

Quality control of rhizome sources should combine morphological authentication with chemical consistency assessment. Rhizomes of *P. sibiricum* show recognizable type differences, and comparative evaluation of Polygonati rhizoma has shown that different rhizome forms have different comprehensive quality, with BJPR and JTPR performing better in nutritional and medicinal evaluation (Hu et al., 2022). At the same time, cultivated *P. sibiricum* can provide a stable supply, but its phytochemical profile is not identical to that of wild material, with 33 phytochemicals differing significantly between cultivated and wild-grown rhizomes (Pan et al., 2022). Even so, artificially cultivated rhizomes with multiple buds show an overall phytochemical profile comparable to wild types and contain important therapeutic compounds, supporting their use as propagation sources when identity and quality are verified (Cheng et al., 2023). For source control, rapid screening tools such as near-infrared spectroscopy combined with chemometrics are also valuable because they provide efficient assessment of polysaccharide and saponin levels and are considered useful for preliminary quality evaluation and raw-material grading (Liao et al., 2023).

4.2 Determination of growth duration and harvest maturity of rhizomes

The determination of rhizome harvest timing should be based on the coordinated evaluation of cultivation age and seasonal stage, because both factors directly affect the accumulation of functional components. Evidence from long-term research on Polygonatum rhizomes shows that quality-related metabolites increase significantly during early-to-middle growth years and then decline after peak accumulation; in a five-year growth cycle, functional components increased from years one to four and decreased from years four to five, with the most active accumulation occurring between years three and four. The four-year-old rhizomes showed the most superior overall quality because they contained higher levels of functional components and more newly formed metabolites (Pu et al., 2024). Although these data come from *P. cyrtoneura*, they provide a strong reference for *P. sibiricum* harvest-standard setting within Polygonatum, indicating that harvest maturity should not be judged solely by rhizome size, but by the balance between biomass formation and metabolite accumulation.

Season also changes rhizome quality, so harvest maturity standards should distinguish between spring and autumn products rather than treating them as equivalent. Comparative seasonal analysis showed that rhizomes harvested in spring and autumn had unequal quality because of significant differences in functional composition; spring rhizomes contained more flavonoids, alkaloids, and phenolic acids, whereas autumn rhizomes contained more steroids (Pu et al., 2024). For *P. sibiricum*, maturity standards should also recognize that young rhizomes are not devoid of value, since their polysaccharide extraction rate reached $(33.88 \pm 1.95)\%$, compared with $(45.08 \pm 1.92)\%$ in mature rhizomes, and their polysaccharide structure and biological activity were broadly similar to those of mature rhizomes. This means mature rhizomes remain the main target for medicinal harvesting, but younger rhizome fractions can still be classified for propagation or comprehensive utilization rather than discarded as waste.

4.3 Grading indicators and commercialization standard system for rhizomes

A commercialization standard system for *P. sibiricum* rhizomes should integrate morphological, agronomic, and chemical indicators into a graded evaluation framework. Morphological indicators should include rhizome type, fullness, segmentation regularity, bud number, diameter, and visible health status, because Polygonatum rhizomes vary significantly in shape and quality type, and some forms have better comprehensive quality than others (Hu et al., 2022). Agronomic indicators should include unit yield potential and plant vigor, with stem diameter retained as a practical proxy indicator because of its positive correlation with yield (Liao et al., 2023). Chemical indicators should center on polysaccharides as a recognized quality-evaluation index, while also incorporating saponins and flavonoids as candidate quality markers for Polygonatum rhizomes. This combined approach is more suitable than relying on a single index, because metabolite composition changes across years and seasons and cannot be fully represented by polysaccharide content alone (Pu et al., 2024).

In commercial practice, rhizomes can be divided into at least three grades. First-grade rhizomes should come from authenticated, well-adapted, disease-free mother stocks and have uniform morphology, strong fullness, intact buds, and high polysaccharide and saponin levels (Shi et al., 2024). Second-grade rhizomes may show moderate