Bangladesh J. Bot. **54**(4): 995-1004, 2025 (December) DOI: https://doi.org/10.3329/bjb.v54i4.86575

GIS-STATISTICAL ANALYSIS OF NUTRITIONAL QUALITY AND REGIONAL DIFFERENTIATION OF *AURICULARIA AURICULA* IN LVLIANG MOUNTAIN

LIHONG LI, JIAN BAI*, RUOTONG WANG[1], YIFAN WANG, HUIJIE SUN, SHICHAO FENG AND WENXUAN DU

Department of Biological and Food Engineering, Lyuliang University, Lyuliang 033001, Shanxi, China

Keywords: *Auricularia auricula*, GIS analysis, Nutritional quality, Environmental factors, Lvliang Mountain

Abstract

This study evaluated the quality of wild *Auricularia auricula* from 13 areas in Lvliang Mountain using GIS and statistical methods to identify high-quality regions. Geographic Information System (GIS) was employed to collect data on location, altitude, and soil type. The relationships between these environmental factors and *A. auricula* quality were examined using principal component analysis and statistical models. Significant variations in nutritional quality were observed among production areas, with coefficients of variation ranging from 0.02% to 0.19%. The top-performing areas were Zhongyang, Liulin, and Jiaocheng counties. *A. auricula* from Zhongyang exhibited superior levels of moisture, crude protein, and total sugar. Principal component analysis grouped eight quality indicators into two components, which collectively accounted for 81.58% of the total variance. Altitude, air temperature, light duration, and precipitation were identified as key factors strongly influencing *A. auricula* quality. Notably, altitude and air temperature negatively affected crude protein content, while light duration positively influenced fat content. Overall, wild *A. auricula* from Zhongyang and Liulin counties received the highest nutritional quality ratings. This study provides a scientific basis for origin-based quality control and sustainable harvesting strategies of wild *A. auricula*, and offers insights for quality management and environmental protection of similar forest crops.

Introduction

Wild fungus, which is rich in polysaccharides, amino acids, and proteins, is recognized as a popular health food of high nutritional value and has garnered significant scientific attention.(Han *et al.* 2023). Prized for their high nutritional value imparted by polysaccharides, amino acids, and proteins, wild fungi such as *Ganoderma lucidum* and *Ophiocordyceps sinensis* are popular health foods, exemplifying species that have garnered substantial scientific attention. However, most studies focus on single regions or specific conditions, lacking systematic analysis of wild fungus quality across multiple regions and climates. Due to the nutrient differences in wild fungus across regions, driven by climate and soil, an in-depth study of these variations is important for both academic and practical purposes. Lvliang Mountain’s varied natural conditions, such as altitude, temperature, and precipitation, make it ideal for studying the link between fungus quality and the environment. Soil properties such as pH and organic matter, significantly affect the formation of polysaccharides and proteins in wild fungus with suitable pH condition enhancing mineral dissolution and promoting nutrient accumulation (Barrow *et al.* 2023). GIS (Geographic Information System) plays a vital role in agricultural research by linking crop yield, soil fertility, and environmental factors to support the optimization of agricultural practices (Mathenge *et al.* 2022). GIS and remote sensing are essential for assessing soil quality, using spatial models to monitor environmental factors that enhance *Auricularia auricular* yield and quality.

*Author for correspondence: <20061018@llu.edu.cn>. [1]College of Landscape Architecture, Northeast Foretry University, Harbin Heilongjiang 150006, China.

The Lvliang Mountains are in western Shanxi Province, ranging from 36°N to 40°N latitude and 110°E to 112°E longitude. The eastern and western parts of the range differ significantly in topography and climate. The eastern side receives more rain and has richer soils, ideal for wild fungus. The western side, part of the Loess Plateau, has fewer soil nutrients but is still good for crops. Lvliang Mountain has a temperate semi-arid climate with 400-600 mm of annual rainfall, mostly in summer, which supports wild fungus growth. Wild fungus thrives in the humid forest environment, benefiting from the humus to boost yields and support ecosystem stability. The Lvliang Mountains' unique climate and geography make it ideal for wild fungus cultivation and for studying how environment impacts its quality.

This study fills the gap by using GIS and statistical methods to analyze how altitude, temperature, and precipitation affect the nutrient composition of wild *A. auricular* in Lvliang Mountain. By investigating the relationship between environment and Auricularia auricular quality, this research provides a scientific basis for identifying high-quality production areas and supporting the development of regional branding. The study also contributes precision cultivation and market competitiveness of the wild *A. auricular* industry, offering new insights into quality evaluation and environmental factors (Wang *et al.* 2024).

