Industrial and regulatory standards are further promoting the standardization of the *G. lucidum* product quality evaluation system. Wu et al. (2024) noted that national and industry standards have incorporated indicators such as ganoderic acids, total triterpenoids, and spore powder wall-breaking rate into quality evaluation systems, and relevant standards are gradually covering product processing, circulation, and traceability. Meanwhile, related reviews emphasize that *G. lucidum* polysaccharides and triterpenoids have complex structures and obvious batch-to-batch variation, requiring multi-index and whole-fingerprint evaluation methods to control quality stability (Wu et al., 2023). Notably, a U.S. market survey showed that only about 26% of commercial *G. lucidum* dietary supplements matched the triterpenoid and polysaccharide contents declared on their labels, suggesting that quality consistency remains a major issue for *G. lucidum* products. Therefore, in facility-based production, quantitative testing, fingerprint analysis, appearance grading, and whole-process records should be combined to establish grading standards such as high-quality, qualified, and unqualified categories, in order to meet the different needs of medicinal use, health food production, and functional product development.

5.3 Safety risk control in *Ganoderma lucidum* production

Safety risk control is an important component of the quality management system in facility-based *G. lucidum* production, directly affecting product safety, consumer health, and sustainable industrial development. As *G. lucidum* is a medicinal and edible product, its production process requires high standards for raw material safety, cultivation environment cleanliness, and processing hygiene. During substrate selection, the sources of sawdust, cottonseed hulls, wheat bran, agricultural residues, and production water should be strictly controlled to avoid raw materials contaminated with heavy metals or pesticide residues. Studies have shown that some *G. lucidum* products have risks of excessive heavy metal contents. For example, among commercial Lingzhi products from China and Southeast Asia, approximately one-third of samples exceeded the allowable limit for arsenic, and more than half exceeded the allowable limit for cadmium (Wong et al., 2020). Another Beijing market survey found that some *G. lucidum* samples, mainly from wild sources, had excessive mercury levels, indicating that wild and cultivated sources may present different safety risks.

Although facility-based production can reduce some safety risks by controlling substrates, water sources, and production environments, regular testing and process supervision mechanisms are still necessary. Regional risk assessments based on ICP-MS have shown that the overall population risk from potentially toxic elements such as arsenic, cadmium, chromium, copper, mercury, nickel, and lead in *G. lucidum* is relatively low, but arsenic, chromium, and high-frequency consumers still require special attention. Pesticide residues are another important factor affecting the safety of *G. lucidum* products. A large-scale screening of Chinese herbal medicines showed that 29 pesticides were detected in 100 *G. lucidum* samples, with more than 90% of samples containing pesticide residues and 27.7% exceeding the maximum residue limits for foods, indicating that pesticide residue standards and supervision for Chinese herbal medicines still need to be strengthened (Chen et al., 2024). Broader studies on agricultural products have also shown that heavy metals and pesticides have bioaccumulative properties and potential health risks; therefore, preventive control measures should be adopted in medicinal fungal production chains (Alengebawy et al., 2021).

In addition to chemical contamination, microbial contamination and pests and diseases also affect the safety of *G. lucidum* production. Under high-temperature and high-humidity conditions, contaminants such as *Trichoderma* and *Penicillium* can proliferate rapidly. They not only inhibit normal *G. lucidum* growth, but may also produce harmful metabolites, thereby affecting product quality and safety. Therefore, facility-based production should strictly implement systems for raw material inspection, substrate sterilization, inoculation disinfection, clean cultivation environment management, and removal of contaminated bags, while minimizing the use of chemical agents to avoid residue risks. Overall, safety risk control in *G. lucidum* should comprehensively include the selection and regular testing of substrates and inputs, implementation of GAP/GMP requirements, batch testing for heavy metals and key pesticide residues, incorporation of safety testing results into traceability and quality grading records, and the establishment of a unified and standardized safety assurance system combining physical control, biological control, and environmental regulation (Wong et al., 2020; Chen et al., 2024; Wu et al., 2024).