

Functional evidence supports this direction: leaf phenolics were metabolized into bioavailable forms during digestion and fermentation, and leaf supplementation ameliorated DSS-induced colitis by improving tight-junction proteins, suppressing pro-inflammatory cytokines, activating Nrf2-related antioxidant defenses, and reshaping gut microbiota and short-chain fatty acids (Wu et al., 2021). Aboveground polysaccharides are also promising, since a novel pectic polysaccharide extracted from the aboveground part showed macrophage immune-enhancing activity and may contain a core active domain suitable for immune-regulatory product development (Tian et al., 2025).

5.2 Development of characteristic products and deep processing

The next step is to convert local raw materials into characteristic products through standardized extraction, processing, and value-added development. *T. hemsleyanum* already has both medicinal value and potential for food-related development, and its roots are widely used as functional tea, dietary supplements, and health-related food materials (Sun et al., 2021; Shu et al., 2023). Its chemical basis for product development is broad, with about 142~150 identified compounds, especially flavonoids and polysaccharides, and these components show antioxidant, anti-inflammatory, anti-tumor, immunoregulatory, antipyretic, and hepatoprotective activities (Hu et al., 2021; Ding et al., 2025). This supports development not only of traditional decoction pieces and health teas, but also of antioxidant extracts, immune-enhancing polysaccharide products, liver-protective preparations, and food, medicine, and cosmetic derivatives (Tian et al., 2025; Xu et al., 2026). At the same time, reviews note that backward processing methods, storage difficulties, and limited quality standards still constrain industrial upgrading, so deep processing must be coupled with stronger process control.

Several studies show that processing and extraction conditions materially change product quality, which makes post-harvest standardization central to deep processing. Extraction optimization increased the total yield of five key flavonoids to 788.12 mg/kg under optimized ethanol-ultrasound conditions, and the resulting extract showed strong DPPH scavenging activity (Shu et al., 2023). Extraction method matters more broadly: ethanol extracts showed better antioxidant and antiproliferative activity than water extracts, while bioactivity of water extracts declined as extraction temperature increased. Processing method also changes efficacy. Different drying methods caused large shifts in ten major constituents, especially rutin, proanthocyanidin B1, and catechin, and among three processed products, the freeze-dried extract preserved bioactive constituents best and showed the strongest hepatoprotective effect (Xu et al., 2026). For polysaccharide products, both extraction technology and structure-function analysis are advancing quickly: multiple extraction and purification methods have been developed, and a glucan isolated after optimized ultrasound-assisted extraction showed significant antipyretic activity through suppression of TNF- α , IL-1 β , cAMP, and PGE2 (Ding et al., 2025). Biotechnological deep processing is another reserve pathway, because hairy roots can be induced at high efficiency and in some cases contain higher levels of several flavonoids and stronger antioxidant activity than 3-year true roots, suggesting a feasible alternative source of raw material for high-value extracts.

5.3 Local brand building and development of regional characteristic industries

Local brand building should rely on the joint logic of origin, quality, and regional identity. *T. hemsleyanum* is already embedded in Zhejiang's regional medicinal identity: it is regarded as one of the new eight Genuine Medicinal Materials of Zhejiang and as the new "Zhebawei," and it has been included in the medical insurance system of Zhejiang and other provinces (Bai et al., 2022). Product markets already distinguish by producing area, and root price varies with origin, which means local branding can build directly on demonstrated geographical quality differentiation (Chu et al., 2024). That differentiation is scientifically supportable: metabolomics across 254 samples from eight areas identified 49 potential chemical markers, including catechin and darendoside B as antioxidant-related quality markers, while origin studies across southern sites showed differences in quercetin and kaempferol and provided technical support for quality evaluation from different origins (Li et al., 2023). A strong local brand therefore needs provenance-linked quality standards, origin authentication, and differentiated product positioning rather than generic bulk sales.

Regional characteristic industry development also depends on organization and governance, not just on resource endowment. Research on medicinal-plant bioeconomies shows that geographical indication labeling can support