Materials and Methods

Elevation data came from the Digital Elevation Model (DEM) via the National Geographic Information Public Service Platform, with 900 m spatial resolution. Climate data was sourced from the China Meteorological Data Sharing Service Network, covering 2014 to 2023. Soil data, including pH, organic matter, and trace elements, came from the China Soil Database.

Wild *A. auricular* samples were systematically collected across 13 counties in the Lvliang Mountain during the growing seasons from May to September, over the period of 2021 to 2023. Sampling locations were chosen based on altitude and light conditions to ensure broad representation. Laboratory tests determined key nutrients such as crude protein and polysaccharides, following national standards (e.g., NY/T 1670-2008). Climate and soil data were standardized, with outliers removed and missing data filled via linear interpolation for consistency. Wild *A. auricular* quality data were normalized to ensure comparability across regions. This study used a comprehensive analysis framework, combining GIS, statistics, and lab testing, to examine how environmental factors affect the nutrient composition and quality of wild *A. auricular* in Lvliang Mountain. The framework involved collecting environmental data, analyzing *A. auricular* quality, spatial analysis, and building and validating statistical models.

Meteorological data were spatially interpolated using ArcGIS 10.8.1 to create climate distribution maps for the region. Soil data processing: GIS created a spatial distribution map of soil properties (e.g., pH, organic matter, trace elements) in the Lvliang region. Pearson correlation analysis was done on environmental factors and *A. auricular* quality indicators using Origin 2024. Wild *A. auricular* quality indicators were analyzed using PCA in Origin 2024. Multivariate linear regression models were built with R4.4.0 on dimensionality-reduced environmental and *A. auricular* quality data.

Min-Max normalization was used to standardize the data within a common range. To maintain data precision, nutrient composition and environmental factors for wild *A. auricular* were normalized separately using the following equations:

$$x' = \frac{x - x_{\min}}{x_{\max} - x_{\min}}$$

x': normalised value, x: original value, x_{min}: The minimum value of the feature,
x_{max}: Maximum value of the feature

Using the results from ANOVA and correlation analysis, regression equations were developed for moisture, total sugar, crude protein, and ash. These were related to altitude, mean air temperature, daily temperature variation, light duration, and precipitation. Intercept values, coefficients for each variable, and R-squared values were computed using normalized data in R.

Results and Discussion

Soil pH and organic matter content show spatial and temporal patterns that are key to understanding the soil characteristics in Lvliang Mountain (Guo *et al.* 2024). As shown in Fig. 1, central Lvliang Mountain has high soil organic matter, mainly in Liulin, western Zhongyang, eastern Linxian, and southern Lishi. Northern Lvliang Mountain has low soil organic matter, with Jiaocheng having the lowest levels. A clear contrast in soil pH was observed between the acidic soils of eastern Lvliang and the alkaline soils of the western region. Trace elements like potassium ion (K^+/mg/kg) are found mostly in northwestern Lvliang, with less in the central-eastern parts. Calcium ion (Ca^{2+}/mg/kg) and nitrogen are concentrated in central and central-eastern Lvliang. Magnesium ion (Mg^{2+}/mg/kg)is mainly distributed in the eastern part of Lvliang Mountain; and quick phosphorus (P/mg/kg) is mainly distributed in the southern region of Lvliang Mountain. The Lvliang Mountain Range caused the spatially consistent distribution of soil environmental factors in the eastern and western regions of the Lvliang Mountains, and the nutrient distribution and organic matter content of the soil were influenced by topographic and climatic factors (Li *et al.* 2020). The growing conditions, especially soil properties (pH, organic matter, trace elements, nitrogen, phosphorus, potassium), significantly impact nutrient accumulation and quality (Fujii *et al.* 2018, Hao *et al.* 2022). Calcium (Ca^{2+}) stabilized the cell wall of *A. auricular*, potassium

