

yield prediction, anomaly detection, process modeling, quality grading, and decision support, so as to continuously improve production efficiency, quality stability, and industrial sustainability.

7 Development Pathways for Facility-Based and Standardized *Ganoderma lucidum* Production

7.1 Construction of regionalized *Ganoderma lucidum* cultivation technology systems

China has a vast territory, and different regions vary significantly in climatic conditions, ecological environments, raw material resources, and industrial foundations. Therefore, facility-based production of *Ganoderma lucidum* cannot completely adopt a single unified model; instead, appropriate cultivation technology systems should be established according to regional characteristics. Relevant studies have pointed out that the standardization of the *G. lucidum* industry should cover the whole industrial chain, including pre-production planning, germplasm management, cultivation production, postharvest processing, circulation and sales, and quality traceability. At the same time, differences in resource conditions and ecological environments among regions should be fully considered to form regionally adaptive technical routes (Wu et al., 2024; Thakur et al., 2024). For example, in southern regions with high temperature and humidity, emphasis should be placed on cooling, ventilation, and disease control to reduce contamination by competing microorganisms and heat stress under humid conditions. In northern regions, winter heat preservation, air humidity regulation, and improvement of facility insulation should be strengthened to ensure the stability of mycelial growth and fruiting body formation.

The construction of regionalized cultivation technology systems should also be optimized according to local resource conditions and market positioning. Regions rich in wood resources may focus on sawdust-based bag cultivation, while regions with favorable under-forest resources may explore facility-based wild-simulated cultivation models to balance *G. lucidum* quality, ecological benefits, and market differentiation. International studies have also shown that the adaptation between local strains and local substrate resources is an important pathway for improving regional production efficiency. A Finnish study on laccate *Ganoderma* found that local wild strains could be successfully domesticated on regional wood by-products, among which *Populus tremula* and *Betula* substrates significantly improved fruiting probability, yield, and β -glucan content, whereas *Pinus sylvestris* was unsuitable for fruiting body production. Research from Pakistan showed that indigenous *G. lucidum* strains could be efficiently cultivated indoors using locally available lignocellulosic wastes, with a sawdust and wheat straw combination producing higher yields and more fruiting flushes while maintaining a mineral composition close to that of wild basidiomata (Ghafoor et al., 2024). These studies indicate that regionalized cultivation can promote the high-value utilization of local biomass resources while providing a localized basis for standardized facility-based production.

In addition, the construction of regionalized technology systems requires strengthened collaboration among research institutions, production enterprises, cultivation bases, and market participants. By conducting regional trials on strain screening, substrate formulation optimization, environmental parameter regulation, and pest and disease control, production parameters and technical protocols suitable for different regions can gradually be established. In some parts of China, permanent sand-bed greenhouse models have been promoted, in which plastic membranes are used to separate substrates from soil in order to reduce the risks of heavy metal and pesticide residues and support stable production that meets medicinal material quality requirements. At the international level, standards such as ISO 21315, *Traditional Chinese Medicine-Ganoderma lucidum* Fruiting Body, as well as relevant standards for cold storage, transportation, and quality evaluation, also provide a basis for embedding international standards into regionalized production systems (Wu et al., 2024). Therefore, regionalized *G. lucidum* cultivation technology systems should form synergy among local resource utilization, domestication of local strains, facility structure optimization, and alignment with standardized protocols, thereby promoting coordinated development of the *G. lucidum* industry.

7.2 Breeding and promotion of superior *Ganoderma lucidum* varieties

Superior varieties are the foundation for improving the yield, quality, and stress resistance of *G. lucidum*, and they are also the core component of facility-based standardized production. The genotype of *G. lucidum* strains directly