

Comparative Evaluation of Phytochemicals and Micronutrients in the Sporocarps of *Hypsizygus tessellatus* and *Leccinum scabrum*

¹Arowora, K. A., ¹Anih, D. C.*, ²Arowora, M. D., ¹Ugwuoke, K. C., ¹Ochijele, V. I., ³Onoja, M. A., ³Ibu, R. O., ³Ugwuoke, P. C. & ³Uroko, F.

¹Department of Biochemistry, Faculty Biosciences, Federal University Wukari, Nigeria

²National Teachers Institute Wukari, Study centre

³Department of Biochemistry, Faculty of Biosciences, Joseph Sarwuan Tarka University, Makurdi, Nigeria

*Corresponding author: anih.david@fuwukari.edu.ng

ABSTRACT

Background/Introduction: Edible mushrooms have garnered attention as sources of bioactive compounds and micronutrients with therapeutic and nutritional values. This study focuses on *Hypsizygus tessellatus* and *Leccinum scabrum*, two underutilized species consumed in Nigeria. Despite their growing relevance, comparative biochemical data remain sparse. The research aims to evaluate their mineral, vitamin, and phytochemical profiles to assess their potential in functional food and nutraceutical applications. **Materials and Methods:** Fresh fruiting bodies of both species were collected from Takum, Nigeria, and identified morphologically. Samples were air-dried, pulverized, and subjected to analysis. Mineral content was assessed via Atomic Absorption Spectrophotometry (AAS) and flame photometry; vitamin levels were quantified using HPLC, and phytochemicals were analyzed through qualitative and quantitative methods following standard protocols. Statistical significance was determined using paired t-tests ($p < 0.05$). **Results and Discussion:** *L. scabrum* showed significantly higher concentrations of calcium, iron, phosphorus, vitamin A, and phenolics, suggesting applications in anemia, bone health, and antioxidant support. *H. tessellatus* was richer in potassium, sodium, folate, alkaloids, and terpenes, indicating roles in neuromuscular, cardiovascular, and immune functions. Phytochemical diversity was substantial in both species, reflecting ecological and physiological differences. **Conclusion:** The distinct micronutrient and phytochemical profiles of *H. tessellatus* and *L. scabrum* support their inclusion in dietary interventions and functional food formulations. Their accessibility and adaptability underscore their potential as sustainable, health-promoting food resources in nutritionally vulnerable regions.

Keywords: Phytochemicals; Micronutrients; Edible Mushrooms; Functional Foods

INTRODUCTION

Edible mushrooms are globally recognized for their rich nutritional profiles and therapeutic properties. Historically embedded in Asian medicine, mushrooms like *Hypsizygus tessellatus* and *Leccinum scabrum* are gaining prominence for their bioactive constituents— β -glucans, terpenoids, phenolics, and polysaccharides—linked to antioxidant, anti-inflammatory, and anticancer effects (Bell *et al.*, 2022; Liuzzi *et al.*,

2023; Yu *et al.*, 2023; Ayimbila & Keawsompong, 2025). Edible mushrooms are increasingly acknowledged as rich sources of nutraceutical compounds with diverse medicinal effects. The primary bioactive constituents— β -glucans, terpenoids, phenolics, and polysaccharides—exhibit functions such as antioxidant activity, immune regulation, anti-inflammatory effects, and tumor suppression (Yu *et al.*, 2023; Jeong *et al.*, 2024; Ayimbila & Keawsompong, 2025). As shown in Figure 1, these compounds are differentially distributed among species and contribute to their medicinal value. For instance, β -glucans and polysaccharides are primarily involved in immunomodulation and antitumor activity (Liuzzi *et al.*, 2023; Ayimbila & Keawsompong, 2025), while phenolics and terpenoids are linked to antioxidant and anti-inflammatory properties (Mukherjee *et al.*, 2024; Konsue *et al.*, 2025). Their combined actions underlie the broad-spectrum health benefits associated with regular mushroom consumption and highlight the importance of evaluating species-specific profiles (Aditya *et al.*, 2024; Senila *et al.*, 2024).

