mycelial growth, stronger spore-producing ability, higher biological efficiency, and better production characteristics, further indicating that regional germplasm evaluation remains an important complement to mutation breeding.

2.3 Optimization of culture medium and nutritional regulation technologies

After elite strains are obtained, efficient spore production depends on matching genotype with suitable carbon sources, nitrogen balance, substrate structure, pH, temperature, illumination, aeration, and spawn materials, because *Ganoderma* species have specific physiological requirements and growth performance varies sharply with medium composition and environmental control (Ahmad et al., 2024). Experimental optimization studies show that mycelial growth can be markedly improved under defined conditions. For example, one study found that coconut water gelatin at pH 6.0, under sealed and lighted conditions at 32 ℃, gave the most efficient mycelial growth, while corn grit was the most suitable grain spawn and a substrate of 70% rice straw and 30% sawdust produced the shortest fructification period of 17.33 days. These results support the view that low-cost agricultural residues can be effectively converted into production substrates, and that rational control of physical and nutritional parameters is a prerequisite for industrial cultivation (Akçay et al., 2025).

Nutritional regulation also affects not only biomass and fructification, but the accumulation of target active components relevant to spore powder quality. In submerged culture, sucrose favored mycelial growth, corn flour supplementation promoted biomass with an optimum around 7.0~7.5 g/L, and an optimized natural medium containing potato extract, sucrose, and corn flour achieved a mycelial yield of 7.51 g/L together with higher triterpenoid and intracellular polysaccharide contents than a nutrient-rich comparison medium (Zheng et al., 2026). Substrate composition likewise alters yield and chemical quality: coconut sawdust and other lignocellulosic substrates can improve biological efficiency, while supplements such as olive oil and copper enhance triterpenoid and phenolic contents (Zhu, 2024). Waste-based substrate screening further showed strong substrate dependence, with oak wood 91%+wheat bran 9% giving the highest mushroom yield at 46 g/kg, whereas corn husk gave the lowest, demonstrating that lignocellulosic composition and bran supplementation materially influence production performance (Akçay et al., 2025). At the level of developmental physiology, active component accumulation is stage-dependent: triterpenoids, steroids, and polyphenols peak in the budding stage, whereas polysaccharides, flavonoids, and purines are higher in the maturation stage of basidiospores, indicating that nutritional regulation and harvest timing should be coordinated to balance yield with the desired chemical profile (Gao et al., 2024). Together, these findings show that an efficient production system for *G. lucidum* spore powder must integrate superior strains, substrate engineering, and stage-specific nutritional regulation to achieve high yield, stable sporulation, and consistent quality (Ren et al., 2025).

3 Key Technologies for Ganoderma Spore Powder

3.1 Precise regulation technologies of cultivation environmental conditions

The efficient production of *G. lucidum* spore powder depends first on stage-specific control of the cultivation environment, because mycelial growth, primordium initiation, fruiting body development, and spore release do not share the same optimal requirements (Zhou, 2017). Studies of solid cultivation report that *G. lucidum* generally performs well at 18~25 ℃ and 85~90% humidity during growth, while fruiting body development is favored around 24~28 ℃ and high humidity, and temperatures below 20 ℃ can cause yellowing and growth arrest (Chanshorphea, 2019). Under subtropical bag cultivation, exposure of spawn bags to (30±1) ℃ and 90~95% RH supported primordium initiation and completion of the crop cycle, showing that local production systems can shift the operating window upward when substrates and strains are adapted to those conditions. Medium-level physiological studies likewise found strong environmental sensitivity: mycelial growth was most efficient on a pH 6.0 medium under sealed, lighted conditions at 32 ℃, and a separate comparative study identified 30 ℃ as the best temperature, pH 6 as optimal, and darkness or alternating light as more favorable than continuous light for vegetative growth (Al-Kaabi and Hussien, 2025).

Environmental regulation must therefore be precise rather than uniform, especially for light, air exchange, and contamination control. Controlled-room experiments showed that light quality materially changes morphology