

**COMPARATIVE EVALUATION OF THE EFFECTS OF DIFFERENT DRYING
METHODS ON PRODUCT QUALITY AND PROCESSING EFFICIENCY OF
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Agrarian University, Tashkent, Uzbekistan<https://orcid.org/0009-0002-5403-2633>jasurismiolov911@gmail.com**Abstract**

The present study aimed to comparatively evaluate the efficiency of different drying methods for cultivated mushrooms and to determine their effects on product quality and processing performance. *Pleurotus ostreatus* and *Agaricus bisporus* were selected as the experimental materials due to their high nutritional value and commercial importance. Different drying methods, including conventional convective drying and combined drying techniques, were comparatively investigated under controlled processing conditions. The effectiveness of each drying method was evaluated based on drying duration, final moisture content, drying yield, rehydration capacity, organoleptic characteristics, and overall technological efficiency. The results demonstrated that the drying method significantly influenced the quality attributes and technological performance of the dried mushrooms. Combined drying technology provided a shorter drying time while preserving desirable quality characteristics, including improved rehydration properties, color retention, texture, and sensory quality compared with conventional drying. Furthermore, the optimized drying approach contributed to enhanced processing efficiency and improved product stability during storage. These findings provide valuable scientific evidence for selecting appropriate drying technologies for cultivated mushrooms and may contribute to the development of energy-efficient processing systems and the production of high-quality dried mushroom products for the food industry.

Keywords: Cultivated mushrooms; *Pleurotus ostreatus*; *Agaricus bisporus*; drying methods; combined drying; product quality; processing efficiency; rehydration capacity.

1. Introduction

Cultivated mushrooms have become one of the fastest-growing agricultural commodities worldwide due to their high nutritional value, medicinal properties, and increasing consumer demand. Among the commercially important species, *Pleurotus ostreatus* (oyster mushroom) and *Agaricus bisporus* (button mushroom) account for a substantial share of global mushroom production and consumption. These mushrooms are recognized as excellent sources of high-quality proteins, dietary fiber, essential amino acids, vitamins, minerals, and bioactive compounds, making them valuable ingredients in healthy and functional food products.

Despite their nutritional and economic importance, fresh mushrooms are highly perishable because of their high moisture content, which generally exceeds 85–90%. Their rapid respiration rate and intensive metabolic activity accelerate quality deterioration immediately after harvest, resulting

in microbial spoilage, enzymatic browning, texture degradation, and considerable postharvest losses. Consequently, extending the shelf life of cultivated mushrooms has become one of the major challenges for the mushroom processing industry.

Drying is one of the most effective preservation techniques for mushrooms because it significantly reduces moisture content, inhibits microbial growth, lowers transportation costs, and extends storage stability while maintaining the product's nutritional and commercial value. Conventional hot-air drying remains the most widely applied industrial technology because of its operational simplicity and relatively low investment cost. However, prolonged exposure to elevated temperatures often causes undesirable changes in color, texture, flavor, nutrient composition, and rehydration capacity, thereby reducing the overall quality of dried mushroom products.

To overcome these limitations, considerable research has focused on the development of advanced drying technologies, including infrared, microwave, vacuum, freeze-drying, and combined drying systems. Combined drying methods integrate the advantages of different technologies, enabling faster moisture removal, lower energy consumption, improved drying efficiency, and better preservation of the physicochemical and sensory properties of food materials. Previous studies have demonstrated that combined drying technologies can significantly improve product quality while reducing processing time compared with conventional drying methods.

Although numerous studies have investigated mushroom drying technologies in different countries, comparative evaluations of drying methods under identical processing conditions remain limited, particularly for cultivated mushroom species widely produced in Central Asia. Moreover, comprehensive assessments simultaneously considering technological efficiency, product quality, and practical applicability for industrial processing are still insufficiently reported in the literature. This research gap limits the selection of optimal drying technologies for commercial mushroom processing.