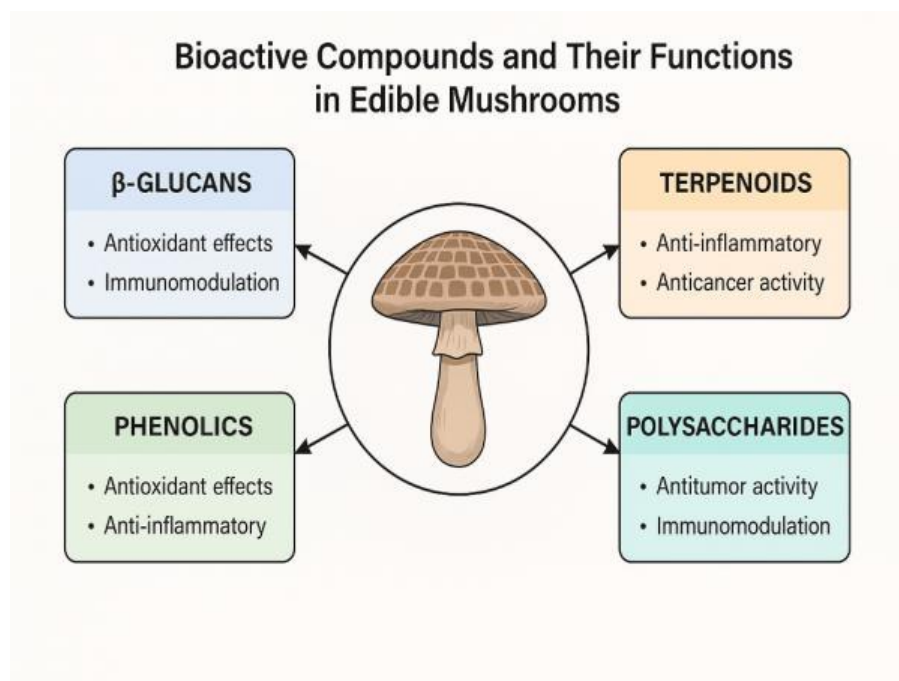


Figure 1. Bioactive Compounds and Their Functions in Edible Mushrooms (Self-generated).

The diagram illustrates four major classes of bioactive compounds commonly found in edible mushrooms— β -glucans, terpenoids, phenolics, and polysaccharides. Each class is linked to its primary biological functions such as antioxidant activity, immunomodulation, anti-inflammatory effects, and anticancer potential. These compounds play crucial roles in the health-promoting properties attributed to mushrooms, making them ideal candidates for nutraceutical and functional food development

Beyond pharmacological relevance, mushrooms are sources of key nutrients such as B-complex vitamins, calcium, magnesium, and dietary fiber. Their affordability and accessibility make them valuable in combating malnutrition in sub-Saharan Africa, where they often serve as meat substitutes (Irshad *et al.*, 2023; Senila *et al.*, 2024)..

Despite increasing global interest, local Nigerian species like *H. tessellatus* (Buna shimeji) and *L. scabrum* (birch bolete) are understudied. *H. tessellatus*, widely cultivated in East Asia, is known for its antioxidant-rich hypsiziprenols and immunomodulatory effects (Aditya *et al.*, 2024; Jeong *et al.*, 2024). *L. scabrum*, a wild ectomycorrhizal species, is abundant in minerals such as iron, calcium, and phosphorus and has culinary importance in the Northern Hemisphere (Konsue *et al.*, 2025).

The morphological characteristics of *Hypsizygus tessellatus* and *Leccinum scabrum* are not only taxonomically significant but also offer practical value for field identification and ecological study. As shown in Figure 2, *H. tessellatus* typically appears in clusters with smooth, cream-colored caps and uniform stems, making it easily distinguishable from *L. scabrum*, which features a broad brown cap and a thick, reticulate stipe. These differences reflect their distinct ecological roles—*H. tessellatus* as a saprophyte in temperate hardwood forests, and *L. scabrum* as an ectomycorrhizal species forming symbiosis with birch trees (Ayala-Vásquez *et al.*, 2023; Singh *et al.*, 2025). Accurate morphological identification remains essential in phytochemical studies, as misidentification can confound species-specific nutritional profiles (Ouali *et al.*, 2023; Mayirnao *et al.*, 2025).

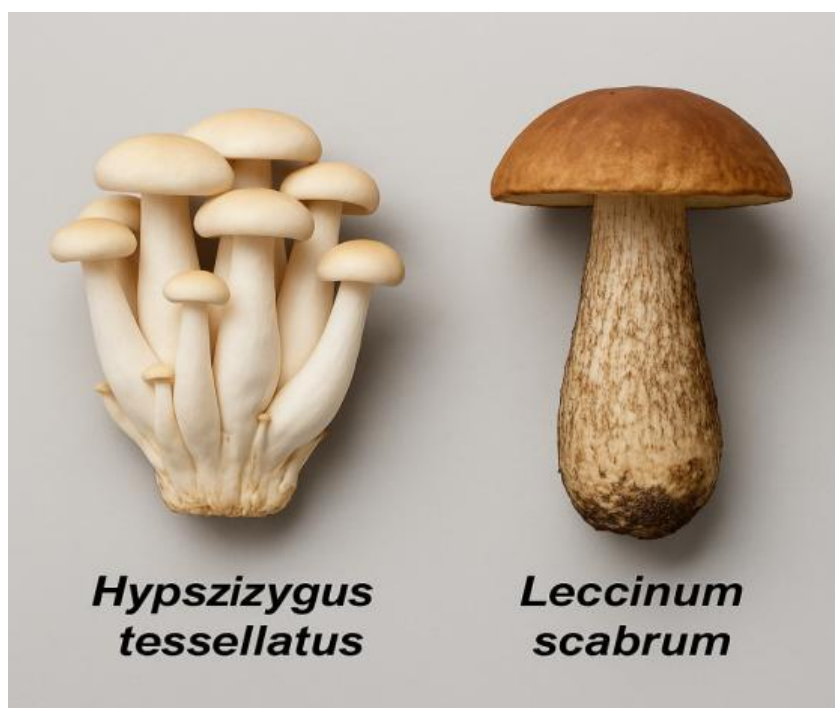


Figure 2. Photographic Comparison of *Hypsizygus tessellatus* and *Leccinum scabrum* (Self-generated).