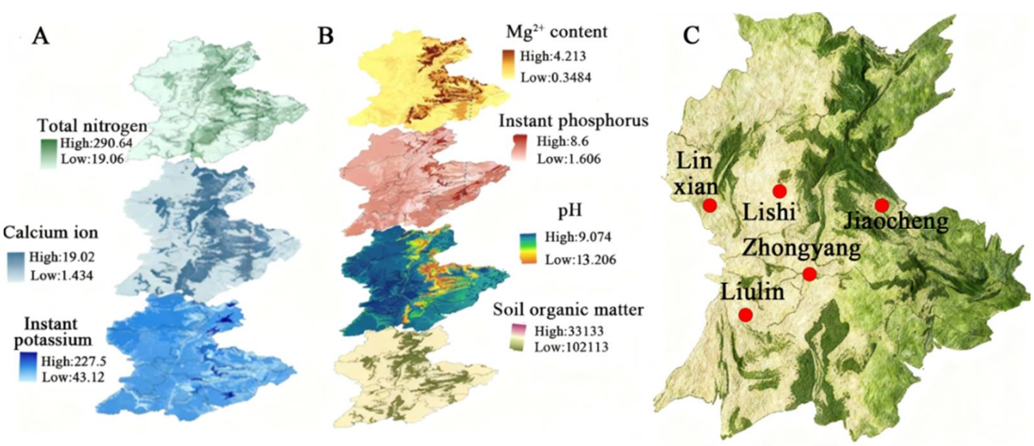

Fig. 1. Spatial distribution of key soil properties related to *Auricularia auricula* growth in the Lvliang Mountain region (A) Total nitrogen (g/kg), calcium ions (mg/kg), and available potassium (mg/kg). (B) Magnesium ions (mg/kg), available phosphorus (mg/kg), soil pH, and soil organic matter (mg/kg). (C) Detailed spatial distribution of soil organic matter content (mg/kg). Note: All geospatial and soil data were obtained from the National Tibetan Plateau/Third Pole Environment Data Center.

(K^+) regulated osmotic pressure, nitrogen (N) promoted protein synthesis, phosphorus (P) promoted energy transfer, and magnesium (Mg^{2+}) assisted photosynthesis. The reasonable balance of these elements is very important for the growth and development of *A. auricular* and the improvement of its yield and quality. Excessive or insufficient growth is limited, precise fertilization is the key. Soil pH directly affects mineral solubility and nutrient availability, with profound implications for the biosynthesis of key biomolecules like polysaccharides and proteins in plants (Hartemink *et al.* 2023). Fungus quality is closely tied to soil conditions. Neutral to slightly acidic soils are ideal, while strongly acidic or alkaline soils reduce quality (Husson *et al.* 2021). Regions with high organic matter content also produce wild fungus with high polysaccharide and protein levels (Chen *et al.* 2024). Therefore, combining the differences in nutrient composition of wild fungus in different regions and their growing environment, especially the analysis of soil physicochemical properties, can help to comprehensively reveal the mechanism of the influence of environmental factors on the quality of wild *A. auricular*.

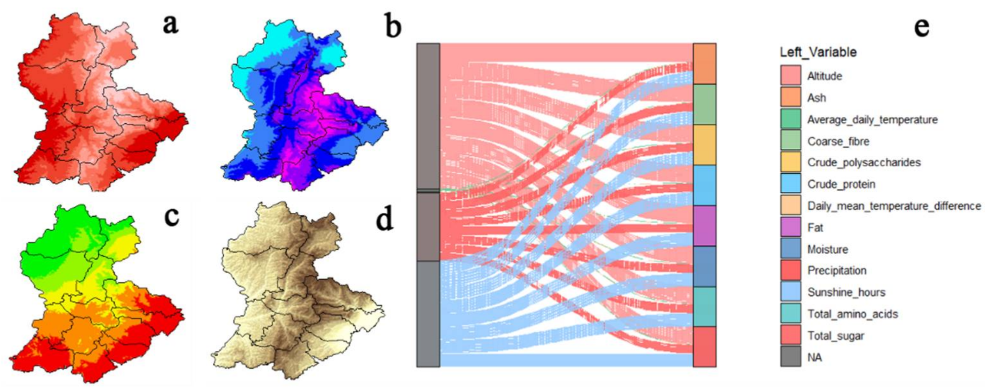

Fig. 2. Correlation analysis between climatic factors and quality of wild *Auricularia auricular*. a. Average daily temperature, b. Precipitation, c. Sunshine, d. Altitude, e. Sankey diagram. Caption: (a) Darker red shades indicate higher temperatures; (b) Colors represent precipitation levels; (c) Colors denote sunshine duration; (d) Darker colors indicate higher altitude; (e) Relationships between environmental factors and nutritional variables.

The Sankey diagram in Fig. 2 illustrates the complex relationship between environmental factors and wild *A. auricular* nutrient composition. Altitude and precipitation strongly impacted nutrient content (e.g., crude protein, fiber, sugars), with higher altitude and precipitation boosting these components. Temperature (mean and daily difference) mainly affected amino acids, fat and ash, highlighting the role of temperature in plant metabolism. Light duration mainly impacted sugar and fiber synthesis, indicating that light greatly aids photosynthesis and structural material buildup. The Lvliang Mountains region features high-altitude terrain, predominantly in Fangshan, Wenshui, Lishi, and Jiaocheng counties, with the highest peak at 1,651 m (DEM data source: National Geographic Information Public Service Platform). Lower altitude regions like Zhongyang and Liulin counties are better suited for growing high-quality wild *A. auricular*, particularly in moisture, protein, and amino acids (Zhang *et al*. 2025). The average annual temperatures in the region ranged from 0.16 ℃ to 12.52 ℃, with those in Zhongyang County ranging from 6.26 ℃ to 10.18 ℃, which were suitable for the growth of wild *A. auricular* substrates. The duration of light significantly affected the growth and quality of wild *A. auricular*, with moderate light in Zhongyang County and Lishi promoting the growth and nutrient accumulation of wild *A. auricular*, whereas prolonged light in the northern part of Lvliang might have led to excessive drying of the wild *A. auricular*, affecting the quality. Relative humidity is key, with studies showing 70% or higher being favorable for wild *A. auricular* growth. In areas with low annual precipitation and high evapotranspiration (e.g., Xingxian County and Lanxian