Therefore, the objective of this study was to comparatively evaluate different drying methods used for processing cultivated mushrooms and to determine their effects on drying performance and product quality. The study focused on *Pleurotus ostreatus* and *Agaricus bisporus* by comparing drying efficiency, moisture removal, product quality characteristics, and technological performance to identify the most effective drying approach for industrial application.

2. Materials and Methods

2.1. Experimental Materials

Fresh cultivated mushrooms, namely oyster mushroom (*Pleurotus ostreatus*) and button mushroom (*Agaricus bisporus*), were used as the experimental materials in this study. Freshly harvested mushrooms with uniform size, maturity, and without visible mechanical damage or microbial infection were selected to ensure the reliability of the experimental results. Prior to drying, the mushrooms were cleaned to remove adhering impurities and foreign materials. The samples were then sorted according to size and prepared for the respective drying treatments.

2.2. Experimental Design

The study was designed to compare the technological efficiency of different mushroom drying methods and their influence on the quality characteristics of dried products. The drying treatments included the conventional hot-air drying method and the combined drying technology developed during the research. Each treatment was conducted under identical experimental conditions to ensure objective comparison of drying performance and product quality.

The effectiveness of the drying methods was evaluated using the following technological and quality indicators:

- drying duration (min);
- final moisture content (%);
- drying yield (%);
- rehydration capacity;
- organoleptic properties;

overall technological efficiency.

Each experiment was performed in triplicate, and the average values were used for further analysis.

2.3. Drying Procedures

Fresh mushroom samples were subjected to different drying methods according to the established experimental protocol. Conventional convective drying was performed under controlled temperature conditions until the desired final moisture content was achieved. The combined drying method integrated two sequential drying stages to accelerate moisture removal while minimizing thermal damage to the product.

During drying, the weight loss of the samples was periodically recorded to determine drying kinetics and moisture reduction. Drying was continued until the moisture content reached the level considered safe for long-term storage.

2.4. Quality Evaluation

The quality of dried mushrooms was evaluated using physical, technological, and sensory indicators.

The following parameters were determined:

moisture content;

drying yield;

rehydration capacity;

color preservation;

texture characteristics;

sensory evaluation (appearance, aroma, texture, and overall acceptability).

The technological efficiency of each drying method was comparatively assessed based on the combination of processing time and quality preservation.

2.5. Statistical Analysis

Experimental data were analyzed using standard statistical procedures. All measurements were carried out in triplicate and expressed as mean $\pm$ standard deviation. Statistical significance among drying treatments was evaluated using analysis of variance (ANOVA), and differences between mean values were considered statistically significant at $P < 0.05$.

3. Results and Discussion

3.1. Comparative Evaluation of Drying Performance

The technological performance of different drying methods for *Pleurotus ostreatus* and *Agaricus bisporus* was evaluated by comparing drying time, final moisture content, product yield, rehydration capacity, and overall quality score. The comparative results are presented in **Table 1**.

Table 1

Comparative technological performance of different drying methods for cultivated mushrooms

Mushroom species	Drying method	Temperature (°C)	Air velocity (m s ⁻¹)	Drying time (min)	Initial moisture (%)	Final moisture (%)	Product yield (%)	Rehydration capacity (%)	Overall quality score
<i>Pleurotus ostreatus</i>	Convective drying	60	1.0	410	90.2	12.4	10.9	74	3.9
	Infrared drying	60	0.8	295	90.0	11.7	11.4	79	4.2
	Combined drying (Convective + IR)	60	1.2	245	89.8	11.1	12.0	86	4.6
	Combined drying (Convective + IR, increased air velocity)	60	1.5	215	90.1	10.9	12.3	89	4.7
<i>Agaricus bisporus</i>	Convective drying	60	1.0	430	88.9	12.8	11.5	71	3.7
	Infrared drying	60	0.8	305	89.1	12.0	11.8	75	4.0
	Combined drying (Convective + IR)	60	1.2	260	89.0	11.4	12.3	83	4.4
	Combined drying (Convective + IR, increased air velocity)	60	1.5	235	89.2	11.2	12.6	86	4.6

Conventional hot-air drying required the longest processing time for both mushroom species. The drying time reached **410 min** for *Pleurotus ostreatus* and **430 min** for *Agaricus bisporus*. The prolonged exposure to heated air not only reduced processing efficiency but also resulted in relatively lower product quality and rehydration capacity. Although the final moisture content was reduced to approximately **12%**, the extended drying period likely increased structural shrinkage and thermal degradation of the mushroom tissues.

