processing, with molecular weight gradually decreasing and neutral sugars converting into uronic acids, while saponins partially degrade into sapogenins or undergo modification. Processing with black bean juice significantly alters chemical fingerprints, increasing lower-polarity compounds and generating six new compounds while degrading medium-polarity constituents. In the cited *P. cyrtonema* experiment, black-bean-juice processing increased measured polysaccharide and saponin contents and enhanced in vitro antioxidant and antidiabetic activities (Zhang et al., 2023). These mechanistic insights provide a scientific basis for establishing standardized processing protocols that balance detoxification with bioactive retention.

Improving the commercial grade classification system requires moving beyond traditional appearance-based grading to integrate multidimensional quality indicators. Traditional Chinese medicine quality control faces challenges lacking multidimensionality and reliable quantitative evidence, and comprehensive evaluation models based on external characteristics and multiple indicator metabolites represent the future research direction. Color quantization based on the CIE L*a*b* system provides objective metrics for tracking processing levels, with parameters h, L, and ΔE demonstrating significant differentiation ability across *Polygonatum sibiricum* samples. The inner transverse section of processed rhizomes gradually turns moist black with specular luster, consistent with the traditional identification standard of "brightness like oil and color like black lacquer," providing a reliable visual marker for processing records. Microscopic characterization of calcium oxalate needle crystals offers an additional traceability marker, as the change rate of needle crystal morphology increases with processing level and exceeds 90% by the fifth cycle. High correlations between color parameters and needle-like crystals confirm the potential applicability of macroscopic and microscopic features for classifying samples from different processing levels. Advanced identification methods are essential for standardizing *Polygonatum* products and preventing adulteration with morphologically similar congeneric species. A multidimensional approach integrating phenological, morphological, anatomical, and molecular characteristics has been developed to distinguish eight *Polygonatum* species, addressing the limitations of single-method identification. Significant interspecific differences were observed in phenological and morphological traits, with coefficients of variation reaching 135.92% for floret number and 117.82% for fruit number (Sun et al., 2025). Molecularly, optimized SCoT-PCR identified 12 polymorphic primers showing 96.56% polymorphism in the studied *Polygonatum* species (Sun et al., 2025), providing a robust basis for species identification and classification. These integrated approaches support botanical species identification; their value for chemical-quality grading requires independent validation.

Coordinating primary processing with industrial standards demands accelerating the selection of improved varieties, ensuring high-quality seedling supply, and eliminating unauthentic species to stabilize the raw material basis. The *Polygonatum* industry currently faces resource depletion, low-tech cultivation, and unclear functional composition, all of which undermine consistent industrial standardization. Strengthening the conservation and rational use of wild resources, alongside breakthroughs in high-quality artificial cultivation technologies for light regulation, site control, density control, and precision harvesting, are essential measures for sustainable development. Future market growth depends on technological innovation, cultural creativity, integration of three industries, brand strategy, and internet-based techniques that integrate processing standards with commercial grading. Despite promising pharmacological properties, underlying mechanisms remain insufficiently elucidated, and clinical evidence supporting therapeutic efficacy is still lacking, necessitating further research to clarify links between chemical constituents and pharmacological activities. Achieving industrial scale requires transitioning laboratory-scale extraction and purification technologies to green, efficient methods suitable for large-scale production. Most current methods for separating dietary polysaccharides from *Polygonatum sibiricum* are suitable only for small-scale laboratory processing and cannot meet the requirements of large-scale production. There is an urgent need for safe, harmless methods of purifying polysaccharides in green and environmentally friendly food industry production to meet consumer demand. Extraction methodologies for flavonoids remain at the laboratory stage with relatively low yields, and no definitive conclusions have been reached regarding optimal parameters for their application. Future investigations should focus on optimizing these methods and developing green, highly efficient extraction technology applicable on an industrial production scale. Exploring the potential applications of *Polygonatum* in functional foods and pharmaceutical formulations is recommended to advance the development