County), low soil humidity is unfavourable to the growth of wild *A. auricular*, leading to a decrease in quality. In contrast, in areas with high precipitation, such as Zhongyang County, the soil humidity was relatively high, creating conditions for good growth of wild *A. auricular*, which exhibited high moisture and nutrient content, thus enhancing quality. A temperature range of 15-25°C is ideal for wild *A. auricular* growth. Moderate light, though it is a shade plant, can boost polyphenol and vitamin D content (Sun *et al.* 2022). Moderate precipitation is also the key to ensure the quality of wild *A. auricular*.

As shown in table 1, the nutrient content of wild *A. auricular* varied across 13 sampling sites in the Lvliang Mountains, revealing geographic differences. The standard deviation showed that moisture, ash, fat, crude protein, crude polysaccharide, crude fiber, and total amino acids had minor variation across the sampling zones. However, total sugar content showed a more noticeable difference. The coefficient of variation (CV) measures how spread out the data are in relation to the mean. A higher CV means a more uneven distribution and greater variability in the data. The CVs for eight quality indicators across the 13 sites were all above 0.01%. Total sugar had the highest CV at 0.189%, with a standard deviation of 12.808 and a mean of 6.74 g/10 g. This suggests high total sugar content overall, with significant differences between regions, indicating that location strongly affects total sugar levels. By contrast, fat content had a low CV of 0.03%, a standard deviation of 0.021, and a mean of 9.8 g/100 g. This indicates minimal regional variation in fat content, which remained consistently low across all sites. CVs for moisture, ash, crude polysaccharides, crude protein, coarse fiber, and total sugars ranged from 0.022% to 0.19%, showing that these components also varied across regions, though the extent of variation differed (Wu *et al* 2024).

Table 1. Wild *Auricularia auricula* Nutrition Statistics from 13 Counties.

Statistic	Moisture	Ash	Fat	Crude Protein	Crude Polysaccharides	Coarse Fibre	Total Sugar	Total Amino Acids
Minimum	7.625	2.407	0.44	9.000	5.834	6.593	5.036	6.352
Maximum	8.266	3.630	2.60	13.803	9.467	7.538	8.615	7.322
Mean g/10 g）	7.922	3.208	9.8	12.179	7.524	6.882	6.74	6.646
Standard Deviation	0.173	0.340	0.021	1.340	1.312	0.31	12.808	0.321
Coefficient of Variation (%)	2.181	10.587	3.004	11.001	17.44	4.506	18.983	4.83

Pearson's analysis showed that environmental factors significantly impacted the nutritional quality of wild *A. auricular*. Fig. 3 highlights the correlations between these factors and the nutritional composition of *A. auricular*. Crude protein and altitude were negatively correlated. As altitude increased, temperatures dropped, slowing wild fungus metabolism and protein synthesis, as the ideal growth temperature is between 15°C and 25°C (Li *et al*. 2021). Light duration positively correlated with fat content in wild fungus. Moderate light exposure promotes the accumulation of photosynthetic products, thus increasing fat content (Kadnikova *et al*. 2015). Both high and low temperatures disrupted the fungus's metabolism during growth. A significant negative correlation was found between average air temperature and fat content, as the study area's temperature was higher than the fungus's optimal range. Higher temperatures within a certain range were linked to increased humidity, which helped maintain moisture in wild fungus. As a result, moisture content showed a positive correlation with air temperature. Altitude significantly impacted ash, crude protein, and total amino acids. Crude polysaccharides and ash were most affected by environmental factors, while moisture content was least influenced. Total amino acids and crude fiber were strongly correlated with other nutritional qualities, while moisture content showed the weakest correlation with other nutrients. Recent studies also confirm the weak correlation between the nutritional value of wild *A. auricular* and its moisture content (Bandara *et al.* 2019).

