processing cycles induce drastic changes in functional component accumulation, while subsequent cycles yield diminishing returns, suggesting that four to six cycles may provide a favorable balance under the processing conditions investigated between enhanced medicinal effects and preserved bioactive components. Establishing a commercial grade classification system that integrates these processing-induced chemical variations with morphological and chromatic criteria is essential for standardizing *Polygonatum* commodity quality and ensuring consistent industrial efficacy (Bi et al., 2025).

5 Analysis of Existing Commercial Specifications and Grading Criteria for *Polygonatum*

5.1 Traditional methods for commercial specification classification

Traditional commercial classification relies primarily on morphological characteristics and geographical origin. As a related methodological example, *Polygonatum odoratum* (PO; Yuzhu), which is a distinct medicinal commodity rather than one of the three official botanical sources of Polygonati Rhizoma (Huangjing), is divided into two main commercial specifications: Xiangyuzhu (XPO) and Guanyuzhu (GPO), which are distinguished by their appearance, origin, and price. According to the "Standard compilation of authentic medicinal materials," XPO is characterized by a thick, long, translucent, and light yellow appearance, with products from Hunan considered authentic and occupying the majority of the Chinese market. GPO, in contrast, is a wild product from Northeast China, Inner Mongolia, and Hebei, and its cost is lower than that of XPO. These traditional specifications also dictate end-use applications; XPO is more frequently used as the raw material for dietary supplements, while GPO is more inclined toward medicinal use (Nan et al., 2023).

Beyond the *P. odoratum* market, *Polygonatum* species used for Huangjing (*P. sibiricum*, *P. kingianum*, and *P. cyrtonema*) exhibit extensive morphological diversity that historically guided classification. However, these morphological characteristics are seasonal, rendering it difficult for taxonomists to identify plants in the wild and complicating consistent commercial sorting. To evaluate germplasm resources systematically, agronomic traits such as stem length, stem diameter, leaf dimensions, and inflorescence characteristics are measured as direct representations of plant growth and quality. Among these traits, stem diameter has been identified as a practical indicator for variety screening and harvest assessment, providing a morphological marker that correlates with yield (Liao et al., 2023).

5.2 Differences in grading standards among production areas and markets

Grading standards and quality traits differ significantly among *Polygonatum* production areas, reflecting both genetic and environmental influences. A common garden experiment cultivating five *Polygonatum* species revealed that the plants mainly differed in yield, saponin and polysaccharide contents, stem diameter, leaf width, and inflorescence length. *P. cyrtonema* (PC) demonstrated high-quality yield when planted in Zhejiang, with output reaching 7.5 tons per hectare, making it particularly suitable for cultivation in Zhejiang and similar surrounding areas. Further analysis of 43 PC provenances from six geographical provinces showed that the specific relationship pattern between PC quality and its provenance was unclear, with most components not significantly correlating with longitude, latitude, or altitude. This suggests that short-term changes in the growth environment do not override long-term genetic variations acquired from original adaptive environments (Liao et al., 2023).

Market grading also reflects chemical composition differences that vary by species and region. In the *P. odoratum* market, current quality control focuses solely on polysaccharide content, yet studies indicate that the polysaccharide content of GPO is actually higher than that of XPO. A comprehensive qualitative analysis identified 62 compounds in PO, from which 13 robust chemical markers-including 6 flavonoids and 7 steroidal saponins-were screened to differentiate the two commercial specifications. The ratio of timosaponin H1 to polygodoraside G was proposed as a promising indicator to distinguish the specifications, with samples having a ratio<2 considered XPO and>5 considered GPO (Nan et al., 2023). For Huangjing species, saponin content varied significantly, with *P. kingianum* reaching 10.54%, significantly higher than PC, PS, and PF, while polysaccharide content ranged from 25.30% to 6.24% across species (Liao et al., 2023).