

JMBFS

Journal of Microbiology, Biotechnology and Food Sciences

International peer-reviewed scientific online journal

Published by Faculty of Biotechnology and Food Sciences

EFFECT OF DRYING TEMPERATURE ON THE RELATIVE FATTY ACID PROFILE, GLUCAN FRACTIONS AND FATTY ACID-DERIVED LIPID QUALITY INDICES IN WILD-GROWING BAY BOLETE MUSHROOM (*IMLERIA BADIA*)

Marek Šnirc[1], Ivona Jančo[2], Silvia Jakabová[1], Július Árvay[3]*

Address(es): PaedDr. Silvia Jakabová, PhD.
[1] Slovak University of Agriculture in Nitra, Faculty of Biotechnology and Food Sciences, Institute of Food Sciences, Tr. A. Hlinku 2, 94976 Nitra, Slovakia, phone no.: +42137641 4345.
[2] Slovak University of Agriculture in Nitra, Agrobiotech Research Centre, Tr. A. Hlinku 2, 94976 Nitra, Slovakia.
[3] Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 94976 Nitra, Slovakia.

*Corresponding author: silvia.jakabova@uniag.sk

https://doi.org/10.55251/jmbfs.14432

ARTICLE INFO

Received 25. 5. 2026
Revised 23. 6. 2026
Accepted 9. 11. 2026
Published xx.xx.201x

Regular article

OPEN ACCESS

ABSTRACT

This study evaluated the effect of drying temperature on the relative fatty acid profile, glucan fractions, and fatty acid profile-derived indices in wild-growing bay bolete mushroom (*Imleria badia*). Fruiting bodies collected in western Slovakia were processed as lyophilized reference material or dried by hot-air drying at 20, 30, 40, and 50 °C. Fatty acid methyl esters were determined by GC-FID, while total, α-, and β-glucans were quantified using the Megazyme enzymatic assay. Across all treatments, the fatty acid profile was dominated by linoleic acid (C18:2 cis-9, cis-12; 60.5–65.8%), followed by oleic acid (C18:1 cis-9; 15.3–18.9%) and palmitic acid (C16:0; 13.7–15.2%). Polyunsaturated fatty acids were the predominant fatty acid class, although their relative proportion decreased at 50 °C, where saturated and monounsaturated fatty acids reached their highest values. The PUFA/SFA ratio ranged from 3.08 to 3.76, while the index of atherogenicity and index of thrombogenicity showed only limited variation among treatments. Total glucans ranged from 22.4 to 26.5 g/100 g dry matter, and β-glucans were the dominant glucan fraction in all samples (17.3–21.4 g/100 g dry matter). The highest β-glucan content and β-glucan/total glucan proportion were observed at 50 °C. These results indicate that drying temperature modified the relative fatty acid distribution of *I. badia*, particularly at 50 °C, but did not reduce β-glucan content under the applied conditions. The calculated lipid indices should be interpreted as comparative descriptors of the relative fatty acid profile rather than evidence of substantial dietary lipid contribution.

Keywords: *Imleria badia; bay bolete; hot-air drying; relative fatty acid profile; glucan fractions; fatty acid profile-derived indices*

INTRODUCTION

Edible wild mushrooms are valued as seasonal foods because they contain proteins, dietary fibre, minerals, vitamins, glucans, phenolic compounds, sterols and other biologically active constituents, while generally having low lipid and energy content (**Predanócyová *et al.*, 2023; Sari *et al.*, 2017; Šnirc *et al.*, 2023; Vetter, 2023**). Their consumer acceptance is also influenced by sensory properties, particularly aroma and flavour, which are important attributes of edible mushrooms (**Štefániková *et al.*, 2021**). In Slovakia, mushroom picking is a widespread leisure activity with both provisioning and cultural ecosystem-service value, and *Imleria badia* is included among the commonly harvested ectomycorrhizal mushrooms considered in Slovak forest ecosystems, together with other frequently collected taxa from Boletaceae and related ectomycorrhizal groups (**Olah *et al.*, 2020**). At the same time, wild mushroom consumption should be interpreted in relation to species identity, collection locality and environmental conditions, because edible wild mushrooms may accumulate potentially toxic elements from their environment (**Šnirc *et al.*, 2023**).

I. badia (Fr.) Vizzini, formerly reported as *Xerocomus badius*, is an edible ectomycorrhizal bolete from the family Boletaceae. In previous glucan studies, *I. badia* showed a high content of total glucans and β-glucans when analysed by the Megazyme enzymatic method (**Mirończuk-Chodakowska and Witkowska, 2020**). Similarly, **Sari *et al.* (2017)** reported high β-glucan proportions in both caps and stipes of *X. badius* syn. *I. badia*, supporting its relevance as a wild edible source of fungal glucans. Glucans are structural polysaccharides of fungal cell walls, and mushroom β-glucans are mainly represented by β-1,3-glucans with β-1,6-linked side chains; their biological relevance depends not only on quantity but also on molecular structure, branching, solubility and higher-order conformation (**Mirończuk-Chodakowska and Witkowska, 2020; Vetter, 2023**).

Drying is commonly used to preserve mushrooms because it reduces water activity, extends shelf life and enables the later use of seasonal fruiting bodies (**Liu *et al.*, 2024; Timm *et al.*, 2019**). However, drying temperature may affect mushroom quality because thermal treatment can modify chemical composition, sensory properties and selected bioactive fractions (**Liu *et al.*, 2024; Timm *et al.*, 2019**).

Although mushrooms generally contain low amounts of total lipids, their lipid fraction is often characterized by a predominance of unsaturated fatty acids; therefore, fatty acid profile-derived indices can be used to compare the nutritional characteristics of the lipid fraction, provided that their interpretation remains limited to relative compositional differences rather than substantial dietary lipid contribution (**Chen and Liu, 2020; Tan *et al.*, 2024**).

Despite available data on glucans in *I. badia*, the combined effect of drying temperature on its relative fatty acid profile, lipid-derived indices and glucan fractions remains insufficiently documented (**Mirończuk-Chodakowska and Witkowska, 2020; Sari *et al.*, 2017; Vetter, 2023**).

The present study aimed to evaluate the effect of drying temperature on the relative fatty acid profile, fatty acid profile-derived indices, and glucan content of wild-growing *I. badia*. The study focused on the comparison of commonly applicable drying temperatures with lyophilized and/or control material in order to determine whether drying conditions are associated with measurable changes in lipid composition and glucan fractions. We hypothesized that drying temperature would significantly affect the relative fatty acid distribution and selected fatty acid profile-derived indices, while changes in total, α-, and β-glucans would reflect the stability or altered analytical extractability of fungal cell-wall polysaccharides under different drying regimes.

MATERIAL AND METHODS

Sampling area

Mushroom samples were collected in October 2025 in the cadastral area of Studienka, Malacky District, western Slovakia. The sampling site was located near Studienka village in the Záhorie region (48.53654°N, 17.11610°E), within the Borská nížina lowland, which is characterized by sandy substrates and forest ecosystems dominated mainly by pine stands.

Technological treatment

The collected mushroom material consisted of whole fruiting bodies, including both caps and stipes. After removal of visible impurities, the samples were cut into slices of comparable size to ensure uniform drying. The prepared mushroom slices were dried in a hot-air drying oven Memmert UF 110m (Memmert GmbH & Co. KG, Schwabach, Germany) at 20 °C, 30 °C, 40 °C, and 50 °C until constant weight was reached, which required approximately 24 h. The selected temperature range was chosen to represent low- to moderate-temperature hot-air drying conditions commonly used in domestic mushroom preservation. Higher drying temperatures, particularly 60–80 °C, were not included because preliminary observations indicated a substantial deterioration of sensory properties, mainly colour, aroma, and overall acceptability of the dried material.
A lyophilized reference sample was prepared in parallel and used as the reference treatment. For clarity and graphical consistency, this treatment is labelled as Control in tables and figures. For this purpose, mushroom slices were cut into approximately 1 × 1 cm pieces, rapidly frozen at −80 °C, and subsequently freeze-dried using a LyoQuest freeze dryer (Telstar SLU, Barcelona, Spain) at −80 °C for 48 h. After drying, all samples were homogenized and used for chemical analyses. For each technological treatment, including the lyophilized reference sample and samples dried at 20 °C, 30 °C, 40 °C, and 50 °C, homogenized composite samples were prepared and analytical determinations were performed in replicate measurements.

