dominant elements as estimated by spectrophotometry analysis.

The calorific values varied from 320.33 to 340.49 Kcal/100g. The values were highest for BHD-dried mushrooms (340.49 Kcal/100g) and lowest for UHD-dried mushrooms (320.33 Kcal/100g). Total phenolic components were found to be highest in UHD-dried mushrooms (33.80 mg GAE/100g) and lowest in BTHD-dried mushrooms (11.96 mg GAE/100g). The phytic acid was highest in UHD-dried mushrooms (0.29%) and lowest in BTHD-dried mushrooms (0.18%). Browning was found to be lowest in BTHD (0.15) and highest in UHD (0.33). Therefore, it can be concluded that pre-treatment of mushrooms resulted in diminishing the enzymatic browning as compared to untreated mushrooms due to the inactivation of the enzyme polyphenol oxidase responsible for browning in mushrooms. The pre-treatment effect on the quality of dehydrated Agaricus bisporus mushrooms was studied by Mudahar and Bains (1982).

The value for Cu content was highest in BHD (1.36 mg/100g) and lowest in BTHD (1.23 mg/100g); for Fe, it was reported highest in UHD (7.86 mg/100g) and lowest in BTHD (6.44 mg/100g); for Zn, it was highest in UHD (6.78 mg/100g) and lowest in BTHD (5.13 mg/100g). Similarly, the Mn content varied between 0.67 (UHD) and BTHD (0.92 mg/100g). The mineral content of blanched and pre-treated mushrooms was lower as compared to the control. This may be attributed to the leaching of minerals during the blanching and steeping process (Fig. 2).

Physico-chemical characteristics of oyster mushroom dried by vacuum drying technique

The chemical composition of vacuum-dried oyster mushrooms is presented in Table 3. The moisture content of vacuum-dried mushrooms ranged between 9.39% and 10.52%. Blanched and treated vacuum-dried (BTVD) mushrooms had the highest value (10.52%), whereas untreated vacuum-dried (UVD) mushrooms had the lowest moisture content (9.39%). Crude fat contents ranged from 0.42% (BTVD) to 0.70% (UVD). The UVD mushrooms contained the highest fiber content (6.37%), and BTVD contained the lowest fiber (5.10%). Crude protein contents ranged between 20.26% (UTVD) and 24.75% (UVD). The ash content varied from 5.16% (BTVD) to 7.19% (UVD). Carbohydrates ranged from 56.58% (BTVD) to 53.08% (UVD). Similar results were obtained by Tiram (2013) during the nutritional evaluation of oyster mushrooms (*Pleurotus sajor-caju*) dried by different drying techniques.

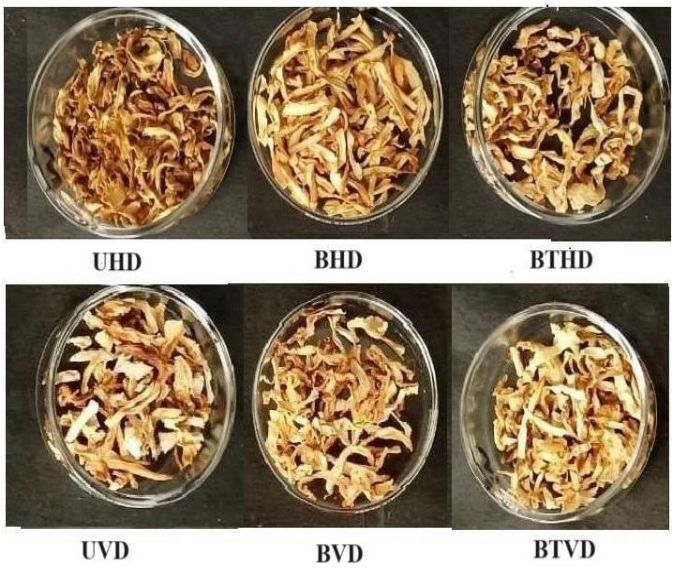

Fig. 2: Oyster mushrooms dried by different drying techniques

UHD - Untreated hot-air oven dried, BHD - Blanched + hot-air oven dried, BTHD - Blanched + treated + hot-air oven dried; UVD - Untreated vacuum dried, BVD - Blanched + vacuum dried, BTVD - Blanched + treated + vacuum dried.