A side-by-side high-resolution comparison of two edible mushroom species studied in this work. On the left is *Hypsizygus tessellatus* (Buna shimeji), characterized by clustered white to cream-colored caps and elongated stems. On the right is *Leccinum scabrum* (birch bolete), a solitary mushroom with a brown cap and mottled stipe. These visual distinctions aid in morphological identification during wild collection and are consistent with standard taxonomic descriptions reported in previous literature

In Nigeria, both species are consumed by rural communities, yet there is limited biochemical data to guide their use in health interventions or policy. This study addresses this gap by comparing their phytochemical and micronutrient contents, with implications for dietary supplementation and therapeutic use.

To ensure methodological rigor, this study followed a structured workflow encompassing five sequential stages, as depicted in Figure 3. These include: (1) sample collection from ecologically relevant sites in Takum, Nigeria; (2) expert morphological identification based on established taxonomic keys (Meng *et al.*, 2021); (3) sample preparation through air-drying and fine pulverization; (4) comprehensive nutritional and phytochemical analysis using AAS, HPLC, and colorimetric methods; and (5) statistical validation through paired t-tests. This schematic captures the workflow commonly employed in contemporary mushroom studies and reflects analytical procedures recommended in previous work (Ouali *et al.*, 2023; Silva *et al.*, 2024; Xin *et al.*, 2025).

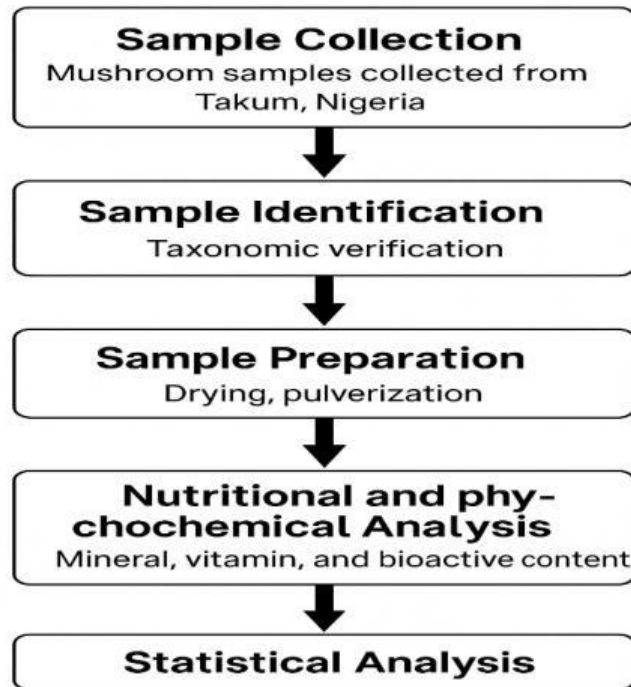


Figure 3. Schematic Overview of Study Workflow (Self-generated, using Canvas and DALL.E Image generating Tools).

This flowchart outlines the key procedural stages in the study, beginning with the field collection of *Hypsizygus tessellatus* and *Leccinum scabrum* samples in Takum, Nigeria. It proceeds through taxonomic identification and morphological verification, sample preparation via drying and pulverization, and analytical stages involving mineral, vitamin, and phytochemical assays. The final step includes statistical analysis for validating interspecies differences. This systematic approach aligns with best practices in mushroom compositional research and standard phytochemical protocols.

MATERIALS AND METHODS

Study Area and Sample Collection

Fresh fruiting bodies (Sporocarps) of *Hypsizygus tessellatus* and *Leccinum scabrum* were collected from wild habitats in Takum, Taraba State, Nigeria, during the peak rainy season in 2023. Geographic coordinates were recorded using GPS, and local environmental parameters were documented to contextualize species distribution. Morphological identification was performed following standard taxonomic keys.

Specimens were authenticated by a mycologist in the Department of Biological Sciences, Federal University Wukari, using morphological and ecological characteristics described by Ayala-Vásquez *et al.* (2023). The field sampling was conducted in Takum, located in the southern region of Taraba State, Nigeria—a zone characterized by humid forest vegetation and rich loamy soil known to support diverse fungal biodiversity. As presented in Figure 4, the GPS-based map marks Takum and surrounding areas, capturing the ecological breadth of the mushroom collection region. These locations have been identified in previous studies as hotspots for wild edible mushroom growth due to favorable climatic and soil conditions ((Senila *et al.*, 2024). Documenting the

collection sites spatially ensures traceability and provides environmental context crucial for understanding mineral uptake and bioactive compound biosynthesis in macro fungi (Ayimbila & Keawsompong, 2025; Singh *et al.*, 2025).