Determination of fatty acid methyl esters

Fatty acid methyl esters were determined after lipid extraction and methylation. Homogenized dried mushroom material was extracted using a modified chloroform–methanol procedure based on the principles of Bligh and Dyer (1959) and Folch *et al.* (1957). Briefly, approximately 0.2 g of each sample was weighed into a 15 mL plastic tube and mixed with 7.6 mL of a chloroform, methanol, and ultra-pure water mixture (2:4:1.6, v/v/v). Chloroform (ChromaSolv ≥99.9%; Honeywell, Seelze, Germany) and methanol (ChromaSolv ≥99.9%; Sigma-Aldrich GmbH, Steinheim, Germany) were used for lipid extraction. The samples were shaken for 3 h using a Unimax 2010 laboratory shaker (Heidolph GmbH, Schwabach, Germany).
After extraction, the mixtures were centrifuged at 2236 × g for 2 min using a Hettich Universal 320 centrifuge (Hettich GmbH, Tuttlingen, Germany) and filtered under reduced pressure using a vacuum manifold. Subsequently, 1 mL chloroform, 1 mL potassium chloride solution (2 mol/L), and 0.9 mL ultra-pure water were added to each sample to promote phase separation. The samples were then centrifuged at 800 × g for 5 min. The lower organic phase was collected and dried using an SPE vacuum manifold (Agilent Technologies, USA) in the presence of anhydrous sodium sulfate.
For methylation, 1.45 mL of the dried lipid extract was transferred into an Eppendorf tube and mixed with 50 µL methanolic potassium hydroxide (2 mol/L) and 500 µL hexane (SupraSolv®, GC purity; Merck KGaA, Darmstadt, Germany). The mixture was vortexed, and after phase separation, 1 mL of the upper clear hexane layer containing fatty acid methyl esters was transferred into a gas chromatography vial for analysis. The procedure followed the analytical approach described by **Benko *et al.* (2024)**, with modifications for dried mushroom material. Fatty acid methyl esters were analysed by gas chromatography with flame ionization detection (GC-FID) using an Agilent 7890A gas chromatograph (Agilent Technologies, USA). A 1 µL aliquot of each sample was injected using a CombiPAL autosampler (CTC Analytics AG, Switzerland). Separation was performed on an HP-88 capillary column (100 m × 0.25 mm × 0.20 µm; Agilent Technologies, USA). Data acquisition and processing were carried out using Agilent OpenLab ChemStation software. Identification and calibration were performed using a certified 37-component FAME Mix standard (TraceCERT®, Supelco, USA). For additional qualitative confirmation of selected fatty acid methyl esters, a 7890B GC system coupled with a 5977A mass detector (Agilent Technologies, USA) was used. Fatty acid composition was expressed as the relative percentage of each identified fatty acid within the total detected FAME profile.

Determination of glucans

Total glucans and α-glucans were determined using the β-Glucan Assay Kit (Yeast and Mushroom; Megazyme, Bray, Ireland) according to the manufacturer's instructions. This enzymatic approach is commonly used for mushroom samples and enables the quantification of glucan fractions based on the spectrophotometric determination of released D-glucose **(Mirończuk-Chodakowska and Witkowska, 2020; Vetter, 2023)**.
In brief, total glucans were determined after acid hydrolysis of homogenized dried mushroom material, followed by neutralization and enzymatic hydrolysis with exo-1,3-β-glucanase and β-glucosidase. The released D-glucose was quantified spectrophotometrically using glucose oxidase/peroxidase reagent at 510 nm.
α-Glucans were determined separately after solubilization and enzymatic hydrolysis with amyloglucosidase and invertase. β-Glucan content was calculated as the difference between total glucans and α-glucans. Total glucans, α-glucans, and β-glucans were expressed as g/100 g dry matter.
Glucan fractions were determined from homogenized composite samples prepared for each technological treatment, and the reported mean ± SD values reflect analytical variability of replicate determinations.

Fatty acid profile-derived indices

elected indices were calculated from the relative fatty acid profile to characterize differences in fatty acid class distribution among the applied drying treatments. Because mushrooms are characterized by low total lipid content, these indices were used as comparative descriptors of the relative fatty acid profile. The evaluated indices included the polyunsaturated to saturated fatty acid ratio (PUFA/SFA), index of atherogenicity (IA), index of thrombogenicity (IT), hypocholesterolemic/hypercholesterolemic ratio (HH), unsaturation index (UI), and total trans fatty acid content (TFA). All indices were calculated from the relative percentages of quantified fatty acid methyl esters obtained by GC-FID analysis.
The calculation of individual fatty acid profile-derived indices followed the approaches described by **Chen and Liu (2020)** and **Gałgowska and Pietrzak-Fiećko (2022)**, with minor adjustments according to the fatty acid composition detected in the mushroom samples.
The PUFA/SFA ratio was used to describe the relative balance between polyunsaturated fatty acids and saturated fatty acids within the fatty acid methyl ester profile. Higher PUFA/SFA values indicate a higher relative proportion of PUFA compared with SFA within the detected FAME profile. The PUFA/SFA ratio was calculated as follows:

$$\text{PUFA/SFA} = \frac{\sum \text{PUFA}}{\sum \text{SFA}}$$

where ΣPUFA represents the sum of all identified polyunsaturated fatty acids and ΣSFA represents the sum of all identified saturated fatty acids, both expressed as relative percentages of the total identified fatty acid methyl esters.
The index of atherogenicity (IA) was used to describe the relative contribution of selected saturated fatty acids, mainly lauric, myristic, and palmitic acids, in relation to the total unsaturated fatty acid fraction. Lower IA values are generally regarded as more favourable, because they indicate a lower relative contribution of fatty acids commonly associated with atherogenic lipid profiles compared with unsaturated fatty acids.

$$IA = \frac{C12{:}0 + (4 \times C14{:}0) + C16{:}0}{\sum UFA}$$

where C12:0, C14:0, and C16:0 represent the relative percentages of lauric, myristic, and palmitic acids, respectively, and ΣUFA represents the sum of all identified unsaturated fatty acids.
The index of thrombogenicity (IT) reflects the relative balance between selected saturated fatty acids and unsaturated fatty acid groups, including MUFA, n-6 PUFA, and n-3 PUFA. Lower IT values are generally considered more favourable, as they indicate a lower relative contribution of fatty acids included in the numerator compared with fatty acids included in the denominator of the equation.

$$IT = \frac{C14{:}0 + C16{:}0 + C18{:}0}{(0.5 \times \sum MUFA) + (0.5 \times \sum n\text{-}6\ PUFA) + (3 \times \sum n\text{-}3\ PUFA) + \left(\frac{\sum n\text{-}3\ PUFA}{\sum n\text{-}6\ PUFA}\right)}$$

where C14:0, C16:0, and C18:0 represent the relative percentages of myristic, palmitic, and stearic acids, respectively; ΣMUFA represents the sum of monounsaturated fatty acids; and Σn-6 PUFA and Σn-3 PUFA represent the sums of n-6 and n-3 polyunsaturated fatty acids, respectively.

The hypocholesterolemic/hypercholesterolemic ratio (HH) compares the relative contribution of cis-oleic acid and PUFA with selected saturated fatty acids included in the denominator. Higher HH values are generally considered more favourable in lipid profile assessment, as they indicate a higher relative proportion of fatty acids included in the hypocholesterolemic part of the equation compared with fatty acids included in the hypercholesterolemic part.

$$HH = \frac{cis\text{-}C18{:}1 + \sum PUFA}{C14{:}0 + C16{:}0 + C18{:}0}$$

where cis-C18:1 represents the relative percentage of cis-oleic acid, ΣPUFA represents the sum of polyunsaturated fatty acids, and C14:0, C16:0, and C18:0 represent the relative percentages of myristic, palmitic, and stearic acids, respectively.
The unsaturation index (UI) was used to describe the overall degree of unsaturation within the relative fatty acid profile. Higher UI values indicate a higher contribution of unsaturated fatty acids, particularly those with multiple double

bonds. In nutritional lipid assessment, a higher degree of unsaturation is often considered favourable, although it may also be associated with greater susceptibility of the lipid fraction to oxidative changes.

$$UI = (1 \times \%monoenoic) + (2 \times \%dienoic) + (3 \times \%trienoic) + \cdots$$

The total trans fatty acid content (TFA) was calculated as the sum of all identified trans fatty acid isomers and expressed as a relative percentage of the total FAME profile.

$$TFA = \sum trans\ fatty\ acid\ isomers$$

Lower TFA values are generally considered more favourable, as dietary trans fatty acids are associated with adverse effects on cardiovascular health in lipid-rich food matrices. In the present study, TFA was used only to characterize the relative occurrence of identified trans isomers within the mushroom fatty acid profile.
Overall, these indices were used to compare the relative distribution of fatty acids among drying treatments and should not be interpreted as evidence of a substantial dietary lipid contribution or direct nutritional effect, because total lipid content was not determined and mushrooms are generally low-lipid food matrices.