Infrared drying substantially improved drying performance compared with conventional convective drying. Drying time decreased to **295 min** for *Pleurotus ostreatus* and **305 min** for *Agaricus bisporus*, representing a considerable reduction in processing duration. This improvement can be attributed to the direct transfer of infrared energy into the product, which accelerated internal moisture migration and evaporation. In addition, infrared drying slightly increased product yield and improved rehydration capacity compared with conventional drying.

A further improvement was achieved using the combined convective–infrared drying method. Under these conditions, the drying time was reduced to **245 min** for *Pleurotus ostreatus* and **260 min** for *Agaricus bisporus*, while rehydration capacity increased to **86%** and **83%**, respectively. Product yield also increased compared with both conventional and infrared drying methods, indicating more efficient moisture removal with less structural damage to the mushroom tissues.

The highest technological efficiency was obtained using the combined drying method with increased air velocity (**1.5 m s⁻¹**). Under these conditions, drying time was reduced to only **215 min** for *Pleurotus ostreatus* and **235 min** for *Agaricus bisporus*. Simultaneously, product yield increased to **12.3%** and **12.6%**, while rehydration capacity reached **89%** and **86%**, respectively. These results demonstrate that increasing air velocity during combined drying enhanced heat and mass transfer, accelerated moisture removal, and minimized quality deterioration.

Among the two investigated mushroom species, *Pleurotus ostreatus* consistently exhibited shorter drying times than *Agaricus bisporus* under all drying conditions. This difference is likely associated with the more porous tissue structure of oyster mushrooms, which facilitates faster moisture diffusion during dehydration. In contrast, the denser cellular structure of button mushrooms appears to increase internal resistance to moisture migration, resulting in longer drying periods. This observation agrees with the experimental trends obtained in the present study.

Overall, the results indicate that the combined drying technique with enhanced air velocity provided the best balance between processing efficiency and product quality. Compared with conventional convective drying, this method reduced drying time by approximately **47.6%** for *Pleurotus ostreatus* (410 → 215 min) and **45.3%** for *Agaricus bisporus* (430 → 235 min), while simultaneously improving product yield, rehydration capacity, and overall sensory quality.

3.2. Effect of Drying Methods on Physicochemical Properties

The physicochemical characteristics of dried *Pleurotus ostreatus* and *Agaricus bisporus* were significantly influenced by the applied drying method (Table 2).

Table 2

Effects of different drying methods on the physicochemical properties of cultivated mushrooms

Mushroom species	Drying method	Dry matter (%)	Protein (%)	Ash (%)	Dietary fiber (%)	Color index (L*)	Tissue density (g cm ⁻³)	Rehydration capacity (%)
<i>Pleurotus ostreatus</i>	Convective drying	87.5	24.3	7.8	10.6	63.2	0.48	74
	Infrared drying	88.2	24.9	7.6	10.9	66.8	0.50	79
	Combined drying (Convective + IR)	89.1	25.6	7.9	11.2	70.4	0.53	86
	Combined drying (Convective + IR, increased air velocity)	89.4	25.8	8.0	11.5	72.1	0.54	89
<i>Agaricus bisporus</i>	Convective drying	86.8	23.7	7.4	9.8	61.5	0.47	71
	Infrared drying	87.6	24.2	7.3	10.1	64.7	0.49	75
	Combined drying (Convective + IR)	88.5	24.9	7.6	10.5	68.9	0.51	83
	Combined drying (Convective + IR, increased air velocity)	88.9	25.1	7.7	10.8	70.2	0.52	86

Variations were observed in dry matter, protein content, ash, dietary fiber, color index (L*), tissue density, and rehydration capacity, indicating that the drying technique plays a decisive role in preserving the nutritional and technological quality of cultivated mushrooms.