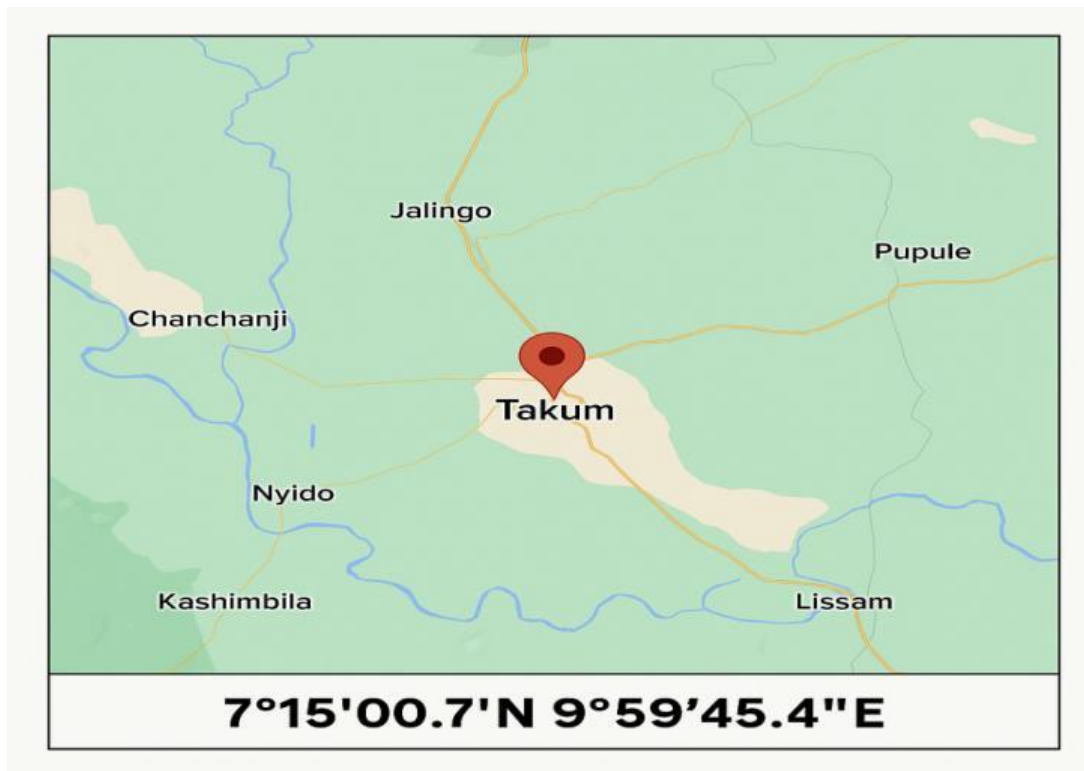


Figure 4. Map of Mushroom Collection Sites in Takum, Taraba State, Nigeria (Self-generated).

The map shows the geographical location of Takum in southern Taraba State, Nigeria, with precise GPS coordinates (7°15'00.7"N, 9°59'45.4"E). It also highlights nearby regions such as Jalingo, Chanchanji, Nyido, Pupule, and Kashimbila, providing spatial context for the ecological zones from which *Hypsizygus tessellatus* and *Leccinum scabrum* samples were collected. This setting is typical of nutrient-rich, forest-dominated ecosystems conducive to wild mushroom proliferation.

Sample Preparation

One kilogram each of air-dried fruiting bodies of the different samples were separately milled to powder using a blender and sieved through a 0.5 mm mesh. The powdered samples were stored in amber-colored, airtight containers at 4°C to preserve phytochemical integrity prior to analysis (Chang & Miles, 2020).

Phytochemical Analysis

Qualitative and quantitative phytochemical screening was carried out using established methods adapted from Ouali *et al.*, 2023; Jeong *et al.*, 2024 and Mayirnao *et al.*, 2025. Compounds analyzed included alkaloids, flavonoids, tannins, saponins, terpenes, phenolics, glycosides, steroids, and sterols.

Quantification was conducted using a Buck Scientific BLC10/11 High-Performance Liquid Chromatography (HPLC) system. Calibration curves for standards were generated using known concentrations of reference compounds with results expressed in mg/100 g dry weight.

Mineral and Vitamin analysis

Essential mineral elements; sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), selenium (Se), phosphorus (P), and copper (Cu) were analyzed using Atomic Absorption Spectrophotometry (AAS; Shimadzu AA-7000F) and flame photometry. Phosphorus was determined using the vanadomolybdate colorimetric method (Singh *et al.*, 2025; Xin *et al.*, 2025). Vitamin profiling (A, B-complex, C, D, E, and K) was performed via reverse-phase HPLC, following extraction protocols standardized by AOAC (2020) and further optimized by Starck *et al.* (2024). Results were expressed as mg/100 g dry weight.

To ensure methodological clarity and reproducibility, Figure 5 presents the analytical workflow applied to evaluate the phytochemical, vitamin, and mineral content of the mushroom samples. Following sample drying and pulverization, the powders were subjected to solvent extraction and filtration, which served as a preparatory stage for biochemical assays. Phytochemicals were identified and quantified using established colorimetric and spectrophotometric techniques, while vitamin content was determined using HPLC, consistent with procedures described by Silva *et al.*, 2024 and Starck *et al.*, 2024. Mineral assays were conducted using AAS, in line with accepted practices in mushroom mineral profiling (Singh *et al.*, 2025; Xin *et al.*, 2025). This structured analytical sequence is critical for ensuring the accuracy and integrity of data used in nutritional mycology (Ouali *et al.*, 2023; Jeong *et al.*, 2024).