The calorific values were highest for BVD mushrooms (332.13 Kcal/100g) and lowest for BTVD dried mushrooms (323.00 Kcal/100g). Total phenolic components were found to be highest in UVD mushrooms (30.3 mg GAE/100g) and lowest in BTVD mushrooms (13.0 mg GAE/100g). The phytic acid was highest in UVD mushrooms (0.35%) and lowest for BTVD dried mushrooms (0.26%). Therefore, the phytic acid, an anti-nutritional component, was decreased after blanching and drying techniques.

Browning was found lowest in BTVD (0.16) and highest in UVD (0.30). Therefore, it can be concluded that pre-treatment of mushrooms resulted in diminishing the enzymatic browning as compared to untreated mushrooms due to the inactivation of the enzyme polyphenol oxidase responsible for browning in mushrooms. Dunkwal et al. (2007) reported that untreated slices in hot air oven drying showed a higher browning index as compared to powders obtained from pretreated mushrooms. Deshpande and Tamhane (1981) also reported that water blanching for three minutes was sufficient to inactivate PPO enzymes, which cause browning during the drying of mushrooms. On the other hand, Chandra and Samsher (2002) reported that the rate of increase in the browning index was significantly lower in blanched plus steeped (KMS 0.5 percent) slices as compared to single treated slices.

The value for Cu was highest in UVD (1.41 mg/100g) and lowest in BTVD (0.88 mg/100g). Similarly, the Fe content was highest in UVD (7.51 mg/100g) and lowest in BTVD (6.09 mg/100g). The value for Zn is highest in UVD (6.43 mg/100g) and lowest in

BTVD (4.78 mg/100g). For Mn, the value ranged between 0.32-0.57/100g. For UVD, the value was highest (0.57 mg/100g) and for BTVD, it was lowest (0.32 mg/100g).

Table 3: Physico-chemical characteristics of vacuum-dried oyster mushroom

Parameters	UVD	BVD	BTVD
Moisture (%)	9.39±0.13^{b}	9.69±0.17^{b}	10.52±0.27^{a}
Fat (%)	0.70±0.07^{a}	0.43±0.08^{b}	0.42±0.03^{b}
Fiber (%)	6.37±0.05^{a}	5.17±0.04^{b}	5.10±0.03^{b}
Protein (%)	24.75±0.04^{b}	21.14±0.05^{a}	20.26±0.05^{c}
Ash (%)	7.19±0.16^{a}	6.82±0.07^{b}	5.16±0.04^{c}
Carbohydrates (%)	53.08±0.43^{a}	56.82±0.30^{b}	56.58±0.42^{a}
Calorific value (Kcal/100g)	332.13±1.31^{a}	326.50±0.73^{b}	323.00±1.09^{c}
Browning (OD values)	0.30±0.01^{a}	0.22±0.01^{b}	0.16±0.01^{c}
Total Phenolic components (mg GAE/100g)	3.03±0.05^{a}	2.52±0.03^{b}	1.30±0.02^{c}
Phytic Acid (%)	0.35±0.03^{a}	0.33±0.01^{a}	0.26±0.02^{b}
Cu (mg/100g)	1.41±0.36^{a}	1.01±0.11^{ab}	0.88±0.16^{b}
Fe (mg/100g)	7.51±0.13^{a}	6.25±0.32^{b}	6.09±0.33^{b}
Zn (mg/100g)	6.43±0.19^{a}	5.14±0.28^{b}	4.78±0.24^{b}
Mn (mg/100g)	0.57±0.06^{a}	0.42±0.11^{ab}	0.32±0.08^{b}

Values in the table are presented as mean ± SD. Values within rows sharing the same letters are not significantly different according to Duncan's LSD post hoc analysis at P ≤ 0.05. UVD-Untreated vacuum dried, BV-blanched+ vacuum dried, BTV-blanched+ treated+ vacuum dried.