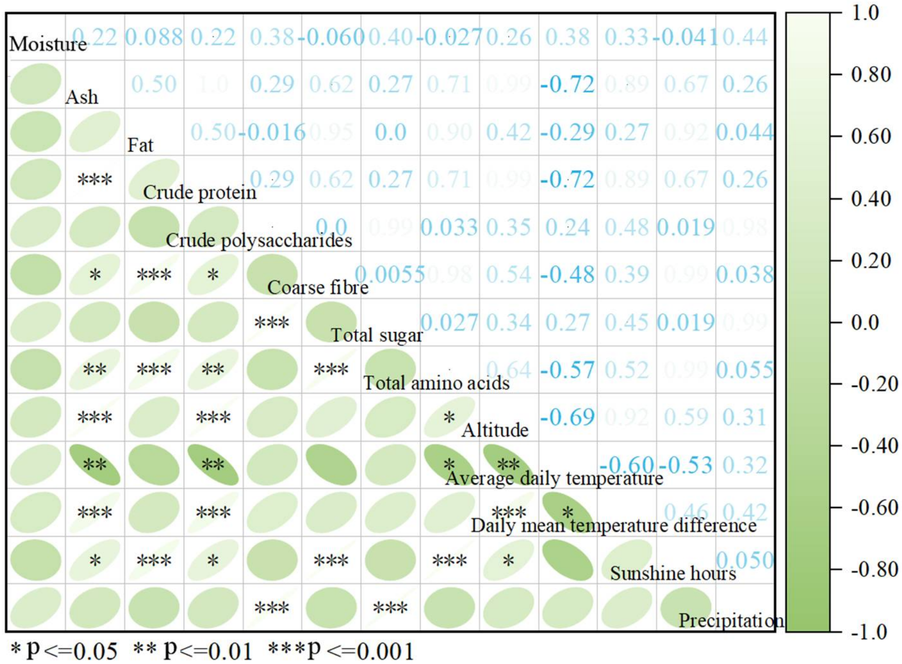

Fig. 3. Correlation matrix between nutritional components of *Auricularia auricula* and environmental factors

PCA analysis (Table 2) revealed that moisture and total sugar content were the primary factors influencing wild *A. auricular* quality. Regions with favorable precipitation and light conditions showed superior nutritional quality. Moisture levels, whether high or low, significantly affected wild *A. auricular* quality by influencing the absorption and retention of trace elements. High total sugar content indicates the maturity of the *A. auricular*. *A. auricular* with higher sugar content typically has better quality, taste, and structural integrity, which is beneficial during processing. Based on the analyses of Table 2, moisture and total sugar content are key indicators for evaluating the nutritional quality of wild *A. auricular* across 13 regions in the Lvliang Mountains.

Figures 4 and 5 show significant variations in the coefficients of determination between environmental factors and the four key nutrients. Altitude had a strong positive correlation with crude protein and ash in wild *A. auricular*. Crude protein content increased with elevation. Altitude impacts mineral distribution and nutrient absorption rates, which explains its influence on ash content in wild *A. auricular* (Rawiningtyas *et al.* 2023). The average temperature had a negative effect on crude protein and ash. Higher temperatures slow mineral uptake and reduce protein stability in wild *A. auricular* (Gao *et al.* 2024). Daily temperature variation was positively correlated with crude protein and ash. Greater temperature fluctuations promoted mineral and protein accumulation, thereby increasing ash content. Precipitation had a significant positive correlation with total sugar. Wild *A. auricular* thrives in low-temperature, humid environments, and precipitation supports growth, leading to higher sugar content (Drewinski *et al.* 2024).

Table 2. Principal Component Analysis (PCA) of Nutritional Components in Wild Fungus.

Indicator	Principal Component 1		Principal Component 2	
	Eigenvector	Loading	Eigenvector	Loading
Moisture	0.401	0.952	-0.083	-0.089
Ash	0.318	0.756	-0.417	-0.445
Fat	0.374	0.887	0.002	0.002
Crude Protein	0.331	0.785	0.324	0.346
Crude Polysaccharides	0.392	0.931	0.031	0.033
Crude Fiber	0.396	0.939	0.084	0.090
Total Sugar	0.283	0.672	0.644	0.688
Total Amino Acids	0.313	0.744	-0.540	-0.577

Using R, the linear regression model was refined into a multiple regression model. Environmental factors served as independent variables, while the four key nutrients were dependent variables. The variables were defined as follows: X1 = elevation, X2 = mean daily temperature, X3 = temperature difference, X4 = light duration, X5 = precipitation.