Data analysis

Data are presented as mean values ± standard deviation. The normality of data distribution was evaluated using the Shapiro–Wilk test. Because the assumptions of normality were not met, non-parametric statistical methods were applied for group comparisons.
Overall differences among technological treatments, including the lyophilized reference sample and samples dried at 20 °C, 30 °C, 40 °C, and 50 °C, were assessed using the Kruskal–Wallis test. When significant differences were detected, Dunn's post hoc test was applied for pairwise comparisons between treatments, with Holm adjustment for multiple comparisons. Statistical significance was accepted at $p < 0.05$ based on Holm-adjusted p-values.
Second-degree polynomial curves were fitted only as descriptive visualization tools to summarize the observed treatment-related patterns in selected fatty acid groups, glucan fractions, and fatty acid profile-derived indices. Because only five treatment levels were included, these curves were not used for inferential interpretation or for establishing biological mechanisms. Statistical interpretation was based primarily on the Kruskal–Wallis test followed by Dunn's post hoc comparisons. Model fit was evaluated using the coefficient of determination (R^2).
All statistical analyses and graphical visualizations were performed in R version 4.4.1 using RStudio version 2024.09.1 and the packages dplyr, ggplot2, ggpmisc, rstatix, and tidyverse **(Aphalo, 2024; Kassambara, 2023; Posit Team, 2024; R Core Team, 2024; Wickham, 2016; Wickham *et al.*, 2019)**.

RESULTS AND DISCUSSION

Individual fatty acid profile

The relative percentage composition of individual fatty acids in *I. badia* as affected by drying temperature is presented in Table 1. Across all analysed treatments, the fatty acid profile was dominated by linoleic acid (C18:2 cis-9, cis-12), which accounted for 60.5–65.8% of total fatty acids. The highest relative proportion was observed in the lyophilized reference sample, while the lowest value was recorded after drying at 50 °C. Despite this decrease at the highest drying temperature, linoleic acid remained the predominant fatty acid in all samples.
Oleic acid (C18:1 cis-9) was the second most abundant fatty acid, ranging from 15.3% in the lyophilized reference sample to 18.9% at 50 °C. Palmitic acid (C16:0) was the dominant saturated fatty acid, with relative proportions between 13.7% and 15.2%. The highest values of both C18:1 cis-9 and C16:0 were observed at 50 °C, whereas this treatment showed the lowest proportion of C18:2 cis-9, cis-12. These results indicate that drying temperature modified the relative distribution of the major fatty acids, particularly at 50 °C, where a lower relative proportion of linoleic acid was accompanied by higher proportions of oleic and palmitic acids. Because fatty acids were expressed exclusively as relative percentages of total detected FAMEs, these changes should be interpreted as proportional shifts within the fatty acid profile rather than as changes in absolute fatty acid content. Since total lipid content and absolute fatty acid concentrations were not determined, the lower relative proportion of linoleic acid or PUFA at 50 °C cannot be interpreted as evidence of actual lipid degradation.
The predominance of linoleic, oleic and palmitic acids is consistent with previous studies on edible mushrooms and bolete species. **Ribeiro *et al.* (2009)** reported that oleic, linoleic, palmitic and stearic acids were generally the major fatty acids in wild edible mushrooms. Similarly, **Dembitsky *et al.* (2010)** identified oleic, linoleic and palmitic acids as the most abundant fatty acids in wild edible *Boletus* species. In *Boletus edulis* from Poland, **Pietrzak-Fiećko *et al.* (2016)** also found C18:2, C18:1 and C16:0 to be the dominant fatty acids, although their proportions varied according to geographical origin and morphological part of the fruiting body.
Compared with the literature values summarized in the previous study on *B. edulis*, the relative proportion of linoleic acid in the present *I. badia* samples was relatively high. In the previous study, linoleic acid in *B. edulis* ranged from 58.7 to 70.1%, whereas broader literature values for edible mushrooms ranged from 10.8 to 81.1% (**Dimitrijevic *et al.*, 2018; Oancea *et al.*, 2023; Pietrzak-Fiećko *et al.*, 2016; Ribeiro *et al.*, 2009; Sande *et al.*, 2019**). Thus, the values observed in *I. badia* were close to those reported for *B. edulis* and belonged to the upper part of the broader range reported for edible mushrooms. **Sande *et al.* (2019)** reported an even higher value of 81.1% in *Coprinus comatus*, while **Das *et al.* (2021)** reported values exceeding 70% in *Pleurotus ostreatus*. In this context, *I. badia* can be characterized as a species with a high relative contribution of linoleic acid to the fatty acid profile.
The relative proportion of oleic acid in the present study was lower than the upper values reported for some other edible mushrooms. In *I. badia*, C18:1 cis-9 ranged from 15.3 to 18.9%, whereas literature values summarized for edible mushrooms range from 17.7 to 79% (**Dimitrijevic *et al.*, 2018; Oancea *et al.*, 2023; Pietrzak-Fiećko *et al.*, 2016; Ribeiro *et al.*, 2009**). **Dimitrijevic *et al.* (2018)** reported the highest value, 79%, in *Russula anthracina*, indicating that some mushroom species may have a fatty acid profile dominated by oleic rather than linoleic acid. In contrast, the present *I. badia* samples showed a profile clearly dominated by linoleic acid, while oleic acid represented a secondary component.
Palmitic acid in *I. badia* ranged from 13.7 to 15.2%, which falls within the broad range reported for edible mushrooms. Previous studies reported palmitic acid values from 5.9 to 39.8%, with the upper value recorded in *Ganoderma lucidum* (**Das *et al.*, 2021**). The palmitic acid content observed in the present samples was therefore moderate compared with the broader literature range and comparable with values commonly reported for bolete mushrooms. **Pietrzak-Fiećko *et al.* (2016)** also identified palmitic acid as the main saturated fatty acid in *B. edulis*, supporting the pattern observed in the present study.
Among minor saturated fatty acids, stearic acid (C18:0) ranged from 1.03 to 1.13%, while pentadecanoic acid (C15:0) occurred at 0.57–0.77%. Heptadecanoic acid (C17:0) showed somewhat higher variability, with values from 0.99% in the lyophilized reference sample to 2.63% at 40 °C. The stearic acid values observed in *I. badia* were low compared with the broad range reported for edible mushrooms. In the previous study, literature values for stearic acid ranged from 0.81 to 76.8%, with the exceptionally high value reported in *Lactarius deliciosus* by **Dimitrijevic *et al.* (2018)**. The present values therefore fall within the lower part of the reported range and are more consistent with the generally low stearic acid levels observed in many edible mushroom species.
The minor monounsaturated fatty acids C16:1 cis-9 and C17:1 cis-10 were present at low levels. Palmitoleic acid (C16:1 cis-9) ranged from 0.50 to 0.59%, while C17:1 cis-10 ranged from 0.24 to 0.32%. These fatty acids contributed only marginally to the total fatty acid profile. The trans isomer C18:1 trans-9 was detected only in the lyophilized reference sample at 0.39% and was not detected in dried samples. This indicates that the applied drying treatments did not increase the detectable proportion of this trans fatty acid. In comparison, **Das *et al.* (2021)** reported elaidic acid in *P. ostreatus* at 0.72–1.32%, which is higher than the value observed in the lyophilized reference sample of *I. badia* and above the non-detected levels in dried samples.
Overall, the fatty acid profile of *I. badia* was characterized by a high relative proportion of linoleic acid, followed by oleic and palmitic acids. This pattern is consistent with previous findings for *Boletus* species and other edible mushrooms, where unsaturated fatty acids, particularly linoleic and oleic acids, are usually dominant (**Ribeiro *et al.*, 2009; Dembitsky *et al.*, 2010; Pietrzak-Fiećko *et al.*, 2016**). Compared with broader literature data, the present *I. badia* samples showed relatively high linoleic acid proportions, moderate palmitic acid proportions, and comparatively lower oleic acid proportions than species in which oleic acid is dominant. Drying temperature affected the relative distribution of individual fatty acids, especially at 50 °C; however, the overall profile remained stable in terms of the dominance sequence C18:2 cis-9, cis-12 > C18:1 cis-9 > C16:0.

Table 1 Relative percentage composition of individual fatty acids in relation to drying temperature. Values are expressed as mean ± SD (n = 3) and represent percentages of total fatty acids.