Physico-chemical and organoleptic evaluation of mushroom-incorporated products

The cookies prepared by incorporating mushroom powder at 5% (MIC1), 10% (MIC2), and 15% (MIC3) in wheat flour were evaluated for physical parameters such as weight, diameter, thickness, and spread ratio. The weight of the cookies ranged from 6.36g (MIC3) to 7.02g (Control). The diameter and thickness of the cookies varied from 4.73mm (MIC3) to 5.27mm (Control) and 0.54mm (Control) to 0.67mm (MIC1), respectively. The spread ratio of the cookies was found in the range of 7.28 (MIC3) to 9.69 (Control). The spread ratio of oyster mushroom-incorporated cookies was lower than that of the control cookies (Table 4).

Chemical Analysis: The mushroom-incorporated cookies were subjected to chemical analysis for different parameters, and the results obtained are presented in Table 4. The moisture content ranged from 2.75% to 4.23%. The values for ash content varied from 1.55% to 3.16% in different formulations. The ash content was highest in MIC3 (3.16%) and lowest in the Control (1.55%).

Table 4: Physico-chemical evaluation of oyster mushroom-incorporated cookies

Values in the table are presented as mean±SD. Values within rows sharing the same letters are not significantly different according to Duncan's LSD post hoc analysis at P≤0.05. MIC- mushroom incorporated cookies, Control-100% wheat flour, MIC1-95% wheat flour+5% mushroom powder, MIC2-90% wheat flour+10% mushroom powder, MIC3-85% wheat flour+15% mushroom powder.

Values for crude fibre contents were highest in MIC3 (8.31%) and lowest in control cookies (3.17%). However, the crude fat contents were highest in the control (24.29%) and lowest in MIC3 (20.33%). The content of carbohydrates ranged from 51.47% (MIC3) to 58.48% (Control). Therefore, there was an increase in crude fibre, ash, or mineral content but a decline in fat content,

which may be attributed to the higher crude fibre and ash content and lower fat content of mushroom powder compared to wheat flour. Similar results were obtained by Kumar and Barmanray (2007) during the nutritional evaluation of button mushroom powder-incorporated biscuits. Calorific values of cookies varied from 451.15-505.68 Kcal/100 g. The values were highest for the control (505.68Kcal/100 g) and lowest for MIC3 (451.15Kcal/100 g). The total phenolic components (TPC) were highest in MIC3 (57.50mg GAE/100g) and lowest in the control (19.50mg GAE/100g). The TPC was enhanced with increased incorporation of mushroom powder in wheat flour. The phytic acid was found to be highest in MIC3 (0.56%) and lowest in the control (0.08%). The values for mineral contents i.e. Cu, Fe, Zn, Mn were highest in MIC3, with values of 0.28, 4.45, 1.65, and 0.36 mg/100g respectively. The values were lowest for the control, with values of 0.15, 1.47, 0.65, 0.11 mg/100g respectively. There was an enhancement in mineral contents of cookies with increased incorporation of mushroom powder in cookies.