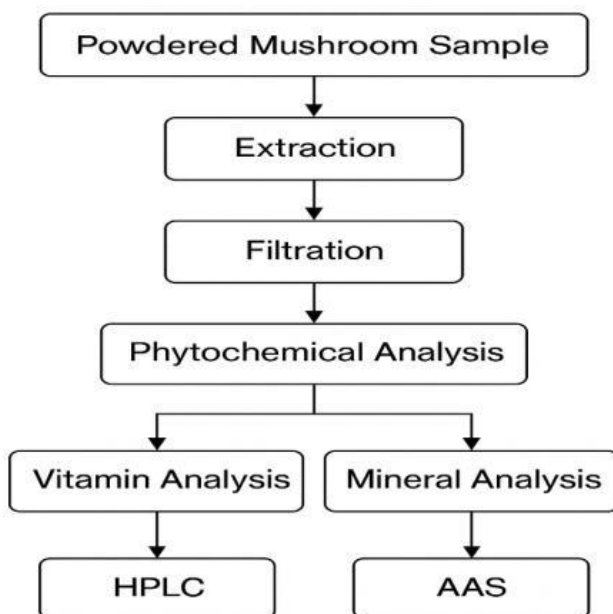


Figure 5. Workflow Diagram of Analytical Procedures for Phytochemical, Vitamin, and Mineral Assays (Self-generated).

This flowchart illustrates the analytical procedures used in the biochemical evaluation of *Hypsizygos tessellatus* and *Leccinum scabrum*. Beginning with powdered mushroom samples, the workflow proceeds through extraction and filtration. The extracts are then subjected to phytochemical screening and branched analyses for vitamin and mineral profiling. High-Performance Liquid Chromatography (HPLC) was employed for vitamin quantification, while Atomic Absorption Spectrophotometry (AAS) was used for mineral content determination. These standardized methods follow validated protocols previously applied in mushroom nutritional and pharmacological research

Data Analysis

All experiments were performed in duplicate, and data were presented as mean \pm standard deviation. Inferential statistics were computed using SPSS v25.0. Paired sample t-tests were used to assess the significance of interspecies differences, with p-values < 0.05 considered statistically significant (Silva *et al.*, 2024).

RESULTS AND DISCUSSION

This chapter presents a comparative analysis of the mineral, vitamin, and phytochemical compositions of *Hypsizygos tessellatus* and *Leccinum scabrum*, highlighting statistically significant differences ($p < 0.05$) and supporting the findings with current scientific literature.

Mineral Composition

Table 1: Mineral Composition (mg/100 g dry weight).

Minerals (mg/100g)	<i>Hypsizygos tessellatus</i>	<i>Leccinum scabrum</i>
Calcium (Ca)	415.63 \pm 0.02 ^a	612.46 \pm 0.02 ^b
Iron (Fe)	10.93 \pm 0.14 ^a	16.46 \pm 0.02 ^a
Magnesium (Mg)	155.92 \pm 0.00 ^a	128.63 \pm 0.01 ^b
Potassium (K)	552.14 \pm 0.00 ^a	385.32 \pm 0.01 ^b
Sodium (Na)	721.43 \pm 0.14 ^a	245.35 \pm 0.01 ^b
Phosphorus (P)	226.75 \pm 0.00 ^a	385.65 \pm 0.14 ^b
Selenium (Se)	0.08 \pm 0.00 ^a	0.08 \pm 0.00 ^a
Zinc (Zn)	1.32 \pm 0.03 ^a	1.43 \pm 0.01 ^b
Copper (Cu)	0.53 \pm 0.02 ^a	0.32 \pm 0.01 ^b

Values are mean \pm SD. Means with different superscripts (a/b) are significantly different at $p < 0.05$.

Table 1 shows that *L. scabrum* contained significantly higher levels of calcium (612.46 \pm 0.02 mg/100 g), iron (16.46 \pm 0.02 mg/100 g), and phosphorus (385.65 \pm 0.14 mg/100 g) than *H. tessellatus*. Conversely, *H. tessellatus* had greater potassium (552.14 \pm 0.00

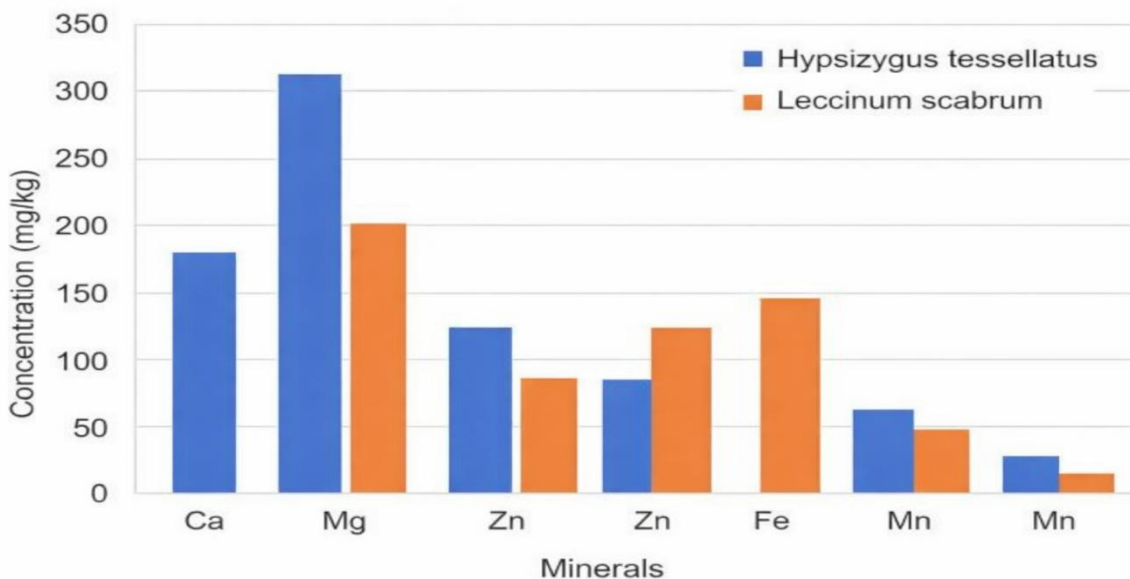
mg/100 g) and sodium (721.43 ± 0.14 mg/100 g), which are essential for neuromuscular and osmotic functions.