Temperature	C15:0	C16:0	C16:1 cis-9	C17:0	C17:1 cis-10	C18:0	C18:1 trans-9	C18:1 cis-9	C18:2 cis-9, cis-12
Control	0.67 ± 0.01	14.8 ± 0.04	0.59 ± 0.01	0.99 ± 0.01	0.32 ± 0.01	1.03 ± 0.02	0.39 ± 0.007	15.3 ± 0.02	65.8 ± 0.09
20 °C	0.67 ± 0.01	14.5 ± 0.01	0.55 ± 0.01	1.27 ± 0.03	0.24 ± 0.01	1.13 ± 0.01	ND	16.5 ± 0.01	65.1 ± 0.01
30 °C	0.63 ± 0.02	14.1 ± 0.01	0.59 ± 0.01	2.01 ± 0.01	0.30 ± 0.01	1.07 ± 0.01	ND	16.8 ± 0.01	64.4 ± 0.05
40 °C	0.57 ± 0.03	13.7 ± 0.01	0.50 ± 0.001	2.63 ± 0.01	0.26 ± 0.01	1.04 ± 0.01	ND	16.8 ± 0.02	64.3 ± 0.04
50 °C	0.77 ± 0.08	15.2 ± 0.01	0.50 ± 0.01	2.49 ± 0.01	0.28 ± 0.01	1.07 ± 0.01	ND	18.9 ± 0.01	60.5 ± 0.04

Note: Control – lyophilized reference sample; ND – not detected

Fatty acid classes and glucan fractions

The relative distribution of fatty acid classes and the contents of total, α- and β-glucans in *I. badia* in relation to drying temperature are presented in Table 2. Polyunsaturated fatty acids (PUFA) represented the dominant fatty acid class in all analysed samples, accounting for 60.5–65.8% of total fatty acids. The highest PUFA proportion was observed in the lyophilized reference sample, while the lowest value was recorded after drying at 50 °C. Saturated fatty acids (SFA) ranged from 17.5 to 19.6%, and monounsaturated fatty acids (MUFA) ranged from 16.6 to 19.7%. Drying at 50 °C was associated with the highest relative proportions of both SFA and MUFA and with the lowest relative proportion of PUFA. These results indicate that drying temperature affected the relative distribution of fatty acid classes, particularly at the highest drying temperature; however, PUFA remained the predominant fraction across all treatments.

The predominance of PUFA in the present samples is consistent with the general fatty acid pattern reported for edible mushrooms, where unsaturated fatty acids commonly prevail over saturated fatty acids (**Ribeiro *et al.*, 2009**). In a review focused on *Boletus* species, **Liu *et al.* (2024)** reported PUFA, SFA and MUFA ranges of 33.55–64.20%, 10.59–33.62% and 15.48–53.62%, respectively. Compared with these values, the PUFA proportions in *I. badia* were at the upper end of the reported range for *Boletus* species. The control and 20 °C samples slightly exceeded the upper value reported by **Liu *et al.* (2024)**, while samples dried at 30 and 40 °C were very close. The PUFA value at 50 °C remained within the reported range. In contrast, SFA and MUFA proportions in the present study were fully within the ranges summarized for *Boletus* species.

The high PUFA proportion mainly reflects the dominance of linoleic acid (C18:2 cis-9, cis-12), which was the principal individual fatty acid in all samples. This agrees with previous studies showing that linoleic, oleic and palmitic acids are usually the major fatty acids in edible mushrooms and bolete species (**Dembitsky *et al.*, 2010; Pietrzak-Fiećko *et al.*, 2016; Ribeiro *et al.*, 2009**). The lower PUFA value observed at 50 °C corresponds with the lower relative proportion of linoleic acid at this drying temperature, accompanied by higher relative proportions of MUFA and SFA. Since the data are expressed as percentages of total fatty acids, these differences should be interpreted as shifts within the relative fatty acid profile, not as changes in absolute lipid content.

The total glucan content ranged from 22.4 to 26.5 g/100 g dry matter. The lowest value was found in the lyophilized reference sample, whereas dried samples showed higher and relatively similar values, ranging from 25.4 to 26.5 g/100 g dry matter. α-Glucans represented the minor glucan fraction, ranging from 4.51 to 5.43 g/100 g dry matter. The highest α-glucan content was recorded at 30 °C, while the lowest value was observed at 50 °C. β-Glucans were the dominant glucan fraction in all samples, with values from 17.3 to 21.4 g/100 g dry matter. Their relative contribution to total glucans ranged from 77.2% in the lyophilized reference sample to 82.6% at 50 °C.

The predominance of β-glucans over α-glucans is consistent with the known glucan profile of edible mushrooms, where β-glucans are important structural polysaccharides of the fungal cell wall (**Mirończuk-Chodakowska and Witkowska, 2020; Vetter, 2023**). The β-glucan contents observed in the present study fall within the range reported by **Wunjuntuk *et al.* (2022)**, who found β-glucan contents of 5.03–24.9 g/100 g dry matter in wild mushrooms and 15.7–43.0 g/100 g dry matter in cultivated mushrooms. In this context, *I. badia* showed comparatively high β-glucan values within the range reported for wild edible mushrooms. The α-glucan contents in the present study were also within the range reported by **Wunjuntuk *et al.* (2022)**, although they were situated close to the upper part of their published values.

The effect of drying on glucan fractions appears less pronounced than the effect observed for fatty acid classes. Total glucans and β-glucans remained relatively high across all drying treatments, and β-glucans were not reduced by hot-air drying under the applied conditions. Similar stability of β-glucans during drying has been reported for *Lentinula edodes*, where **Timm *et al.* (2019)** found no significant differences in β-glucan content among samples dried at 35, 45 and 55 °C. Although this comparison refers to a different mushroom species, it supports the view that moderate drying temperatures do not necessarily reduce β-glucan content in edible mushrooms.

I. badia was characterized by a PUFA-dominated fatty acid profile and by a glucan profile dominated by β-glucans. Drying temperature modified the relative distribution of fatty acid classes, mainly at 50 °C, where the relative PUFA proportion was lower and the relative SFA and MUFA proportions were higher. These results describe proportional changes within the detected FAME profile and do not demonstrate actual lipid degradation, because absolute lipid content was not determined. In contrast, total glucans and β-glucans remained high in all dried samples. Compared with published data, the PUFA proportion in *I. badia* was at the upper end of the range reported for *Boletus* species, while β-glucan contents were within the range reported for wild edible mushrooms.

Table 2 Relative distribution of fatty acid classes and total, α- and β-glucan content in relation to drying temperature. Values are expressed as mean ± SD (n = 3).

Temperature	SFA (%)	MUFA (%)	PUFA (%)	Total glucans (g/100 g)	α-Glucans (g/100 g)	β-Glucans (g/100 g)	β-Glucan/total glucans (%)
Control	17.5 ± 0.05	16.6 ± 0.02	65.8 ± 0.09	22.4 ± 0.01	5.12 ± 0.01	17.3 ± 0.01	77.2
20 °C	17.6 ± 0.02	17.3 ± 0.01	65.1 ± 0.01	25.5 ± 0.01	4.93 ± 0.01	20.6 ± 0.01	80.7
30 °C	17.8 ± 0.04	17.5 ± 0.30	64.4 ± 0.05	26.5 ± 0.03	5.43 ± 0.01	21.1 ± 0.03	79.6
40 °C	18.0 ± 0.01	17.5 ± 0.05	64.3 ± 0.04	25.4 ± 0.05	4.67 ± 0.01	20.7 ± 0.05	81.4
50 °C	19.6 ± 0.02	19.7 ± 0.01	60.5 ± 0.04	25.9 ± 0.01	4.51 ± 0.01	21.4 ± 0.01	82.6

Note: Control – lyophilized reference sample

Effect of drying temperature on fatty acid classes

The effect of drying temperature on the relative distribution of fatty acid classes is shown in Figure 1. PUFA represented the dominant fatty acid class in all analysed samples, while SFA and MUFA formed smaller proportions of the total fatty acid profile. The highest PUFA value was observed in the lyophilized reference sample, whereas the lowest value was recorded after drying at 50 °C. In contrast, the relative proportions of both SFA and MUFA increased with increasing drying temperature and reached their highest values at 50 °C.

The Kruskal–Wallis test followed by Dunn's post hoc test showed that the 50 °C treatment differed significantly from the control for SFA and MUFA, as indicated by different significance letters. For PUFA, the lyophilized reference sample differed significantly from the 50 °C treatment, while the intermediate drying temperatures were not clearly separated from either group. Exact Holm-adjusted p-values from Dunn's post hoc comparisons for fatty acid classes and glucan fractions presented in Figures 1 and 2 are provided in Supplementary Table S1. These results indicate that the most pronounced shift in the fatty acid class distribution occurred at the highest drying temperature.

The second-degree polynomial curves are presented only as descriptive visual summaries of the observed pattern and were not used for inferential interpretation. SFA and MUFA showed an upward trend with increasing drying temperature, with relatively high coefficients of determination shown in the figure. Conversely, the relative PUFA proportion showed a downward trend, particularly at 50 °C. This pattern is consistent with the results for individual fatty acids, where the lower relative PUFA proportion was mainly associated with the lower relative proportion of linoleic acid at 50 °C. However, because the data are expressed as percentages of total fatty acids, the observed changes should be interpreted as relative compositional shifts within the fatty acid profile, not as changes in absolute lipid content.

