

Previous studies have indicated that ganoderic acids and other constituents show growth-stage-specific differences; therefore, accurate recording of growth stage and harvest time is an important prerequisite for ensuring stable product chemical profiles (Zhang et al., 2023).

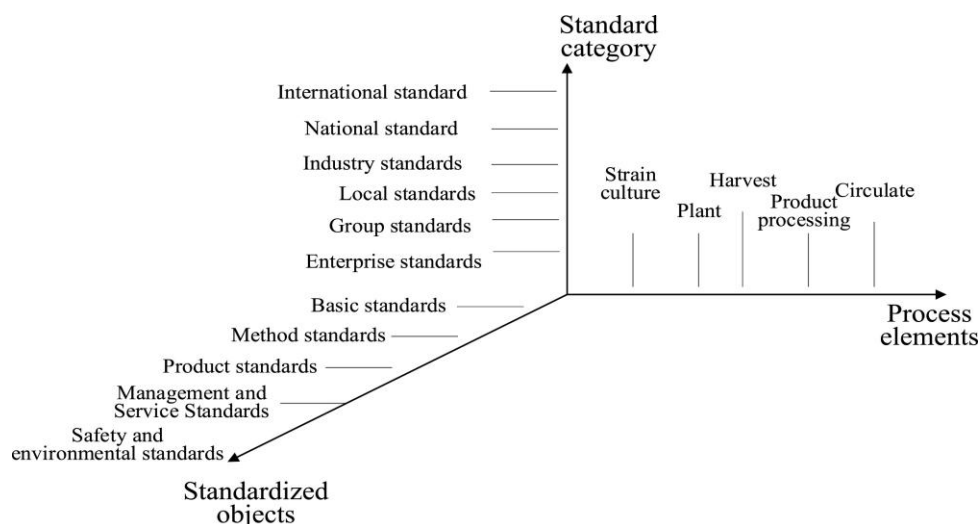


Figure 2 A three-dimensional framework model of the standard system for the entire industry chain of GL (Adopted from Wu et al., 2024)

Whole-process records should also be integrated with modern analytical authentication technologies to improve the scientific reliability and credibility of the traceability system. Elemental and stable isotope fingerprints, such as $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, $\delta^{18}\text{O}$, C%, and N%, combined with chemometric methods, can be used to distinguish the geographical origin, cultivar, and growth stage of *G. lucidum*, providing technical support for verifying origin information and production records (Zhang et al., 2023; Wadood et al., 2023). HPLC fingerprints and multivariate analysis can also be used to identify sample origin, cultivation method, and consistency with declared information. Therefore, facility-based *G. lucidum* production should integrate batch records, environmental monitoring, quality testing, and analytical authentication technologies on the basis of unified record templates, thereby forming a closed-loop quality assurance system.

5.2 Quality evaluation and grading standards for *Ganoderma lucidum* products

Quality evaluation of *G. lucidum* products is an important basis for assessing the level of facility-based production and the market value of products. Current market requirements for *G. lucidum* products have gradually shifted from simply pursuing yield to focusing on quality, safety, active component content, and batch consistency. Therefore, quality evaluation should include not only sensory indicators such as appearance, pileus size, color, integrity, degree of drying, impurity content, and mildew status, but also active component indicators such as polysaccharides, triterpenoids, and ganoderic acids. Polysaccharides and triterpenoids are widely recognized as the main active components of *G. lucidum* and have been adopted as important quality control indicators in pharmacopoeias and related standards (Wu et al., 2023; Yang et al., 2025). Therefore, facility-based production should establish a comprehensive evaluation system composed of appearance grade, physicochemical indicators, active components, and safety indicators.

Modern detection technologies provide an objective basis for grading *G. lucidum* products. HPLC-DAD can quantitatively detect multiple major ganoderic acids and related triterpenoids in fruiting body and spore extracts, accurately reflecting the level of active components in products and serving as an important tool for grading based on content levels and fingerprint similarity (Yeung et al., 2021). In addition, HPLC and HPLC-MS fingerprints combined with chemometric methods such as PCA, HCA, and PLS-DA can be used to distinguish *G. lucidum* samples from different origins, cultivation methods, and quality grades, and to identify key discriminant markers (Chen et al., 2008). This indicates that quality evaluation of *G. lucidum* products should shift from single-index testing toward a combined model integrating multiple markers, whole fingerprints, and comprehensive grading.