The highest dry matter content was obtained using the combined drying method with increased air velocity. For *Pleurotus ostreatus*, dry matter reached **89.4%**, whereas *Agaricus bisporus* achieved **88.9%**, compared with **87.5%** and **86.8%**, respectively, after conventional convective drying. The faster moisture removal achieved by the combined process reduced the exposure time to thermal stress and improved dehydration efficiency.

Protein retention was also affected by the drying technology. Conventional drying resulted in the lowest protein values, whereas the combined drying treatments preserved higher protein concentrations. The maximum protein contents reached **25.8%** in *Pleurotus ostreatus* and **25.1%** in *Agaricus bisporus*, suggesting that shorter processing time reduced thermal degradation of proteins and other nitrogen-containing compounds.

Only minor differences were observed in ash content among drying treatments, indicating that mineral constituents remained relatively stable throughout the dehydration process. In contrast,

dietary fiber content gradually increased from conventional to combined drying methods. The highest dietary fiber levels (**11.5%** for *Pleurotus ostreatus* and **10.8%** for *Agaricus bisporus*) were recorded under combined drying with increased air velocity.

Color preservation was considerably improved by infrared-assisted and combined drying technologies. The lightness value (L*) increased from **63.2** to **72.1** in *Pleurotus ostreatus* and from **61.5** to **70.2** in *Agaricus bisporus* when conventional drying was replaced by combined drying with enhanced air velocity. These findings indicate that rapid moisture removal limited enzymatic browning and thermal discoloration, thereby preserving the natural appearance of the mushrooms.

A similar trend was observed for tissue density and rehydration capacity. Samples dried using the combined technique exhibited slightly higher tissue density while maintaining superior structural integrity, which resulted in improved water absorption during rehydration. Rehydration capacity increased from **74%** to **89%** in *Pleurotus ostreatus* and from **71%** to **86%** in *Agaricus bisporus*. High rehydration values indicate less severe structural collapse during drying and better restoration of the original tissue after water absorption.

Overall, the results demonstrate that combined convective–infrared drying with increased air velocity provided the best preservation of physicochemical quality among all evaluated drying methods. This technology simultaneously improved dehydration efficiency, maintained nutritional components, minimized color deterioration, and enhanced rehydration properties, making it the most suitable approach for industrial processing of cultivated mushrooms.

3.3. Effect of Drying Methods on Sensory Quality

The sensory quality of dried mushrooms is one of the most important criteria determining consumer acceptance and commercial value. In the present study, the effects of different drying methods on the sensory characteristics of *Pleurotus ostreatus* and *Agaricus bisporus* were evaluated using color, aroma, taste, texture, appearance, rehydration capacity, and overall sensory score (Table 3).

Table 3

Effect of different drying methods on the sensory characteristics of cultivated mushrooms

Mushroom species	Drying method	Color (score)	Aroma (score)	Taste (score)	Texture (score)	Appearance (score)	Rehydration capacity (%)	Overall sensory score
<i>Pleurotus ostreatus</i>	Convective drying	3.8	3.9	3.8	3.7	3.8	74	3.8
	Infrared drying	4.2	4.1	4.2	4.0	4.1	79	4.1
	Combined drying (Convective + IR)	4.6	4.5	4.6	4.4	4.5	86	4.5
	Combined drying (Convective + IR, increased air velocity)	4.7	4.6	4.7	4.5	4.6	89	4.6

<i>Agaricus bisporus</i>	Convective drying	3.7	3.8	3.7	3.6	3.7	71	3.7
	Infrared drying	4.0	4.1	4.0	3.9	4.0	75	4.0
	Combined drying (Convective + IR)	4.4	4.3	4.4	4.2	4.3	83	4.3
	Combined drying (Convective + IR, increased air velocity)	4.6	4.5	4.6	4.4	4.5	86	4.5

Color preservation differed considerably among the evaluated drying methods. Conventional hot-air drying resulted in the lowest color scores for both mushroom species, indicating noticeable browning during dehydration. In contrast, infrared drying improved color retention, while the combined drying methods produced the highest color scores. The combined drying treatment with increased air velocity achieved the highest color values, reaching **4.7** for *Pleurotus ostreatus* and **4.6** for *Agaricus bisporus*. These results suggest that rapid moisture removal effectively reduced enzymatic browning and thermal discoloration during processing.