Effect of drying temperature on glucan fractions

The effect of drying temperature on total, α- and β-glucan content is shown in Table 2 and Figure 2. The relatively low SD values observed for glucan fractions reflect the analytical variability of replicate determinations performed on homogenized composite samples and should not be interpreted as biological variability among individual fruiting bodies. Total glucan content was lowest in the lyophilized reference sample and increased in dried samples, with the highest value observed at 30 °C. According to the Dunn post hoc test, the lyophilized reference sample differed significantly from the 30 °C treatment, while the remaining drying treatments showed intermediate values and were not clearly separated from both groups.

α-Glucan content showed a different pattern. The highest value was observed at 30 °C, whereas the lowest value was recorded at 50 °C. The significance letters indicate that the 30 °C and 50 °C treatments differed significantly, while the lyophilized reference sample, 20 °C and 40 °C treatments showed intermediate values. This suggests that α-glucans were more variable across drying treatments than total glucans, but their contribution to the overall glucan profile remained lower than that of β-glucans.

β-Glucans were the dominant glucan fraction in all analysed samples. Their content was lowest in the lyophilized reference sample and highest at 50 °C. The control and 50 °C treatments were significantly different, while the 20–40 °C treatments showed intermediate values. These results indicate that hot-air drying did not reduce β-glucan content under the applied conditions. On the contrary, dried samples showed higher β-glucan values than the lyophilized reference sample. The higher β-glucan values observed in dried samples should be interpreted cautiously. Although drying-induced changes in sample matrix properties or analytical extractability may partly explain this pattern, no structural characterization of glucans, cell-wall matrix changes, or extraction-efficiency measurements were performed. Therefore, the present data do not allow the underlying mechanism to be confirmed.

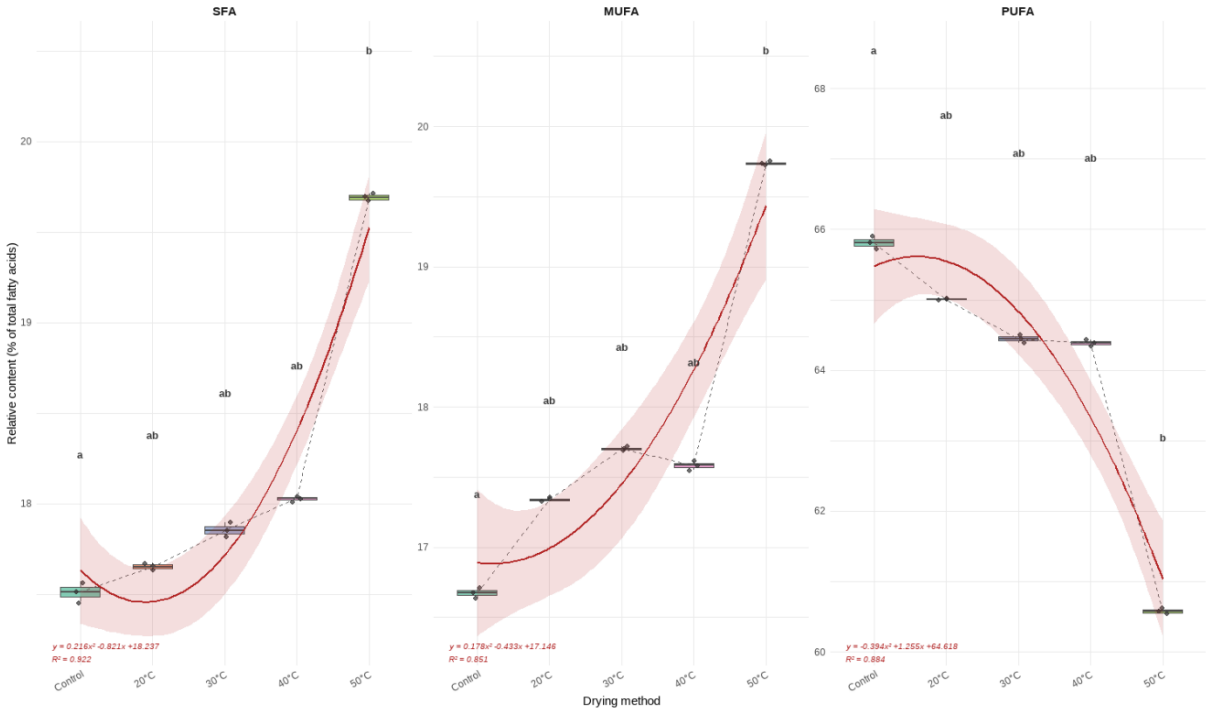


Figure 1 Effect of drying temperature on fatty acid classes in *Imleria badia*.
Note: Control denotes the lyophilized reference sample; values are expressed as mean ± SD (n = 3) and represent percentages of total fatty acids. Different letters indicate significant differences among drying treatments based on Kruskal–Wallis test followed by Dunn's post hoc test ($p < 0.05$). Polynomial curves with 95% confidence intervals are shown as descriptive visualizations of the temperature-related trend.

The descriptive polynomial curves suggest an increase in total glucans and β-glucans after drying, followed by a relatively stable or slightly variable pattern across drying temperatures. For α-glucans, the curve suggests a maximum around 30 °C and a decrease at 50 °C. These curves should be interpreted as visual summaries of the observed pattern, while the statistical interpretation should be based primarily on the Kruskal–Wallis and Dunn post hoc results.

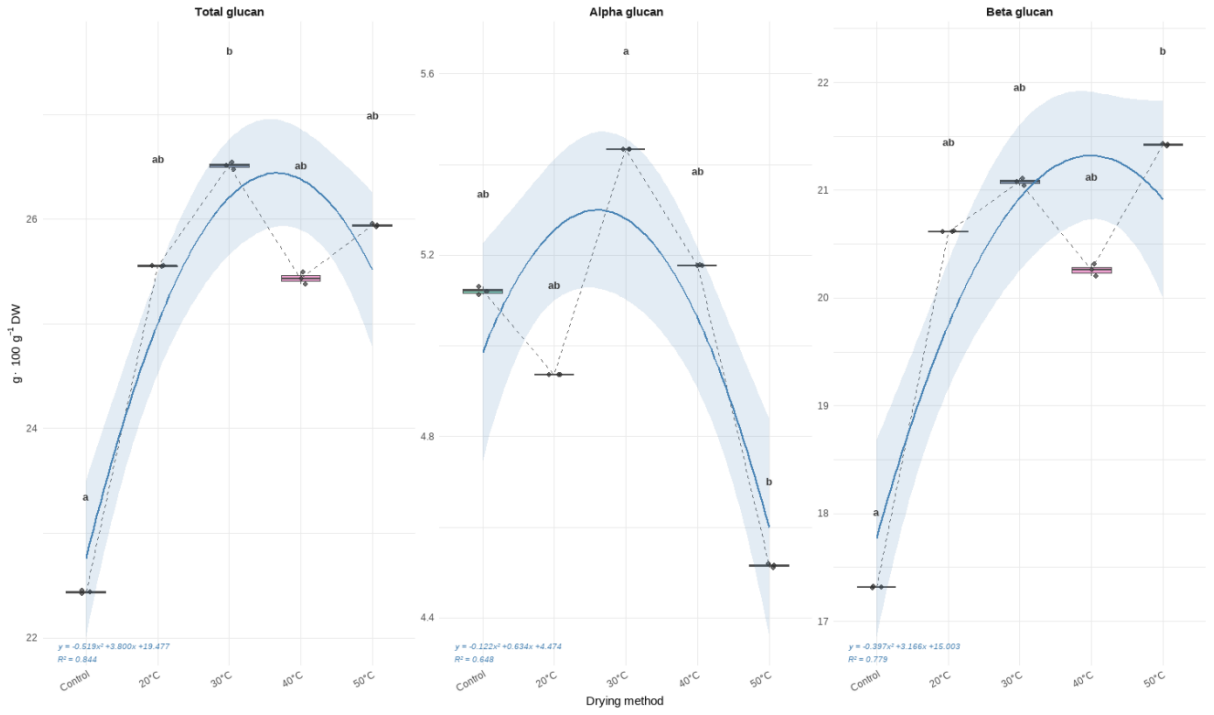


Figure 2 Effect of drying temperature on total, α- and β-glucan content in *Imleria badia*.
Note: Control denotes the lyophilized reference sample; values are expressed as mean ± SD (n = 3) in g/100 g dry matter. Different letters indicate significant differences among drying treatments based on Kruskal–Wallis test followed by Dunn's post hoc test ($p < 0.05$). Polynomial curves with 95% confidence intervals are shown as descriptive visualizations of the temperature-related trend.

