Large-scale production is further limited because suitable production parameters are not yet unified across provenance, habitat, and cultivation mode. Environmental studies show that metabolite accumulation changes markedly with temperature, humidity, precipitation, and season, indicating that large-scale cultivation cannot rely on a single fixed technical package across all producing areas (Shi et al., 2022). Under-forest planting under Moso bamboo can increase biomass when supported by biochar-based organic fertilizer, but this effect depends on changes in soil physicochemical properties and microbial communities, again showing that management standards must be ecologically specific. Even where more productive systems have been identified, they do not always align with the under-forest model: greenhouse cultivation combined with stereoscopic planting improved both yield and quality and outperformed understory planting in some comparisons, which suggests that under-forest cultivation still lacks a consistently validated standard model for industrial scaling (Hu et al., 2023). In practice, this means current under-forest development often remains fragmented, with uneven technical levels, weak nursery standardization, and limited capacity to build certified large-scale production bases despite policy interest in the under-forest economy (Zhang et al., 2020).

6.3 Insufficient product development, brand building, and industrial chain extension

Product development and deep processing still lag behind the resource base and pharmacological potential of *T. hemsleyanum*. Around 150 compounds have been isolated from the species, and the plant shows broad anti-inflammatory, anti-tumor, antioxidant, immunoregulatory, and related bioactivities, yet reviews explicitly argue that new clinical uses and more comprehensive utilization still need to be developed (Hu et al., 2021). The same reviews note backward processing methods, storage difficulties, and imperfect detection methods, all of which directly limit industrial upgrading (Ji et al., 2021). Mechanistic quality research also shows that the active material basis is still not fully clear and that the industry lacks a scientific, universal, and measurable quality-control system, making it difficult to support stable high-end products in market circulation (Xia et al., 2023). Although roots are already marketed as functional foods and their price varies by origin, this market differentiation is not yet equivalent to mature brand construction, because origin-linked metabolic profiles and bioactivity markers still need further clarification for credible product grading and certification (Chu et al., 2024).

Industrial chain extension is also insufficient because the species' aboveground resources, polysaccharides, and origin-authentication tools have not yet been fully converted into a coordinated local specialty industry. Leaves and fibrous roots contain many distinctive metabolites and have been proposed as potential new medicinal parts, but current commercialization remains far more root-centered than evidence would justify. Polysaccharides show broad potential in food, medicine, and cosmetics, and new aboveground pectic polysaccharides with immune-enhancing activity have already been characterized, but this remains an emerging development direction rather than a mature downstream sector (Tian et al., 2025). Brand building is further weakened by market-order problems: simulated-wild and greenhouse products differ measurably in isotopes, yet mislabeling of conventional products as higher-priced wild or simulated-wild material can occur for profit, showing that brand premiums are not secure without robust traceability systems (Wang et al., 2026). More broadly, even the genetic resource base is still incomplete, because the previous lack of mitochondrial-genome information was considered a limitation on breeding, conservation, and development, which underscores that industrial chain extension still depends on stronger upstream scientific infrastructure as well as downstream branding and processing (Han et al., 2026).

7 Optimization Pathways for Local Resource Development and Under-Forest Industrial Development of *Tetrastigma hemsleyanum*

7.1 Establishment of a system for local germplasm conservation and elite germplasm utilization

Establish an integrated system that combines in situ conservation, ex situ preservation, elite germplasm identification, and rapid propagation. *Tetrastigma hemsleyanum* remains under strong resource pressure because wild populations are scarce, growth is slow, and the species usually requires 3-5 years to reach commercial medicinal standards. This pressure is intensified by persistent market demand and overharvesting, and the species has already been listed among preferentially protected crop germplasm resources in Zhejiang Province (Hu et al.,