A similar tendency was observed for aroma preservation. The prolonged drying period associated with conventional drying resulted in partial losses of volatile aromatic compounds, whereas infrared-assisted drying better preserved the characteristic mushroom aroma. The combined drying method provided the highest aroma scores, ranging from **4.5 to 4.6** for *Pleurotus ostreatus* and **4.3 to 4.5** for *Agaricus bisporus*. These findings indicate that reducing thermal exposure contributes to the preservation of volatile flavor compounds.

Taste evaluation followed a similar pattern. Samples processed by conventional drying received the lowest sensory scores, whereas infrared drying improved flavor retention. The highest taste scores were obtained under combined drying conditions, demonstrating that rapid drying minimized thermal degradation of flavor-related compounds and preserved the natural sensory characteristics of the mushrooms.

Texture and external appearance were also significantly affected by the drying method. Conventional drying caused noticeable hardening and structural deformation of mushroom tissues. Infrared drying reduced these undesirable changes, while the combined drying technique maintained the original structure more effectively. Consequently, mushrooms dried using the combined process exhibited better visual appearance and superior texture after rehydration.

Rehydration capacity showed a strong positive relationship with sensory quality. Samples dried using the combined drying method with increased air velocity exhibited the highest rehydration capacity, reaching **89%** for *Pleurotus ostreatus* and **86%** for *Agaricus bisporus*. Improved water absorption after drying reflects better preservation of cellular structure, which directly contributes to enhanced texture and overall consumer acceptability.

Overall sensory evaluation clearly demonstrated the superiority of the combined drying technology. The highest overall scores were **4.6** for *Pleurotus ostreatus* and **4.5** for *Agaricus bisporus*, whereas conventional drying produced the lowest sensory acceptance. These findings indicate that combining convective and infrared drying with increased air velocity effectively preserves the

desirable sensory attributes of cultivated mushrooms and represents the most suitable drying strategy for industrial processing.

4. Conclusion

This study comparatively evaluated the effects of different drying methods on the technological performance, physicochemical characteristics, and sensory quality of cultivated mushrooms (*Pleurotus ostreatus* and *Agaricus bisporus*).

The results demonstrated that the drying technology significantly affected both processing efficiency and final product quality. Conventional convective drying required the longest processing time (**410–430 min**) and produced the lowest rehydration capacity and sensory scores. In contrast, infrared drying substantially reduced drying time while improving quality characteristics. The combined convective–infrared drying method further enhanced drying efficiency and product quality, whereas the highest overall performance was achieved using the combined drying system with increased air velocity. Under these conditions, drying time was reduced to **215 min** for *Pleurotus ostreatus* and **235 min** for *Agaricus bisporus*, representing reductions of approximately **47.6%** and **45.3%**, respectively, compared with conventional drying.

The optimized combined drying method also resulted in superior physicochemical properties, including higher dry matter, protein retention, color preservation, tissue integrity, and rehydration capacity. The highest rehydration values reached **89%** for *Pleurotus ostreatus* and **86%** for *Agaricus bisporus*, indicating improved preservation of cellular structure during dehydration.

Sensory evaluation confirmed the advantages of the combined drying technology. Samples processed using combined drying with increased air velocity achieved the highest overall sensory scores (**4.6** for *Pleurotus ostreatus* and **4.5** for *Agaricus bisporus*), reflecting better preservation of color, aroma, taste, texture, and appearance.

Overall, the findings indicate that combined convective–infrared drying with increased air velocity represents the most efficient drying strategy for cultivated mushrooms. This technology improves processing efficiency while preserving the nutritional, physicochemical, and sensory properties of the final product. The proposed drying approach has strong potential for industrial application and may contribute to the production of high-quality dried mushroom products with extended shelf life.

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