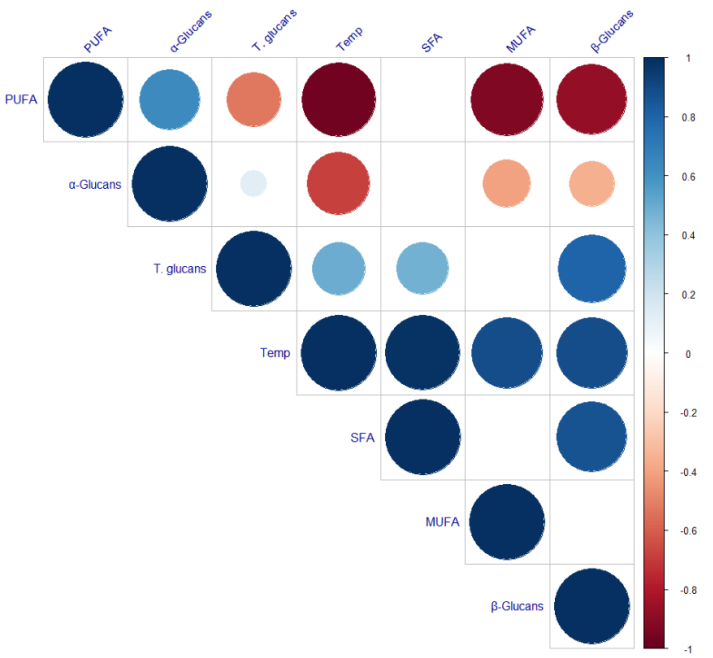


Figure 3 Spearman correlation matrix among drying temperature, fatty acid classes and glucan fractions in *Imleria badia*. Note: Circle size and colour intensity indicate the strength and direction of Spearman's rank correlation coefficient (ρ). Blue circles represent positive correlations, while red circles represent negative correlations.

Correlation analysis

The Spearman correlation matrix is shown in Figure 3. Drying temperature was strongly positively associated with SFA and MUFA, indicating that higher drying temperatures were related to higher relative proportions of these fatty acid classes. In contrast, drying temperature was strongly negatively associated with PUFA, confirming the trend toward a lower relative PUFA proportion observed in Figure 1.

For glucan fractions, drying temperature showed a positive association with β-glucans and a weaker positive association with total glucans, while α-glucans showed a negative association with drying temperature. This agrees with the graphical trends, where β-glucan content increased in dried samples and reached the highest value at 50 °C, whereas α-glucan content decreased at the highest temperature.

The correlation matrix also illustrates the inverse relationship between PUFA and both SFA and MUFA. However, these relationships should be interpreted with caution because SFA, MUFA, and PUFA are compositional variables expressed as relative percentages of total detected FAMEs and are therefore constrained to sum to approximately 100%. Consequently, inverse correlations among these fatty acid classes are mathematically expected and should not be interpreted as biologically independent associations. In this context, the correlations mainly confirm the proportional redistribution within the relative fatty acid profile. Similarly, the positive relationship between total glucans and β-glucans reflects the fact that β-glucans represented the major fraction of total glucans in all samples.

The graphical and correlation analyses indicate that drying temperature had a clearer effect on the relative fatty acid class distribution than on total glucan content. The most distinct fatty acid shift occurred at 50 °C, where the relative proportions of SFA and MUFA were higher, while the relative proportion of PUFA was lower. This pattern should be interpreted as a compositional redistribution within the relative fatty acid profile rather than as evidence of absolute fatty acid loss or lipid degradation. In contrast, β-glucans remained high across dried samples and were not negatively affected by the applied drying temperatures.

Fatty acid profile-derived indices

The indices calculated from the relative fatty acid profile of *I. badia* are presented in Table 3. The PUFA/SFA ratio ranged from 3.08 to 3.76, with the highest value observed in the lyophilized reference sample and the lowest value after drying at 50 °C. The average PUFA/SFA ratio was 3.54. This decrease at 50 °C corresponded with the lower relative proportion of PUFA and the higher relative proportion of SFA observed at the same drying temperature. Therefore, the PUFA/SFA ratio reflected the temperature-related shift in the proportional distribution of fatty acid classes.

The PUFA/SFA ratio, index of atherogenicity (IA), index of thrombogenicity (IT), hypocholesterolemic/hypercholesterolemic ratio (HH), unsaturation index (UI) and trans fatty acids (TFA) are commonly used to describe and compare fatty acid profiles (**Chen and Liu, 2020**). However, these indices should be interpreted as calculated descriptors of fatty acid composition rather than as direct evidence of a nutritional or health effect, particularly in mushrooms, which generally have low total lipid content despite a lipid fraction often rich in unsaturated fatty acids (**Tan *et al.*, 2024**).

Table 3 Fatty acid profile-derived indices calculated from the relative fatty acid profile in relation to drying temperature.

Temp	PUFA/SFA	IA	IT	HH	UI	TFA
Control	3.76	0.18	0.38	5.13	148	0.39
20 °C	3.68	0.18	0.38	5.19	147	ND
30 °C	3.61	0.17	0.37	5.34	147	ND
40 °C	3.57	0.17	0.36	5.48	146	ND
50 °C	3.08	0.19	0.41	4.87	141	ND
Average	**3.54**	**0.18**	**0.38**	**5.2**	**146**	**NC**

Note: Control – lyophilized reference sample; PUFA/SFA – polyunsaturated fatty acids/saturated fatty acids ratio; IA – index of atherogenicity; IT – index of thrombogenicity; HH – hypocholesterolemic/hypercholesterolemic ratio; UI – unsaturation index; TFA – trans fatty acids; ND – not detected; NC – not calculated.

The PUFA/SFA values observed in the present study were higher than the mean value reported for Polish *I. badia* samples by **Gałgowska and Pietrzak-Fiećko (2022)**, who reported a PUFA/SFA ratio of 2.16. In the same study, *B. edulis* and *Cantharellus cibarius* showed PUFA/SFA ratios of 3.25 and 3.07, respectively. Thus, the present *I. badia* samples showed a higher PUFA/SFA ratio than the previously reported mean for *I. badia* and values comparable to or slightly higher than those reported for *B. edulis* and *C. cibarius*. This comparison should be interpreted cautiously because the studies differed in sample origin, mushroom material and experimental design.

The index of atherogenicity showed only narrow variation among drying treatments, ranging from 0.17 to 0.19, while IT ranged from 0.36 to 0.41. The slightly higher IA and IT values observed at 50 °C reflected the higher relative SFA proportion and lower relative PUFA proportion at this drying temperature. However, the magnitude of these differences was small. Therefore, IA and IT should be interpreted only as minor shifts in calculated descriptors of the relative fatty acid profile rather than as evidence of biologically meaningful differences in nutritional quality.

Compared with the data reported by **Gałgowska and Pietrzak-Fiećko (2022)**, the IA values in the present study were slightly lower than the mean value reported for *I. badia* (0.21), but higher than those reported for *B. edulis* (0.12) and comparable with *C. cibarius* (0.16). The IT values in the present study were lower than the mean value reported for *I. badia* (0.45), higher than that reported for *B. edulis* (0.28), and comparable with *C. cibarius* (0.39). These differences likely reflect species-specific and sample-specific variation in the relative proportions of saturated, monounsaturated and polyunsaturated fatty acids.

The HH ratio ranged from 4.87 to 5.48, with an average value of 5.20. The highest HH value was observed at 40 °C, while the lowest value was recorded at 50 °C. These values were close to the mean HH ratio reported for *I. badia* by **Gałgowska and Pietrzak-Fiećko (2022)**, who found a value of 4.97. However, they were lower than the value reported for *B. edulis* (8.42) and comparable with *C. cibarius* (4.76). The lower HH value at 50 °C corresponded with the lower PUFA/SFA ratio and the lower UI value at this drying temperature.

The unsaturation index, calculated from relative fatty acid percentages, decreased progressively with increasing drying temperature, from 148 in the lyophilized reference sample to 141 at 50 °C. This decrease reflected the lower relative proportion of PUFA, particularly linoleic acid, at the highest drying temperature. **Piskov *et al.* (2022)** also showed that the drying method affected the lipophilic profile of *P. ostreatus* powder, including differences in linoleic acid among drying treatments. This comparison should be considered only as general context, because the cited study used a different mushroom species and different drying conditions.

Trans fatty acids were detected only in the lyophilized reference sample, where their relative value reached 0.39%. In all hot-air dried samples, TFA were not detected. Therefore, the average TFA value was not calculated, because calculating a mean value would require treating non-detected values as zero. The result more appropriately indicates that the applied hot-air drying treatments did not increase detectable TFA levels under the present experimental conditions. The calculated indices reflected the same pattern observed in the fatty acid class data. Drying at 50 °C was associated with the lowest PUFA/SFA, HH and UI values and with the highest IA and IT values. However, the differences among treatments were numerically small, particularly for IA and IT. Therefore, these indices should be interpreted only as comparative descriptors calculated from the relative fatty acid profile of *I. badia*. This interpretation is consistent with the general use of fatty acid indices as profile-based descriptors (**Chen and Liu, 2020**) and with the cautious interpretation required for edible mushrooms because of their low total lipid content (**Tan *et al.*, 2024**).