Parameters	Control	MIC1	MIC2	MIC3
Weight (g)	7.02±0.56^{a}	6.75±0.61^{a}	6.58±0.66^{a}	6.36±0.92^{a}
Thickness (cm)	0.54±0.02^{b}	0.67±0.01^{a}	0.64±0.07^{a}	0.65±0.02^{a}
Diameter (cm)	5.27±0.21^{a}	5.20±0.20^{a}	4.80±0.10^{b}	4.73±0.25^{b}
Spread Ratio	9.69±0.11^{a}	7.72±0.19^{b}	7.59±0.70^{b}	7.28±0.26^{b}
Moisture (%)	2.75±0.31^{c}	3.45±0.22^{b}	4.10±0.11^{a}	4.23±0.07^{a}
Protein (%)	9.76±0.24^{d}	10.73±0.23^{c}	11.40±0.49^{b}	12.50±0.31^{a}
Fat (%)	24.29±0.54^{a}	23.29±0.51^{b}	20.93±0.15^{c}	20.33±0.57^{c}
Fiber (%)	3.17±0.35^{d}	4.79±0.07^{c}	6.90±0.09^{b}	8.31±0.30^{a}
Ash (%)	1.55±0.05^{d}	1.90±0.05^{c}	2.51±0.14^{b}	3.16±0.03^{a}
Carbohydrates (%)	58.48±1.09^{a}	55.84±0.33^{b}	54.16±0.30^{b}	51.47±1.09^{d}
Calorific value (Kcal/100g)	505.68±4.07^{a}	489.37±2.57^{b}	463.56±0.93^{c}	451.15±1.67^{d}
Total Phenolic components (mg GAE/100g)	19.50±0.26^{d}	41.30±0.10^{c}	46.97±0.90^{b}	57.50±4.37^{a}
Phytic Acid	0.08±0.01^{d}	0.25±0.02^{c}	0.43±0.01^{b}	0.56±0.01^{a}
Cu (mg/100g)	0.15±0.01^{b}	0.20±0.06^{b}	0.27±0.01^{a}	0.28±0.01^{a}
Fe (mg/100g)	1.47±0.01^{d}	1.94±0.01^{c}	3.62±0.20^{a}	4.45±0.15^{a}
Zn (mg/100g)	0.65±0.06^{d}	1.07±0.10^{c}	1.52±0.01^{b}	1.65±0.02^{a}
Mn (mg/100g)	0.11±0.01^{c}	0.51±0.01^{b}	0.54±0.01^{b}	0.86±0.03^{a}

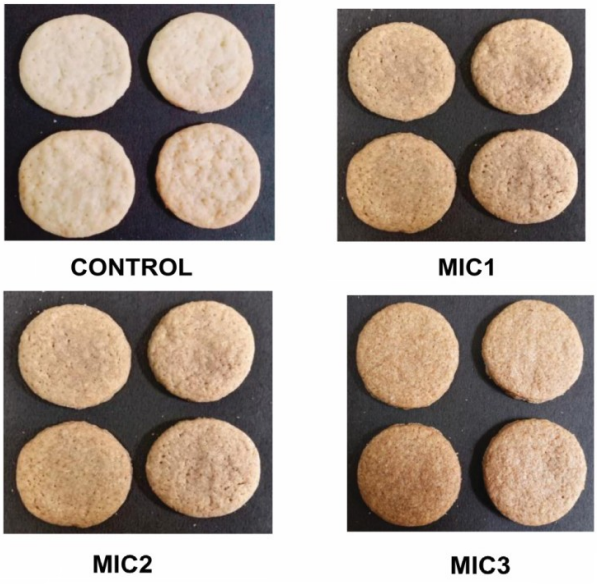

Fig. 3: Mushroom-incorporated cookies prepared with different formulations

MIC - Mushroom Incorporated Cookies, Control - 100% wheat flour, MIC1 - 95% wheat flour + 5% mushroom powder, MIC2 - 90% wheat flour + 10% mushroom powder, MIC3 - 85% wheat flour + 15% mushroom powder.