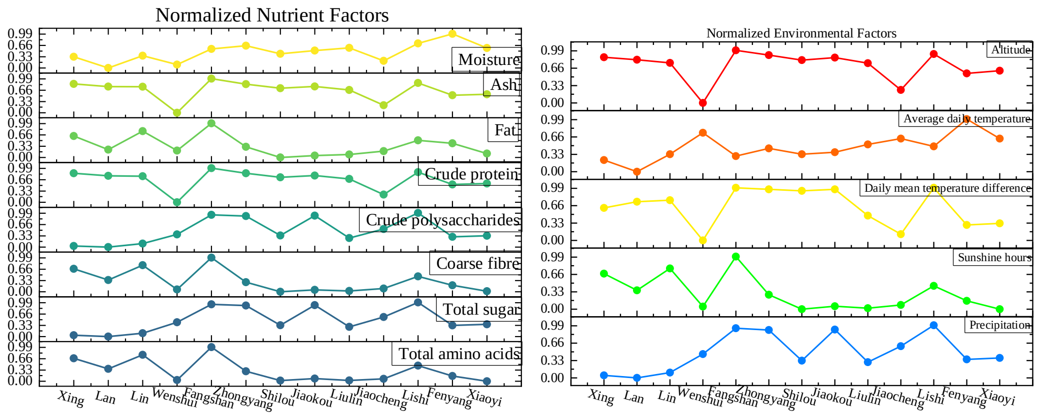

Fig. 4. Plot of the analysis of the normalized data of nutrient composition of wild fungus and environmental factors.

This study shows that environmental factors, such as temperature, precipitation, light duration, and soil pH, have a significant impact on wild *A. auricular* quality in different regions of Lvliang Mountain. Wild *A. auricular* grows best in shaded areas, accumulating nutrients through its metabolism. Bai *et al.* (2022) found that extended light exposure promotes polysaccharide and antioxidant production in the fungus. The mycelium absorbs trace elements from its environment, engaging in physiological processes that lead to ash accumulation in the fungus. Due to the spatial variation of trace elements in Lvliang Mountain, the ash accumulation in wild *A. auricular* differs across regions. Wild *A. auricular* breaks down cellulose and lignin through its mycelium, absorbing amino acids and peptides, and synthesizes protein through metabolic pathways. Since wild *A. auricular* doesn't photosynthesize, it relies on decomposing organic matter like lignin and cellulose to produce energy and fatty acids, which accumulate as fat. Crude fibers are undigested polysaccharides like cellulose, hemicellulose, and lignin, which accumulate to form the structural foundation of the wild *A. auricular*. PCA and correlation analysis reveal that moisture and total sugar content are key indicators for evaluating the nutritional quality of wild *A. auricular* across 13 regions in Lvliang Mountains. The correlation analysis highlights the relationship between environmental factors and the quality of wild *A. auricular*. A humidity range of 90–95% promotes the most active growth and yields the highest biomass in wild *A. auricular*. Lower humidity levels cause the *A. auricular* to lose moisture and go dormant, reducing growth and yield. A temperature around 25°C and 80%-90% humidity are ideal for wild *A. auricular*, encouraging both mycelium and fruiting body formation, and enhancing moisture, antioxidants, and polysaccharides, which boost its bioactivity and health benefits (Khan *et al.* 2023). Humidity plays a critical role in the respiration of wild *A. auricular*. A decrease in humidity impairs respiration and growth in *A. auricular*, leading to slower metabolism, reduced oxygen consumption, and diminished heat production, which consequently compromises its quality. Increasing soil minerals like magnesium, calcium, and zinc can improve the total sugar content in wild *A. auricular* (Long *et al.* 2025).