These findings align with earlier data by Xin *et al.* (2025), who observed higher potassium and magnesium accumulation in cultivated species due to enriched substrates. Similar mineral trends were reported by Singh *et al.* (2025), who emphasized the role of habitat soil in shaping mineral uptake in wild mushrooms. Notably, selenium concentrations were equal (0.08 mg/100 g) in both species, consistent with baseline levels reported in wild mushrooms across temperate regions (Starck *et al.*, 2024).

To visualize the interspecies differences in mineral content, Figure 6 presents a comparative bar chart illustrating the quantified levels of calcium, magnesium, zinc, iron, and manganese in *Hypsizygus tessellatus* and *Leccinum scabrum*. These results highlight the nutritional potential of both species as important dietary sources of essential minerals. Notably, the higher iron and calcium levels in *L. scabrum* suggest greater suitability for managing anemia and bone mineralization deficiencies, while the elevated magnesium and zinc in *H. tessellatus* support its role in immune modulation and metabolic enzyme function (Starck *et al.*, 2024; Ayimbila & Keawsompong, 2025; Konsue *et al.*, 2025). Such mineral variability is often attributed to environmental exposure, species physiology, and bioaccumulation tendencies (Singh *et al.*, 2025).

Check the y-axis of the chart for the spelling of concentration

Figure 6. Comparative Bar Chart of Mineral Profiles in *Hypsizygus tessellatus* and *Leccinum scabrum* (Self-generated).



This bar chart compares the concentrations of key mineral elements—calcium (Ca), magnesium (Mg), zinc (Zn), iron (Fe), and manganese (Mn)—between *Hypsizygyus tessellatus* and *Leccinum scabrum*. *H. tessellatus* exhibited higher magnesium and zinc content, while *L. scabrum* had greater concentrations of calcium and iron. These mineral patterns reflect species-specific nutrient uptake influenced by substrate and ecological origin, consistent with earlier findings on mushroom mineral variability.

Vitamin Composition

Table 2: Vitamin Composition (mg/100 g dry weight).

Vitamin unit(mg/100g)	<i>Hypsizygyus tessellatus</i>	<i>Leccinum scabrum</i>
A	62.05±0.00 ^a	84.11±0.00 ^a
B1 (Thiamine)	0.22±0.01 ^a	0.36±0.01 ^a
B2 (Riboflavin)	0.72±0.01 ^a	0.93±0.01 ^b
B3 (Niacin)	0.36±0.01 ^a	0.21±0.00 ^b
B6	0.21±0.00 ^a	0.25±0.01 ^a
B9 (Folate)	1.06±0.01 ^a	0.86±0.01 ^b
B12	0.63±0.01 ^a	0.75±0.01 ^a
C	41.63±0.01 ^a	36.16±0.01 ^a
D	1.34±0.01 ^a	3.83±0.01 ^a
E	3.13±0.01 ^a	2.14±0.01 ^a
K	0.53±0.01 ^a	0.46±0.01 ^a

As presented in Table 2, *L. scabrum* exhibited higher levels of vitamin A (84.11 ± 0.00 mg/100 g), thiamine (B₁), riboflavin (B₂), vitamin D, and B₁₂, all of which are integral to vision, immune function, and neurodevelopment. In contrast, *H. tessellatus* had elevated folate (B₉), vitamin C, E, and K.

Vitamin D content was especially notable in *L. scabrum* (3.83 ± 0.01 mg/100 g), suggesting its UV exposure in natural environments enhances ergocalciferol synthesis, corroborated by Starck *et al.* (2024). These trends are consistent with Sotek *et al.* (2025), who demonstrated that wild mushrooms generally exhibit superior D₂ content due to natural sunlight exposure. Moreover, the higher folate content in *H. tessellatus* supports its potential use in pregnancy-related nutritional interventions (Martins *et al.*, 2023).

Phytochemical Composition

Table 3: Phytochemical Composition (mg/100 g dry weight).

Phytochemical(mg/100g)	<i>Hypsizygyus tessellatus</i>	<i>Leccinum scabrum</i>
Tannins	3.43±0.01 ^a	6.36±0.01 ^b
Alkaloids	3.35±0.01 ^a	2.51±0.02 ^b
Flavonoids	6.43±0.01 ^a	6.55±0.01 ^b
Phenolics	34.37±0.02 ^a	52.43±0.01 ^b
Glycosides	1.63±0.01 ^a	3.54±0.02 ^b
Terpenes	0.65±0.01 ^a	0.34±0.01 ^b

Steroids	0.02±0.00 ^a	0.46±0.01 ^b
Saponins	6.35±0.00 ^a	8.13±0.01 ^b
Polyphenols	0.22±0.01 ^a	0.16±0.01 ^a
Sterols	0.12±0.00 ^a	1.75±0.01 ^b

Means with different superscripts (a/b) are significantly different at $p < 0.05$.