Overall, the present findings are best interpreted in terms of technological preservation and relative compositional stability rather than nutritional optimization. Drying temperature mainly affected the proportional distribution of fatty acid classes, whereas glucan fractions remained comparatively stable or increased in dried samples under the applied conditions.

CONCLUSION

This study demonstrated that drying temperature affected the relative fatty acid profile and glucan fractions of *I. badia*, although the magnitude and direction of these changes differed between lipid and carbohydrate fractions. The fatty acid profile was consistently dominated by linoleic acid (C18:2 cis-9, cis-12), followed by oleic acid (C18:1 cis-9) and palmitic acid (C16:0), confirming that *I. badia* has a PUFA-rich lipid fraction. Among fatty acid classes, PUFA remained the predominant group under all drying conditions, but their relative proportion decreased at 50 °C, while SFA and MUFA increased. This finding reflects a proportional change within the detected FAME profile and should not be interpreted as direct evidence of PUFA degradation. This shift was also reflected in the calculated fatty acid profile-derived indices, particularly by lower PUFA/SFA, HH and UI values and slightly higher IA and IT values at 50 °C. However, these indices should be interpreted only as comparative descriptors of the relative fatty acid profile, not as direct evidence of a substantial nutritional effect, because mushrooms generally contain low total lipid amounts.

Glucan fractions showed a different response to drying. Total glucans and β-glucans were higher in dried samples than in the lyophilized reference sample, while β-glucans remained the dominant glucan fraction in all treatments. The highest β-glucan content and the highest proportion of β-glucans in total glucans were observed at 50 °C, whereas α-glucans represented a minor fraction and decreased at the highest drying temperature. These results indicate that the applied drying temperatures did not reduce β-glucan content in *I. badia* under the present experimental conditions.

Overall, drying at 50 °C produced the most pronounced changes in the relative fatty acid distribution, but it did not negatively affect β-glucan content. From a practical consumer perspective, drying at 20–40 °C appears more suitable when the aim is to preserve the PUFA-rich relative fatty acid profile of I. badia, because these temperatures maintained a fatty acid class distribution closer to the lyophilized reference sample. Drying at 50 °C may still be acceptable for preserving glucan fractions under the applied conditions, but it was associated with a lower relative PUFA proportion and the greatest shift in the fatty acid class distribution. Therefore, moderate hot-air drying temperatures, particularly within the 20–40 °C range, can be recommended for consumers seeking to preserve the overall compositional characteristics of dried *I. badia*. This recommendation should be understood from a technological and compositional perspective rather than as evidence of nutritional optimization or a substantial dietary lipid benefit. Future studies should include absolute lipid content, direct lipid oxidation markers and additional storage experiments to better distinguish between relative compositional shifts and actual degradation or preservation effects during mushroom processing.

Acknowledgments: The study was supported by the Ministry of Education, Science, Research and Sport of the Slovak Republic (grant no. VEGA 1/0307/25).

REFERENCES

Aphalo, P. J. (2024). *ggpmisc: Miscellaneous extensions to ggplot2*. R package.

Benko, F., Árvay, J., Jančo, I., Ďuračka, M., Mohammadi-Sangcheshmeh, A., Lukáč, N., Ivanič, P., & Tvrdá, E. (2024). In vitro versus cryo-induced capacitation of bovine spermatozoa, part 3: Compositional and molecular changes to the plasma membrane. *Cryobiology, 117*, 104972. https://doi.org/10.1016/j.cryobiol.2024.104972

Bligh, E. G., & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology, 37*(8), 911–917. https://doi.org/10.1139/o59-099

Chen, J., & Liu, H. (2020). Nutritional indices for assessing fatty acids: A mini-review. *International Journal of Molecular Sciences, 21(16)*, 5695. https://doi.org/10.3390/ijms21165695

Das, A. K., Nanda, P. K., Dandapat, P., Bandyopadhyay, S., Gullón, P., Sivaraman, G. K., McClements, D. J., Gullón, B., & Lorenzo, J. M. (2021). Edible mushrooms as functional ingredients for development of healthier and more sustainable muscle foods: A flexitarian approach. *Molecules, 26(9)*, 2463. https://doi.org/10.3390/molecules26092463

Dembitsky, V. M., Terent'ev, A. O., & Levitsky, D. O. (2010). Amino and fatty acids of wild edible mushrooms of the genus *Boletus*. *Records of Natural Products, 4(4)*, 218–223.

Dimitrijevic, M. V., Mitic, V. D., Nikolic, J. S., Djordjevic, A. S., Mutic, J. J., Jovanovic, V. P. S., & Stojanovic, G. S. (2018). Comparative study of fatty acids profile in eleven wild mushrooms of Boletacea and Russulaceae families. *Chemistry & Biodiversity, 15(1)*, e1700434. https://doi.org/10.1002/cbdv.201700434

Folch, J., Lees, M., & Sloane Stanley, G. H. (1957). A simple method for the isolation and purification of total lipides from animal tissues. *Journal of Biological Chemistry, 226*(1), 497–509. https://doi.org/10.1016/S0021-9258(18)64849-5

Gałgowska, M., & Pietrzak-Fiećko, R. (2022). Evaluation of the nutritional and health values of selected Polish mushrooms considering fatty acid profiles and lipid indices. *Molecules, 27(19)*, 6193. https://doi.org/10.3390/molecules27196193

Kassambara, A. (2023). *rstatix: Pipe-friendly framework for basic statistical tests*. R package version 0.7.2

Liu, Q., Sun, L., Ding, Y., & Zhuang, Y. (2024). Chemical composition, health benefits, food processing effects and applications of *Boletus*: A review. *Critical Reviews in Food Science and Nutrition, 64(29)*, 10812–10834. https://doi.org/10.1080/10408398.2023.2229426

Mirończuk-Chodakowska, I., & Witkowska, A. M. (2020). Evaluation of Polish wild mushrooms as beta-glucan sources. *International Journal of Environmental Research and Public Health, 17(19)*, 7299. https://doi.org/10.3390/ijerph17197299

Oancea, S., Popa, M., Socaci, S. A., & Dulf, F. V. (2023). Comparative study of raw and dehydrated *Boletus edulis* mushrooms by hot air and centrifugal vacuum processes: Functional properties and fatty acid and aroma profiles. *Applied Sciences, 13(6)*, 3630. https://doi.org/10.3390/app13063630

Olah, B., Kunca, V., & Gallay, I. (2020). Assessing the potential of forest stands for ectomycorrhizal mushrooms as a subsistence ecosystem service for socially disadvantaged people: A case study from Central Slovakia. *Forests, 11(3)*, 282. https://doi.org/10.3390/f11030282

Pietrzak-Fiećko, R., Gałgowska, M., & Bakuła, S. (2016). Fatty acid composition in wild *Boletus edulis* from Poland. *Italian Journal of Food Science, 28(3)*, 402–411. https://doi.org/10.14674/1120-1770/ijfs.v42

Piskov, S., Timchenko, L., Avanesyan, S., Siddiqui, S. A., Sizonenko, M., Kurchenko, V., Rzhepakovsky, I., Blinov, A., Nagdalian, A., Shariati, M. A., *et al.* (2022). A comparative study on the structural properties and lipid profile of mushroom (*Pleurotus ostreatus*) powder obtained by different drying methods. *Agriculture, 12(10)*, 1590. https://doi.org/10.3390/agriculture12101590

Posit Team. (2024). *RStudio: Integrated development environment for R*. Posit Software, PBC, Boston, MA, USA.

Predanócyová, K., Árvay, J., & Šnirc, M. (2023). Exploring consumer behavior and preferences towards edible mushrooms in Slovakia. *Foods, 12(3)*, 657. https://doi.org/10.3390/foods12030657

R Core Team. (2024). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria.