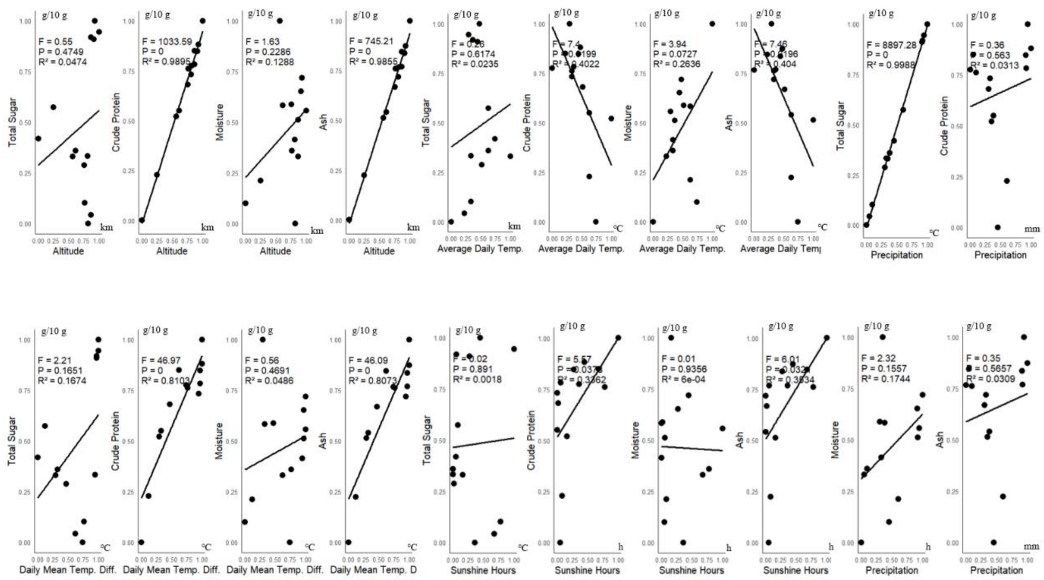

Fig.5 Regression analysis of environmental factors with major nutrients of wild fungus

Ash = $-0.0005 + 0.593X_1 + 0.086X_2 + 0.152X_3 + 0.285X_4 - 0.080X_5$, Moisture = $-0.0155 + 0.316X_1 - 0.172X_2 - 0.192X_3 + 0.279X_4 + 0.313X_5$, Total Sugar = $-0.0031 + 0.056X_1 - 0.082X_2 + 0.011X_3 - 0.052X_4 + 1.026X_5$, Crude Protein = $-0.2088 + 0.746X_1 - 0.0215X_2 - 0.439X_3 - 0.0201X_4 + 0.636X_5$, Ash = $-0.0005 + 0.593X_1 + 0.086X_2 + 0.152X_3 + 0.285X_4 - 0.080X_5$

GIS and environmental modeling revealed that the spatial heterogeneity of soil and climate critically governs the nutritional quality and regional differentiation of wild *A. auricular* in the Lvliang Mountains. A distinct east-west soil gradient was identified, wherein neutral pH (6.5–7.2) and higher organic matter enhanced the uptake of K^+, Mg^{2+}, Ca^{2+}, and nitrogen, directly increasing the ash content and improving key quality components of the fungus. Phosphorus is also crucial for promoting growth, stress resistance, and the synthesis of key biomolecules such as polysaccharides and proteins (Bechtaoui *et al*., 2021). Specifically, eastern areas (Zhongyang Fangshan) with higher soil nitrogen and potassium were associated with elevated protein and total sugars, while central regions richer in Ca^{2+} exhibited enhanced antioxidant capacity (Feng *et al.* 2023). Concurrently, altitude positively influenced moisture, protein, and polysaccharides, whereas precipitation was the primary driver of sugar accumulation. Temperature extremes and prolonged light exposure exhibited inhibitory effects on specific nutrients.

Synthesis of these spatial patterns enables the formulation of a regionally-specific cultivation strategy. Northwestern Jiaocheng, western Wenshui, and southern Zhongyang—characterized by high altitude, ample precipitation, and prolonged light—are optimal for cultivating protein-rich *A.*

auricular. In contrast, Lanxian, with its strong light, Mg^{2+}/Ca^{2+}-rich soils, and cool temperatures, favors polysaccharide synthesis. Taken together, the integration of GIS with principal component analysis identifies Zhongyang and Liulin as the most favorable regions for quality-oriented cultivation. These findings provide a scientific basis for targeted agricultural planning, precision management, and the sustainable development of the wild *A. auricular* industry in similar montane ecosystems.

Acknowledgements

This research was funded by the National Undergraduate Innovation and Entrepreneurship Training Program (Grant No. 202510812007). Additional support was provided by the Shanxi "Three Districts" Science and Technology Talent Support Program (Grant No. 202533) and the Lvliang Science and Technology Top Talents Program (Grant No. 202503).

References

Bai L, Xu D, Zhou YM, Zhang YB, Zhang H, Chen YB and Cui YL 2022. Antioxidant activities of natural polysaccharides and their derivatives for biomedical and medicinal applications. Antioxidants **11**(12): 2491.

Bandara AR, Rapior S, Mortimer PE, Kakumyan P, Hyde KD and Xu J 2019. A review of the polysaccharide, protein and selected nutrient content of *Auricularia*, and their potential pharmacological value. Mycosphere J, **10**(1): 579-607.

Barrow NJ and Hartemink AE 2023. The effects of pH on nutrient availability depend on both soils and plants. Plant Soil **487**(1): 21-37.

Bechtaoui N, Rabiu MK, Raklami A, Oufdou K, Hafidi M and Jemo M 2021. Phosphate-dependent regulation of growth and stresses management in plants. Front. Plant Sci. **12**: 679916.

Chen Y, Liu Z, Zeng W, Liu Y, Zhao D, Zhang Y and Jia X 2024. Screening and identification of soil selenium-enriched strains and application in *Auricularia auricula*. Microorganisms **12**(6): 1136.

