sterilization, in which high temperature is used to kill contaminating spores and harmful microorganisms in the substrate. Some processes also involve disinfection after pre-fermentation to improve substrate stability and reduce contamination risk (Roy et al., 2015). During sterilization, temperature, pressure, and time should be strictly controlled to ensure complete sterilization both inside and outside the substrate. If sterilization is insufficient, contaminants such as *Trichoderma* and *Penicillium* may rapidly proliferate during spawn run; if sterilization is excessive, the nutritional structure of the substrate may be damaged, affecting *G. lucidum* mycelial activity. Therefore, establishing standardized sterilization parameters and batch recording systems is an important guarantee for stable production.

Inoculation management should be carried out under aseptic or clean conditions to reduce contamination by external microorganisms. The inoculation room should be disinfected with ultraviolet light in advance, air purification should be performed, and the workbench should be cleaned. Operators should wear clean work clothes and strictly follow sanitation protocols. During inoculation, mycelial blocks or grain spawn can be inserted into the central hole or multiple inoculation points of the cultivation bag, followed by sealing and incubation. The spawn medium itself also needs to be optimized. For example, wheat grain or corn grain spawn can support faster colonization and stronger mycelial growth, providing vigorous inoculum for production bags. After inoculation, cultivation bags should be transferred to the incubation room and cultivated under dark or low-light conditions, at approximately 25℃~30℃, relatively high humidity, and suitable $CO_2$ levels until the mycelia fully colonize the substrate (Roy et al., 2015). During spawn run, contamination, water accumulation, mycelial degeneration, and uneven growth should be checked regularly, and abnormal bags should be removed or treated in time to ensure batch production stability.

### 4.3 Fruiting management, harvesting, and processing standards of *Ganoderma lucidum*

The fruiting stage of *G. lucidum* is a critical period determining fruiting body quality, yield, and commercial consistency. After the mycelia fully colonize the cultivation bags, primordium formation should be induced through bag opening, humidity enhancement, ventilation, appropriate light, and necessary physiological stimulation. Studies have shown that, in some boreal strains, cold stimulation at 5℃ can improve primordium formation and fruiting probability in indoor systems, especially for *G. lucidum* cultivation on *Populus tremula* and *Betula* substrates (Table 1) (Cortina-Escribano et al., 2020).

Table 1 Effect of the factors strain, wood and treatment on the yield of *G. lucidum* (Adopted from Cortina-Escribano et al., 2020)

| Source | Numerator df | Denominator df | F | *p*-Value |
|---|---|---|---|---|
| Intercept | 1 | 69 | 308.99 | <0.001 |
| Strain | 5 | 69 | 3.40 | 0.008 |
| Wood | 4 | 69 | 9.71 | <0.001 |
| Treatment | 1 | 69 | 0.48 | 0.492 |
| Strain * Wood | 14 | 69 | 1.12 | 0.361 |
| Wood* Treatment | 1 | 69 | 0.15 | 0.697 |

Table caption: The interaction between variables is shown with an asterisk between variables names (Adopted from Cortina-Escribano et al., 2020)

In general bag cultivation, the fruiting stage requires 25℃~32℃, 85%~95% relative humidity, moderate light, and good aeration to support fruiting body formation and pileus expansion (Roy et al., 2015). In seasonal mushroom-house cultivation, approximately (30±1)℃, high $CO_2$, and 90% relative humidity can be maintained during spawn run and primordium formation; during fruiting, $CO_2$ should be reduced and temperature and humidity adjusted to promote normal fruiting body development. This indicates that fruiting management should be regulated stage by stage according to strain, substrate, facility type, and product goals.