Ribeiro, B., Guedes de Pinho, P., Andrade, P. B., Baptista, P., & Valentão, P. (2009). Fatty acid composition of wild edible mushroom species: A comparative study. *Microchemical Journal, 93(1)*, 29–35. https://doi.org/10.1016/j.microc.2009.04.005

Sande, D., de Oliveira, G. P., e Moura, M. A. F., de Almeida Martins, B., Lima, M. T. N. S., & Takahashi, J. A. (2019). Edible mushrooms as a ubiquitous source of essential fatty acids. *Food Research International, 125*, 108524. https://doi.org/10.1016/j.foodres.2019.108524

Sari, M., Prange, A., Lelley, J. I., & Hambitzer, R. (2017). Screening of beta-glucan contents in commercially cultivated and wild growing mushrooms. *Food Chemistry, 216*, 45–51. https://doi.org/10.1016/j.foodchem.2016.08.010

Šnirc, M., Jančo, I., Hauptvogl, M., Jakabová, S., Demková, L., & Árvay, J. (2023). Risk assessment of the wild edible *Leccinum* mushrooms consumption according to the total mercury content. *Journal of Fungi, 9(3)*, 287. https://doi.org/10.3390/jof9030287

Štefániková, J., Martišová, P., Šnirc, M., Kunca, V., & Árvay, J. (2021). The effect of *Amanita rubescens* Pers developmental stages on aroma profile. *Journal of Fungi, 7(8)*, 611. https://doi.org/10.3390/jof7080611

Tan, R. Y., Ilham, Z., Wan-Mohtar, W. A. A. Q. I., Halim-Lim, S. A., Usuldin, S. R. A., Ahmad, R., & Adlim, M. (2024). Mushroom oils: A review of their production, composition, and potential applications. *Heliyon, 10(11)*, e31594. https://doi.org/10.1016/j.heliyon.2024.e31594

Timm, T. G., Pasko, R. Z., Campos, C. S. G., Helm, C. V., & Tavares, L. B. B. (2019). Drying process of *Lentinula edodes*: Influence of temperature on β-glucan content and adjustment of mathematical models. *Ciência e Agrotecnologia, 43*, e025719. https://doi.org/10.1590/1413-7054201943025719

Vetter, J. (2023). The mushroom glucans: Molecules of high biological and medicinal importance. *Foods, 12(5)*, 1009. https://doi.org/10.3390/foods12051009

Wickham, H. (2016). *ggplot2: Elegant graphics for data analysis*. Springer-Verlag, New York. https://doi.org/10.1007/978-3-319-24277-4

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L. D., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T. L., Miller, E., Bache, S. M., Müller, K., Ooms, J., Robinson, D., Seidel, D. P., Spinu, V., Takahashi, K., Vaughan, D., Wilke, C., Woo, K., & Yutani, H. (2019). Welcome to the tidyverse. *Journal of Open Source Software, 4(43)*, 1686. https://doi.org/10.21105/joss.01686

Wunjuntuk, K., Ahmad, M., Techakriengkrai, T., Chunhom, R., Jaraspermsuk, E., Chaisri, A., Kiwwongngam, R., Wuttimongkolkul, S., & Charoenkiatkul, S. (2022). Proximate composition, dietary fibre, beta-glucan content, and inhibition of key enzymes linked to diabetes and obesity in cultivated and wild mushrooms.

Journal of Food Composition and Analysis, 105, 104226. https://doi.org/10.1016/j.jfca.2021.104226

SUPPLEMENTARY MATERIAL

Supplementary Table S1. Exact Holm-adjusted p-values from Dunn's post hoc comparisons for fatty acid classes and glucan fractions presented in Figures 1 and 2.

Variable	Comparison	Dunn z	Unadjusted p-value	Adjusted p-value (Holm)	Significance
SFA	Control vs. 20 °C	-0.8215838	0.411313792	1	ns
SFA	Control vs. 30 °C	-1.6431677	0.100348246	0.702437725	ns
SFA	Control vs. 40 °C	-2.4647515	0.01371083	0.123397471	ns
SFA	Control vs. 50 °C	-3.2863353	0.001015001	0.010150009	*
SFA	20 °C vs. 30 °C	-0.8215838	0.411313792	1	ns
SFA	20 °C vs. 40 °C	-1.6431677	0.100348246	0.702437725	ns
SFA	20 °C vs. 50 °C	-2.4647515	0.01371083	0.123397471	ns
SFA	30 °C vs. 40 °C	-0.8215838	0.411313792	1	ns
SFA	30 °C vs. 50 °C	-1.6431677	0.100348246	0.702437725	ns
SFA	40 °C vs. 50 °C	-0.8215838	0.411313792	1	ns
MUFA	Control vs. 20 °C	-0.8215838	0.411313792	1	ns
MUFA	Control vs. 30 °C	-2.4647515	0.01371083	0.123397471	ns
MUFA	Control vs. 40 °C	-1.6431677	0.100348246	0.702437725	ns
MUFA	Control vs. 50 °C	-3.2863353	0.001015001	0.010150009	*
MUFA	20 °C vs. 30 °C	-1.6431677	0.100348246	0.702437725	ns
MUFA	20 °C vs. 40 °C	-0.8215838	0.411313792	1	ns
MUFA	20 °C vs. 50 °C	-2.4647515	0.01371083	0.123397471	ns
MUFA	30 °C vs. 40 °C	0.82158384	0.411313792	1	ns
MUFA	30 °C vs. 50 °C	-0.8215838	0.411313792	1	ns
MUFA	40 °C vs. 50 °C	-1.6431677	0.100348246	0.702437725	ns
PUFA	Control vs. 20 °C	0.82158384	0.411313792	1	ns
PUFA	Control vs. 30 °C	1.82574186	0.067889155	0.475224084	ns
PUFA	Control vs. 40 °C	2.28217732	0.022478873	0.179830987	ns
PUFA	Control vs. 50 °C	3.28633535	0.001015001	0.010150009	*
PUFA	20 °C vs. 30 °C	1.00415802	0.315302452	1	ns
PUFA	20 °C vs. 40 °C	1.46059349	0.144127035	0.864762209	ns
PUFA	20 °C vs. 50 °C	2.46475151	0.01371083	0.123397471	ns
PUFA	30 °C vs. 40 °C	0.45643546	0.648076868	1	ns
PUFA	30 °C vs. 50 °C	1.46059349	0.144127035	0.864762209	ns
PUFA	40 °C vs. 50 °C	1.00415802	0.315302452	1	ns
Total glucan	Control vs. 20 °C	-1.6431677	0.100348246	0.702437725	ns
Total glucan	Control vs. 30 °C	-3.2863353	0.001015001	0.010150009	*
Total glucan	Control vs. 40 °C	-0.8215838	0.411313792	1	ns
Total glucan	Control vs. 50 °C	-2.4647515	0.01371083	0.123397471	ns
Total glucan	20 °C vs. 30 °C	-1.6431677	0.100348246	0.702437725	ns
Total glucan	20 °C vs. 40 °C	0.82158384	0.411313792	1	ns
Total glucan	20 °C vs. 50 °C	-0.8215838	0.411313792	1	ns
Total glucan	30 °C vs. 40 °C	2.46475151	0.01371083	0.123397471	ns
Total glucan	30 °C vs. 50 °C	0.82158384	0.411313792	1	ns
Total glucan	40 °C vs. 50 °C	-1.6431677	0.100348246	0.702437725	ns
Alpha glucan	Control vs. 20 °C	0.82453388	0.409636275	1	ns
Alpha glucan	Control vs. 30 °C	-0.8245339	0.409636275	1	ns
Alpha glucan	Control vs. 40 °C	1.64906775	0.099133755	0.693936283	ns
Alpha glucan	Control vs. 50 °C	2.47360163	0.013375875	0.120382878	ns
Alpha glucan	20 °C vs. 30 °C	-1.6490678	0.099133755	0.693936283	ns
Alpha glucan	20 °C vs. 40 °C	0.82453388	0.409636275	1	ns
Alpha glucan	20 °C vs. 50 °C	1.64906775	0.099133755	0.693936283	ns
Alpha glucan	30 °C vs. 40 °C	2.47360163	0.013375875	0.120382878	ns
Alpha glucan	30 °C vs. 50 °C	3.29813551	0.000973292	0.009732915	**
Alpha glucan	40 °C vs. 50 °C	0.82453388	0.409636275	1	ns
Beta glucan	Control vs. 20 °C	-0.8215838	0.411313792	1	ns
Beta glucan	Control vs. 30 °C	-2.4647515	0.01371083	0.123397471	ns
Beta glucan	Control vs. 40 °C	-1.6431677	0.100348246	0.702437725	ns
Beta glucan	Control vs. 50 °C	-3.2863353	0.001015001	0.010150009	*
Beta glucan	20 °C vs. 30 °C	-1.6431677	0.100348246	0.702437725	ns
Beta glucan	20 °C vs. 40 °C	-0.8215838	0.411313792	1	ns
Beta glucan	20 °C vs. 50 °C	-2.4647515	0.01371083	0.123397471	ns
Beta glucan	30 °C vs. 40 °C	0.82158384	0.411313792	1	ns
Beta glucan	30 °C vs. 50 °C	-0.8215838	0.411313792	1	ns
Beta glucan	40 °C vs. 50 °C	-1.6431677	0.100348246	0.702437725	ns

Note: ns – not significant; * $p < 0.05$; ** $p < 0.01$