Drewinski MP, Zied DC, Gomes EP and Menolli JrN 2024. Cultivation of a wild strain of wood ear Auricularia cornea from Brazil. Curr. Microbiol. **81**(11): 390.

Feng D, Wang X, Gao J, Zhang C, Liu H, Liu P, and Sun X 2023. Exogenous calcium: Its mechanisms and research advances involved in plant stress tolerance. Front. Plant Sci. **14**: 1143963.

Fujii K, Shibata M, Kitajima K, Ichie T, Kitayama K and Turner BL 2018. Plant–soil interactions maintain biodiversity and functions of tropical forest ecosystems. Ecol. Res. **33**: 149-160.

Gao Y, Zhang X, Wang R, Sun Y, Li X and Liang J 2024. Physicochemical, quality and flavor characteristics of starch noodles with Auricularia cornea var. Li. Powder. Foods **13**(8): 1185.

Guo BX, Zhou J, Zhan LQ, Wang ZY, Wu W, and Liu HB 2024. Spatial and temporal variability of soil pH, organic matter and available nutrients (N, P and K) in Southwestern China. Agron. **14**(8): 1796.

Han Q, Li H, Zhao F, Gao JA, Liu X and Ma B 2023. *Auricularia auricula* peptides nutritional supplementation delays H_2O_2-induced senescence of HepG2 cells by modulation of MAPK/NF-κB signaling pathways. Nutrients **15**(17): 3731.

Hao Z, Zhang WE, Tian F, Wei R and Pan X 2022. Enhancing the nutritional and functional properties of *Auricularia auricula* through the exploitation of walnut branch waste. Foods **11**(20): 3242.

Hartemink AE and Barrow NJ 2023. Soil pH-nutrient relationships: the diagram. Plant Soil **486**(1): 209-215.

Husson O, Sarthou JP, Bousset L, Ratnadass A, Schmidt HP, Kempf J and Lamichhane JR 2021. Soil and plant health in relation to dynamic sustainment of Eh and pH homeostasis: A review. Plant Soil **466**(1): 391-447.

Kadnikova IA, Costa R, Kalenik TK, Guruleva ON and Yanguo S 2015. Chemical composition and nutritional value of the mushroom Auricularia auricula-judae. J. Food Nutr. Res. **3**(8): 478-482.

Khan AA, Lu LX, Yao FJ, Fang M, Wang P, Zhang YM and Xu B 2023. Characterization, antioxidant activity, and mineral profiling of *Auricularia cornea* mushroom strains. Front. Nutr. **10**: 1167805.

Li Y, Ma J, Xiao C, and Li Y 2020. Effects of climate factors and soil properties on soil nutrients and elemental stoichiometry across the Huang–Huai–Hai River Basin, China. J. Soils Sediments **20**: 1970-1982.

Long Y, Chen M, Zhou W, Xiao N and Cai J 2025. Process optimization and effectiveness verification of liquid amino acid-containing fertilizer prepared from hydrolysis of carp scales. Waste Biomass Valor. **16**(3): 1411-1421.

Mathenge M, Sonneveld B G and Broerse J E 2022. Application of GIS in agriculture in promoting evidence-informed decision making for improving agriculture sustainability: A systematic review. Sustain. **14**(16): 9974.

Rawiningtyas S, Purnomo A S and Fatmawati S 2023. Evaluation of nutrient content and antioxidant activity of wood ear mushroom (*Auricularia auricula-Judae*) in the addition of reeds (*Imperata cylindrica* (L.) Beauv) as a cultivation medium. HAYATI J. Biosci. **30**(2): 224-231.

Sun X, Yang C, Ma Y, Zhang J and Wang L 2022. Research progress of *Auricularia heimuer* on cultivation physiology and molecular biology. Front. Microb. **13**: 1048249.

Wang J, Ma Z, Wang C and Chen W 2024. Melanin in *Auricularia auricula*: biosynthesis, production, physicochemical characterization, biological functions, and applications. Food Sci. Biotechnol. **33**(8): 1751-1758.

Wu Y, Zhou G, Song X, Song Y, Ren S, Geng J and Zhao H 2024. Key stage and its optimum meteorological conditions affecting the nutritional quality of maize. Agron. **14**(3): 420.

Zhang L, Si B, Lv M, Zhu Q, Du H, Ma W and Qu J 2025. Vegetable–Mushroom rotation increases morel (*Morchella esculenta* L.) yields by improving soil micro-environments and enhancing overall soil quality. Plants **14**(21): 3317.

(Manuscript received on 30 July, 2025; revised on 08 December, 2025)