optimized extraction and analytical methods remain necessary for key actives: ultrasonic-assisted extraction and HPLC quantification have already been optimized for steroidal saponins in P. kingianum, providing a practical reference for processing-linked quality control across production areas (He et al., 2022).

5.3 Enhancing industrial chain coordination and market competitiveness

The third key issue is that *Polygonatum* still faces weak industrial-chain coordination and insufficient market competitiveness, a pattern that matches the broader medicinal-plant sector. Medicinal-plant value chains are often long, weakly integrated, and poorly coordinated across producers, collectors, processors, and traders, with little vertical integration and limited horizontal collaboration (Chandra and Kumar, 2021). Comparable value-chain studies identify recurrent bottlenecks at farm, trader, and consumer stages, including low prices, weak demand, poor post-harvest technology, limited finance, inadequate training, and weak communication among chain actors (Palash et al., 2021; Geyo, 2024). Market studies also show that MAP sectors increasingly compete against lower-cost imports and need more innovation, actor agreements, and digital upgrading to remain competitive (Spina et al., 2023; Lestari et al., 2026).

The main optimization strategy is to build an integrated *Polygonatum* chain around producer organization, processing, branding, certification, and market networks. Cross-sector MAP research identifies market development, certification and labelling, and transformation and processing as core strategic priorities, while experts consistently rank new product design, producer-consumer networks, geographic branding, and proper raw-material storage and processing as high-value actions. Certification schemes that document origin, product quality, organic or forest-management compliance, and sustainable harvesting are particularly important because consumers weigh geographical origin, tradition, and the people behind the product in purchase decisions (Taghouti et al., 2022). Participation in broader value chains can improve product quality, market access, and innovation, but it requires technological upgrading, stronger partnerships, managerial training, and institutional support (Palash et al., 2021; Lestari et al., 2026). For *Polygonatum*, this implies a coordinated model led by enterprises, cooperatives, and producing areas that links understory cultivation bases with standardized processing, differentiated medicinal-food products, traceable regional brands, digital marketing, and farmer-oriented benefit-sharing mechanisms.

6 Development Trends and Prospects

6.1 Transition from resource utilization to high-value product development

The future direction of *Polygonatum* development is a clear shift from primary resource utilization toward high-value product development based on bioactive compounds, processing science, and diversified end uses. Current reviews consistently identify *Polygonatum* as a medicinal-and-edible genus with substantial market utilization value, especially because its polysaccharides are major active components with antioxidant, immunoregulatory, anti-inflammatory, anti-osteoporotic, and antidiabetic functions (Yang et al., 2025; Zhao et al., 2026). Research attention has already moved beyond traditional crude use toward extraction, structural characterization, and food-oriented application of functional ingredients, with specific emphasis on functional foods, pharmaceuticals, cosmetics, and bio-based materials (Li et al., 2023). This trend is especially strong for *Polygonatum* polysaccharides, which have entered the food system as beverages, health foods, additives, and packaging-related materials, indicating that *Polygonatum* is moving from raw medicinal material supply toward ingredient innovation and deep processing.

The main prospect is not only more products, but better differentiated products through processing control, species selection, and quality-oriented functional design. Processing methods such as nine steaming and nine drying, wine processing, and honey processing alter polysaccharide structure and bioactivity, so future competitiveness will depend on targeted process optimization rather than simple primary processing (Zhao et al., 2026). Product upgrading can also come from fermentation and flavor engineering: in *P. cyrtonema* beverage development, Lactiplantibacillus plantarum fermentation increased free amino acids, polyphenols, and flavonoids,