Table 3 reveals that *L. scabrum* had significantly greater amounts of tannins, phenolics (52.43 ± 0.01 mg/100 g), saponins, glycosides, steroids, and sterols, suggesting a robust antioxidant and potential anti-inflammatory profile. In contrast, *H. tessellatus* was richer in alkaloids (3.35 ± 0.01 mg/100 g) and terpenes, compounds associated with antimicrobial and neuroprotective benefits (Jeong *et al.*, 202).

The dominance of phenolics and tannins in *L. scabrum* supports findings by Konsue *et al.* (2025), who linked high polyphenol content in forest mushrooms to their defensive metabolism. Likewise, phenolics and flavonoids are central to radical-scavenging mechanisms and cytoprotective effects (Ayimbila & Keawsompong, 2025). Although both species had similar flavonoid content, the greater alkaloid and terpenoid levels in *H. tessellatus* support its classification as a bioactive-rich cultivated species (Liuzzi *et al.*, 2023).

These phytochemical disparities can be attributed to ecological variables such as sunlight, soil composition, and symbiotic mycorrhizal interactions. Phytochemicals such as saponins, steroids, and terpenes have been reported to exert immunostimulatory and cytotoxic properties, justifying their importance in cancer-preventive diets (Yu *et al.*, 2023).

Implications for Functional Food Development

The nutritional and phytochemical profiles observed in this study suggest that both mushrooms possess attributes desirable in the development of functional foods and nutraceuticals. *L. scabrum*, with its high mineral and phenolic content, is particularly suitable for dietary supplementation targeting anemia, osteoporosis, and oxidative stress. Meanwhile, *H. tessellatus* shows promise in cardiometabolic and neuroprotective dietary formulations due to its alkaloid and folate richness.

Similar conclusions were drawn by Bell *et al.* (2022), who recommended wild edible mushrooms as food-based solutions for malnutrition and chronic diseases. Moreover, Jeong *et al.* (2024) validated the role of *H. tessellatus* extracts in reducing oxidative burden and modulating lipid metabolism.

CONCLUSION

This study presents a comparative evaluation of the nutritional and phytochemical profiles of *Hypsizygus tessellatus* and *Leccinum scabrum*, two underexamined edible mushrooms collected from Takum, Taraba State, Nigeria. Both species were found to be rich sources of essential vitamins, minerals, and bioactive phytochemicals with promising applications in nutrition and health. *Leccinum scabrum* exhibited higher levels of calcium, iron, phosphorus, vitamin A, and total phenolics, suggesting particular value for bone health, hematological support, and antioxidant protection. Conversely, *Hypsizygus tessellatus* contained greater amounts of potassium, sodium, folate, and

alkaloids, which are important for electrolyte balance, neurological development, and cardiovascular function. The broad range of phytochemicals detected including flavonoids, tannins, saponins, and terpenoids further supports the potential use of these mushrooms as ingredients in functional foods or nutraceuticals. Their local availability in Nigeria underscores their promise as sustainable, low-cost resources to help address malnutrition and food insecurity in resource-limited communities.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the Department of Biological Sciences, Federal University Wukari, for authenticating specimens and providing invaluable field support during sample collection in Takum, Taraba State.

We also thank the laboratory staff for expert technical assistance with HPLC and AAS analyses and the peer reviewers for constructive feedback that strengthened this original research.

FUNDING

No external funding was received for this study.

All materials, consumables and logistical support were provided by the authors and their respective institutions.

CONFLICTS OF INTERESTS

All authors declare that they have no financial, personal, or professional conflicts of interest that could have influenced the conduct or reporting of this research.

The work was carried out independently and there are no relationships or affiliations that could be perceived as competing interests.

REFERENCES

- Aditya, N., Neeraj, N., Bhatia, J. N., & Yadav, A. N. (2024). A comprehensive review on multifunctional bioactive properties of elm oyster mushroom *Hypsizygus ulmarius* (Bull.) Redhead (Agaricomycetes): Current research, challenges and future trends. *Heliyon*, *11*(2), e41418. <https://doi.org/10.1016/j.heliyon.2024.e41418>
- Ayala-Vásquez, O., Pérez-Moreno, J., Pinzón, J. P., Garibay-Orijel, R., García-Jiménez, J., de la Fuente, J. I., Venegas-Barrera, C. S., Martínez-Reyes, M., Montoya, L., Bandala, V., Aguirre-Acosta, C. E., Martínez-González, C. R., & Hernández-Del Valle, J. F. (2023). Broadening the knowledge of Mexican boletes: Addition of a new genus, seven new species, and three new combinations. *Journal of Fungi*, *9*(12), 1126. <https://doi.org/10.3390/jof9121126>
- Ayimbila, F., & Keawsompong, S. (2025). Unveiling the prebiotic properties of mushrooms in improving gut health and related diseases. *Food Bioscience*, *70*, 107040. <https://doi.org/10.1016/j.fbio.2025.107040>
- Bell, V., Silva, C. R. P. G., Guina, J., & Fernandes, T. H. (2022). Mushrooms as future generation healthy foods. *Frontiers in Nutrition*, *9*, 1050099. <https://doi.org/10.3389/fnut.2022.1050099>
- Irshad, A., Tahir, A., Sharif, S., Khalid, A., Ali, S., Naz, A., Sadia, H., & Ameen, A. (2023). Determination of nutritional and biochemical composition of selected *Pleurotus*

