

raw-material supply, scalable seedling propagation, expansion of cultivation areas, and the formation of complete industrial chains from cultivation to processing and health-product manufacture (Figure 2) (Cheng et al., 2019). It also offers practical residue-control advantages when managed well: one standardized comparison found no organophosphorus pesticide residues in growth-chamber cultivation, whereas residues were detected in bedstead production. These features make facility cultivation especially important for supplying medicinal, food, and health-product markets that require stable volume, traceability, and manageable production schedules.

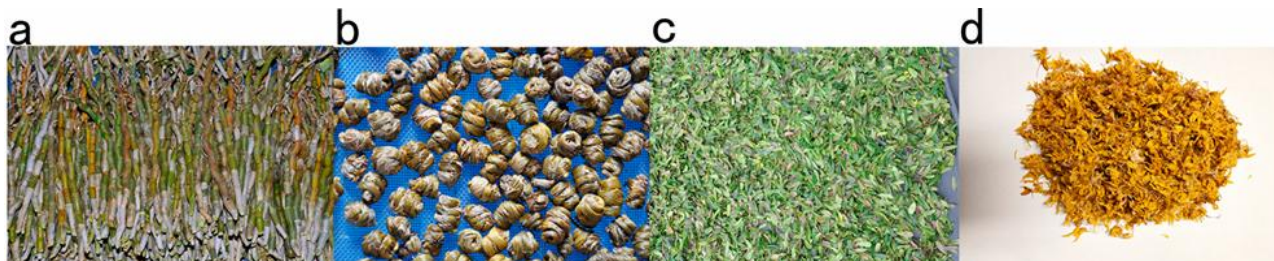


Figure 2 The usable parts and forms of *Dendrobium officinale* (Adopted from Cheng et al., 2019)

Image caption: (a) Stems; (b) Tiepi Fengdou; (c) Leaves; (d) Dry flowers (Adopted from Cheng et al., 2019)

Its challenges are equally clear. Evidence across comparative studies shows that artificial-sheltered or greenhouse cultivation can alter phenotype, metabolite composition, and sometimes medicinal efficacy relative to more natural cultivation environments, so higher controllability does not automatically mean higher medicinal quality (Jia et al., 2022; Yi et al., 2026). The industry also faces germplasm mixing, uneven quality and yield, incomplete national standards, and a still-low level of deep product development (Cheng et al., 2019). In addition, some comparative evidence suggests that greenhouse-grown material can be inferior to stone-epiphytic material for broad metabolite richness and some functional outcomes, even though greenhouse samples may equal or exceed other modes for specific indicators such as polysaccharides (Yang et al., 2023; Hou et al., 2025). Even with these limitations, facility cultivation has strong industrial prospects because *D. officinale* is now embedded in the expanding food-medicine homology sector, provincial standards for leaves and flowers are emerging, ISO-related standardization is advancing, and the genus already has broad economic value in medicinal, food, ornamental, and cosmetic applications. Overall, facility cultivation is best positioned as the scale and standardization platform of the *D. officinale* industry, while future progress depends on better varieties, tighter standards, lower chemical inputs, and more precise quality-oriented environmental regulation.

5 Comprehensive Comparison of Wild-Simulated and Facility Cultivation Modes

5.1 Differences in ecological environment and production management between the two modes

Wild-simulated cultivation and facility cultivation differ first in their basic ecological logic. Wild-simulated cultivation aims to restore the original habitat and site conditions of *Dendrobium officinale* as much as possible, typically through stone or tree epiphytic planting in forested or mountainous settings with more natural light, airflow, microbial communities, and environmental fluctuation (Zhang et al., 2020; Lan et al., 2022). Facility cultivation instead relies on greenhouse or other sheltered systems that create a controllable microenvironment through artificial shade, irrigation, ventilation, and substrate management. This ecological contrast matters because the main medicinal components of *D. officinale* are tightly linked to growing conditions, including relative humidity, maximum temperature, sunshine duration, soil pH, and substrate nitrogen and phosphorus status (Wang et al., 2025). Recent predictive work also suggests that greenhouse cultivation changes the environmental drivers of polysaccharide accumulation, shifting key influences from rainfall and temperature toward altitude and sunlight and moving high-quality production zones away from the pattern seen in wild habitats (Yang et al., 2026).

The two modes also differ substantially in production management. Wild-simulated systems usually emphasize ecological base selection, breathable epiphytic substrates, moderate shade, lower planting density, and the preservation of symbioses with endophytic or mycorrhizal fungi, because fungal interactions contribute to growth, stress resistance, and quality stability (Zhang et al., 2024; Liu et al., 2025b). Facility cultivation emphasizes