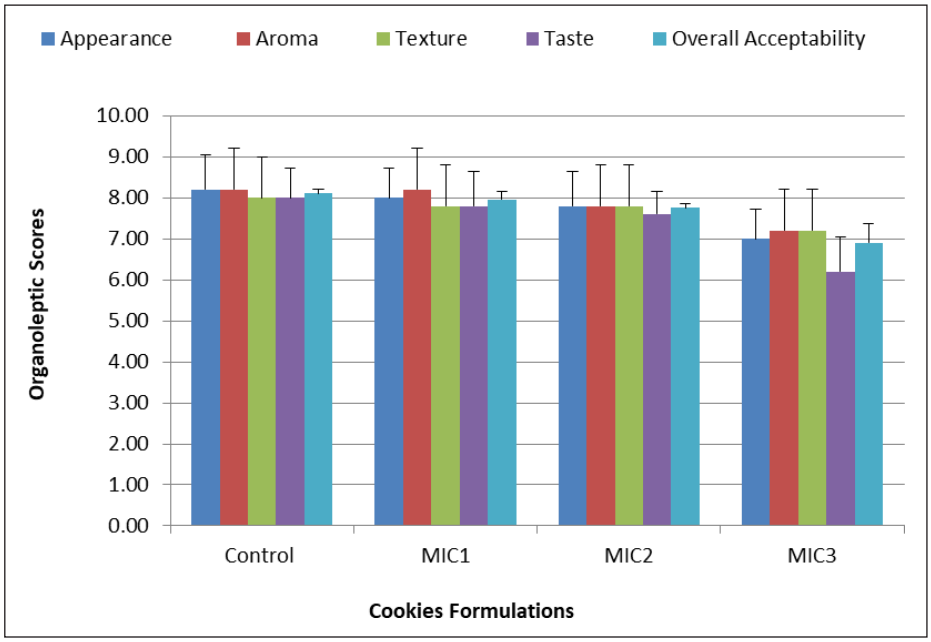

Fig. 4: Organoleptic evaluation of oyster mushroom incorporated cookies

MIC - Mushroom Incorporated Cookies

Control - 100% wheat flour

MIC1 - 95% wheat flour + 5% mushroom powder

MIC2 - 90% wheat flour + 10% mushroom powder

MIC3 - 85% wheat flour + 15% mushroom powder

Organoleptic evaluation:Organoleptic evaluation of gluten-free cookies after processing is presented in Fig. 4. Cookies were subjected to organoleptic evaluation by a semi-trained panel. The overall acceptability score for the control, MIC1, MIC2, and MIC3 was 8.5, 8.0, 7.70, and 6.8. There was a slight decrease in the overall acceptability of mushroom-incorporated cookies (MIC1, MIC2, and MIC3) compared to the control, but these cookies were moderately acceptable according to the 9-point hedonic rating scale.

CONCLUSION

The present investigation was carried out to study the drying of oyster mushrooms by involving two methods, i.e., hot-air-oven drying and vacuum drying, after different pre-treatments. There was a decrease in the browning of mushrooms dried after blanching and steeping in anti-browning agents such as citric acid (0.5%) and ascorbic acid (0.5%). The browning was observed to be lowest in vacuum-dried mushrooms compared to hot-air oven-dried mushrooms. Therefore, the mushrooms dried by vacuum drying techniques, pre-treated with citric acid (0.5%) and ascorbic acid (0.5%) solutions after blanching, were utilized for the preparation of mushroom powder to be incorporated in cookies.

The cookies prepared by incorporating mushroom powder at 5%, 10%, and 15% by replacing wheat flour were subjected to organoleptic evaluation by a semi-trained panel to judge the acceptance of different formulations of oyster mushroom-incorporated cookies. The results of the organoleptic evaluation concluded that different formulations of products were moderately acceptable,

having an organoleptic score of more than 7.0 on a point hedonic rating scale. However, the products containing higher levels of mushroom powder (15%) scored slightly lower (having an overall score of less than 7) compared to other formulations. This was mainly due to the low score in parameters such as color, flavor, and taste of such products. The cookies were significantly rich in essential nutrients such as crude fiber, crude fat, ash or mineral contents, total polyphenolic contents, and especially crude proteins. It can be concluded that partially substituting wheat flour with mushroom flour in fortified cookies is a useful strategy for providing consumers with wholesome, antioxidant-rich, and functional food products.

