conditions (Al-Kaabi and Hussien, 2025). For example, Magday (2014) found that a wild Philippine strain of *G. lucidum* showed better mycelial growth at pH 6.0, 32°C, and under light conditions; Lengare et al. (2023) reported that vegetative growth performed well at 25°C, 95%-100% relative humidity, and a 12 h light/12 h dark cycle. Therefore, facility-based *G. lucidum* cultivation is not merely the control of a single environmental parameter, but requires integrated regulation according to different growth stages.

During fruiting body formation, *G. lucidum* has stricter requirements for air humidity, light, and ventilation. Appropriate humidity promotes primordium formation and pileus expansion, whereas insufficient ventilation may lead to elevated CO_2 concentration in the facility, resulting in elongated stipes, poor pileus development, or abnormal morphology. A Korean bed-cultivation study showed that 28°C~30°C, light intensity of 1 000~1 500 lux, and approximately 1% CO_2 were suitable for fruiting body formation. Recent studies on light quality regulation further indicate that green light can promote stipe elongation, pileus expansion, fresh weight increase, and the contents of crude protein, polysaccharides, triterpenoids, and extracellular enzyme activity, whereas red light may inhibit fruiting body differentiation. Therefore, spectral selection and lighting regime design should be emphasized in factory cultivation (Liu et al., 2024). This suggests that light not only affects the appearance quality of *G. lucidum*, but is also closely related to the accumulation of active components.

In addition to physical environmental factors, substrate chemical properties and facility cleanliness are also important factors affecting stable *G. lucidum* production. Continuous cultivation can alter organic matter, pH, salinity, and enzyme activities in soil or substrates, leading to changes in the metabolite composition of fruiting bodies (Wang et al., 2022). Meanwhile, competitive fungi such as *Trichoderma* can proliferate readily in *G. lucidum* cultivation environments and inhibit *G. lucidum* growth through volatile and non-volatile metabolites, causing contamination and yield loss (Lim et al., 2024). Therefore, facility-based *G. lucidum* production should integrate temperature and humidity regulation, light management, CO_2 control, pH and salinity adjustment, substrate disinfection, and spatial sanitation management to establish a stable and reproducible environmental control system.

2.2 Main models of facility-based *Ganoderma lucidum* cultivation

With the development of modern agricultural facility technologies, *G. lucidum* production has gradually shifted from traditional open-field cultivation and simple greenhouse cultivation toward facility-based, controllable, and standardized models. At present, greenhouses and indoor mushroom houses are common solid-state cultivation models for fruiting body production. They usually use sawdust, agricultural residues, or logs as substrates, and are equipped with functional areas such as inoculation rooms, incubation rooms, sterilization rooms, fruiting rooms, packaging rooms, and waste disposal areas (Thakur et al., 2024; Akçay et al., 2025). Standardized bed cultivation generally uses formulated sawdust-based substrates and promotes fruiting body formation under controlled temperature, light, and CO_2 conditions. Compared with traditional open-field cultivation, greenhouse and mushroom-house cultivation can reduce the influence of external climate fluctuations and improve production stability and year-round supply capacity.

In solid-state facility cultivation, bag cultivation and multi-layer rack cultivation are important forms of current large-scale production. Bag cultivation uses lignocellulosic wastes such as sawdust, rice straw, wheat straw, and hazelnut shells as main raw materials. By optimizing substrate formulations, it can shorten mycelial colonization time and improve yield and the number of fruiting flushes (Akçay et al., 2025). Multi-layer rack cultivation improves space utilization by vertically arranging cultivation bags, facilitating unified sterilization, inoculation, incubation, and fruiting management. Some regions have also developed permanent greenhouse sand-bed cultivation models, in which cultivation substrates are separated from soil using plastic membranes and combined with sprinkler and shading systems. This can reduce the risks of heavy metals, pesticide residues, and competitive microbial contamination, and increase yield by approximately 30% compared with traditional open-field methods. This type of model combines environmental controllability with quality and safety advantages, making it suitable for standardized medicinal *G. lucidum* production.