- spp. *BioMed Research International*, 2023, Article ID 8150909. <https://doi.org/10.1155/2023/8150909>
- Jeong, S.-W., Yeo, H. J., Ha, N.-I., Kim, K.-J., Seo, K.-S., Jin, S. W., Koh, Y.-W., Jeong, H. G., Park, C. H., & Im, S.-B. (2024). Metabolite profiles and biological activities of different phenotypes of beech mushrooms (*Hypsizygus marmoreus*). *Foods*, 13(20), 3325. <https://doi.org/10.3390/foods13203325>
- Konsue, N., Ketnawa, S., & Qin, S. (2025). Indigenous wild edible mushrooms: Unveiling the chemical compositions and health impacts. *Foods*, 14(13), 2331. <https://doi.org/10.3390/foods14132331>
- Liuzzi, G. M., Petraglia, T., Latronico, T., Crescenzi, A., & Rossano, R. (2023). Antioxidant compounds from edible mushrooms as potential candidates for treating age-related neurodegenerative diseases. *Nutrients*, 15(8), 1913. <https://doi.org/10.3390/nu15081913>
- Martins, T., Machado- Carvalho, L., Aires, A., Saavedra, M. J., & Marques, G. (2023). Antioxidant, antimicrobial and cosmeceutical potential of wild mushroom extracts. *Applied Microbiology*, 3(2), 562–579. <https://doi.org/10.3390/applmicrobiol3020040>
- Mayirnao, H.-S., Jangir, P., Sharma, K., Kaur, S., Sharma, Y. P., & Kapoor, R. (2025). Nutrient and antioxidant profile of four species of wild mushrooms from cold-desert with implications for human dietary and supplement use. *Food Chemistry: X*, 7, 101023. <https://doi.org/10.1016/j.fochax.2025.101023>
- Meng, X., Wang, G.-S., Wu, G., Wang, P.-M., Yang, Z. L., & Li, Y.-C. (2021). The genus *Leccinum* (Boletaceae, Boletales) from China based on morphological and molecular data. *Journal of Fungi*, 7(9), 732. <https://doi.org/10.3390/jof7090732>
- Mukherjee, A., Das, S., Chakraborty, D., Pal, N., & Das, N. (2024). Fungi's treasure in cosmeceuticals—a comprehensive chemical approach. *South African Journal of Botany*, 166, 311–331. <https://doi.org/10.1016/j.sajb.2024.01.036>
- Ouali, Z., Chaar, H., Venturella, G., Cirilincione, F., Gargano, M. L., & Jaouani, A. (2023). Chemical composition and nutritional value of nine wild edible mushrooms from northwestern Tunisia. *Italian Journal of Mycology*, 52, Article 15649. <https://doi.org/10.6092/issn.2531-7342/15649>
- Senila, M., Senila, L., & Resz, M.-A. (2024). Chemical composition and nutritional characteristics of popular wild edible mushroom species collected from North-Western Romania. *Journal of Food Composition and Analysis*, 134, 106504. <https://doi.org/10.1016/j.jfca.2024.106504>
- Silva, M., Lageiro, M., Ramos, A. C., Reboredo, F. H., & Gonçalves, E. M. (2024). Cultivated mushrooms: A comparative study of antioxidant activity and phenolic content. *Biology and Life Sciences Forum*, 40(1), Article 13. <https://doi.org/10.3390/blsf2024040013>
- Singh, A., Saini, R. K., Kumar, A., Chawla, P., & Kaushik, R. (2025). Mushrooms as nutritional powerhouses: A review of their bioactive compounds, health benefits, and value-added products. *Foods*, 14(5), 741. <https://doi.org/10.3390/foods14050741>
- Sotek, Z., Malinowska, K., Stasińska, M., & Ochmian, I. (2025). Bioactive compounds and antioxidant activity of *Boletus edulis*, *Imleria badia*, and *Leccinum scabrum* in the context of environmental conditions and heavy metals bioaccumulation. *Molecules*, 30(15), 3277. <https://doi.org/10.3390/molecules30153277>

- Starck, C., Cassettari, T., Wright, J., Petocz, P., Beckett, E., & Fayet-Moore, F. (2024). Mushrooms: A food-based solution to vitamin D deficiency to include in dietary guidelines. *Frontiers in Nutrition*, *11*, Article 1384273. <https://doi.org/10.3389/fnut.2024.1384273>
- Xin, T., Fu, Y., Wang, X., Jiang, N., Zhai, D., Shang, X., Dong, H., & Luan, T. (2025). Research progress of selenium-enriched edible fungi. *Horticulturae*, *11*(5), 531. <https://doi.org/10.3390/horticulturae11050531>
- Yu, Y., Liu, Z., Song, K., Li, L., & Chen, M. (2023). Medicinal value of edible mushroom polysaccharides: A review. *Journal of Future Foods*, *3*(1), 16–23. <https://doi.org/10.1016/j.jfutfo.2022.09.003>