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REFERENCES

A.O.A.C. (1990). Official Methods of Analysis (15th ed.). Association of Official Analytical Chemists, Washington, D.C.

Alam, N., Amin, R., Khan, A., Ara, I., Shim, M.J., Lee, M.W., Lee, U.Y., & Lee, T.S. (2009). Comparative effects of oyster mushrooms on lipid profile, liver and kidney function in hypercholesterolemic rats. *Mycobiology, 37*(1), 37-42.

Bahl, N. (2002). *Handbook on Mushrooms*. Oxford and IBH Publishing Company Pvt. Ltd., New Delhi.

Bisaria, R., Vasudevan, P., & Bisaria, V. (1990). Utilization of spent agro-residues from mushroom cultivation for biogas production. *Applied Microbiology and Biotechnology, 33*, 607-609.

Chandra, S., & Samsher, S. (2002). Studies on quality of dehydrated oyster mushroom as influenced by various pre-treatments and drying method. *Mushroom Research, 11*, 107-112.

Deepalakshmi, K., & Sankaran, M. (2014). *Pleurotus ostreatus*: An oyster mushroom with nutritional and medicinal properties. *Journal of Biochemical Technology, 5*(2), 718-726.

Deshpande, A., & Tamhane, D. (1981). Studies on dehydration of mushrooms (*Volvariella volvacea*). *Journal of Food Science and Technology, 18*(3), 96-101.

Dunkwal, V., Jood, S., & Singh, S. (2007). Physico-chemical properties and sensory evaluation of *Pleurotus sajor caju* powder as influenced by pre-treatments and drying methods. *British Food Journal, 109*(9), 749-759.

Kakon, A., Choudhury, M. B. K., & Saha, S. (2012). Mushroom is an ideal food supplement. *Journal of Dhaka National Medical College and Hospital, 18*(1), 58-62.

Kumar, K. (2020). Nutraceutical potential and processing aspects of oyster mushrooms (*Pleurotus* species). *Current Nutrition and Food Science, 16*(1), 3-14.

Kumar, K., & Barmanray, A. (2007). Nutritional evaluation and storage studies of button mushroom powder fortified biscuits. *Mushroom Research, 16*(1), 31-35.

Manzi, P., Aguzzi, A., & Pizzoferrato, L. (2001). Nutritional value of mushrooms widely consumed in Italy. *Food Chemistry, 73*(3), 321-325.

Miles, P. G., & Chang, S. T. (1997). *Mushroom biology: Concise basics and current developments*. World Scientific.

Nadew, T. T., Reshad, A. S., & Tedla, T. S. (2024). Oyster mushroom drying in tray dryer: Parameter optimization using response surface methodology, drying kinetics, and characterization. *Heliyon, 10*(2), e24623.

Rai, R., & Arumuganathan, T. (2008). Economics for pickling. *Post Harvest Technology. Technical Bulletin, NRCM, Solan*, 68-69.

Ranganna, S. (1986). *Handbook of analysis and quality control for fruit and vegetable products*. Tata McGraw-Hill Education.

Tiram, C. (2013). Effect of different drying techniques on the nutritional values of oyster mushroom (*Pleurotus sajor-caju*). *Sains Malaysiana, 42*(7), 937-941.

WHO, F. (1973). Energy and protein requirements. Paper presented at the Geneva: FAO/WHO. (FAO Nutrition Meetings Report Series 52).

Vaintraub, I.A., & Lapteva, N.A. (1988). Colorimetric determination of phytate in unpurified extracts of seeds and the products of their processing. *Analytical Biochemistry, 175*(1), 227-230.

Ainsworth, E.A., & Gillespie, K. M. (2007). Estimation of total phenolic content and other oxidation substrates in plant tissues using Folin–Ciocalteu reagent. *Nature Protocols, 2*(4), 875.