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Advances in Wine Processing Technique of Polygonati Rhizoma and Associated Changes in Chemical Components and Pharmacological Efficacy Before and After Processing

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Abstract This paper provides a systematic review of optimization methods applied to the wine processing technique of Polygonati Rhizoma, and analyzes the transformation patterns of chemical components during processing from the perspective of polysaccharides, saponins, flavonoids, and Maillard reaction products. Furthermore, it elucidates the scientific connotation for the efficacy enhancement of wine processing by examining pharmacodynamic indicators, including antioxidative activity, immune regulation, hypoglycemic effects, and anti-aging properties. The analysis indicates that the mechanism of toxicity reduction in wine processing involves the degradation of phlegmatic temperament and the passivation of calcium oxalate needle crystal morphology. This synergistic mechanism is closely associated with the enrichment of low-molecular-weight polysaccharides, the remodeling of monosaccharide composition, and the formation of active compounds such as 5-hydroxymethylfurfural (5-HMF). Moderate processing (four to six cycles of steaming and six cycles of processing) can achieve the detoxification and synergistic effects comparable to the traditional "nine steaming and nine processing cycles". This study provides a theoretical foundation for transitioning the wine processing technique of Polygonati Rhizoma from "empirical practice" to "scientific regulation".

Key words Polygonati Rhizoma, Wine processing, Processing technique, Chemical component, Polysaccharide, Efficiency

1 Introduction

Polygonati Rhizoma refers to the dried rhizome of *Polygonatum sibiricum* Red., *Polygonatum kingianum* Coll. et Hemsl., or *Polygonatum cyrtonema*, all belonging to the genus *Polygonatum* of the Liliaceae family. This substance is a major Chinese medicinal material recognized for its dual use as both food and medicine and is included in the *Pharmacopoeia of the People's Republic of China* (2025 Edition)[1]. Polygonati Rhizoma is characterized by a sweet taste and a neutral nature. It is traditionally recognized for its functions in tonifying qi and nourishing yin, strengthening the spleen, moistening the lungs, and benefiting the kidneys. Contemporary research has shown that its components, including polysaccharides, saponins, and flavonoids, exhibit various biological activities such as antioxidation, hypoglycemic effects, immune modulation, and anti-aging properties[2-5]. However, raw Polygonati Rhizoma contains large amounts of calcium oxalate needle crystals and viscous polysaccharides (phlegmatic temperament). Direct consumption of the raw form may irritate the mucous membranes of the oral cavity and tongue, resulting in numbness and an astringent sensation[6]. Therefore, processing is necessary to "reduce toxicity and enhance therapeutic efficacy". Wine processing is the most traditional method employed for the preparation of Polygonati Rhizoma. Yellow wine serves as an auxiliary agent, leveraging its warming and dredging properties to direct the medicinal effects upward and to enhance the functions of tonifying the spleen and moistening the lungs. According to the *Pharmacopoeia of the People's Republic of China*, for every 100 kg of Polygonati Rhizoma, 20 kg of yellow wine should be utilized, with the mixture being thoroughly stewed or steamed[1]. In recent years, with the rapid increase in market demand for Polygonati Rhizoma in functional foods and health products, its scientific and standardized wine processing techniques have become a critical bottleneck for the high-quality development of the industry.

In recent years, researchers have extensively investigated the optimization of wine processing technique parameters for Polygonati Rhizoma, the transformation patterns of chemical components before and after processing, and the associated changes in pharmacological efficacy. Notable advancements have been achieved in process optimization techniques, including orthogonal experiments and response surface methodology, as well as in quality control indicators such as polysaccharide molecular weight distribution, monosaccharide composition, and Maillard reaction products[7-8]. However, existing research exhibits three primary limitations. First, there is considerable variability in process parameters across studies. The amount of wine added (10% - 30%), steaming duration (1 - 20 h), and temperature (80 - 130 ℃) differ greatly, and no standardized protocol has been established for broader application. Second, the elucidation of the correlative mechanism between changes in chemical components and enhanced pharmacological efficacy remains insufficiently explored. Most investigations focus primarily on quantifying component content, leaving the causal links between specific component alterations and efficacy enhancement unclear. Third, current quality evaluation indicators are limited in scope, rendering it challenging to comprehensively assess the extent of wine processing and overall product quality[9].

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Therefore, systematically delineating the interrelationships among wine processing techniques, chemical component variations, and changes in pharmacological efficacy, as well as elucidating the scientific connation for "toxicity reduction and efficacy enhancement", is crucial for developing a scientific quality evaluation system.

This article provides a systematic review of recent advancements in the wine processing of Polygonati Rhizoma, examining three key aspects: the optimization of wine processing techniques, alterations in chemical components before and after processing, and changes in pharmacological efficacy. It emphasizes the analysis of the intrinsic relationships among polysaccharide structural remodeling, saponin transformation, the formation of Maillard reaction products, and the enhancement of pharmacological efficacy. Furthermore, the article explores the mechanisms underlying toxicity reduction and efficacy enhancement during wine processing, and critically evaluates the limitations of current research and proposes directions for future investigation, aiming to offer theoretical guidance for the scientific, standardized, and industrial application of wine processing technique for Polygonati Rhizoma.

2 Wine processing technique of Polygonati Rhizoma

The researchers identified key parameters, including the amount of wine added, steaming duration, temperature, and the number of processing cycles, and optimized the wine processing technique through orthogonal experiments, response surface methodology, and a multi-index comprehensive scoring approach. Feng Ying *et al.* [10] concluded that the optimal process, based on polysaccharide content, involved adding 20% yellow wine and stewing for 10 h. Zhang Jie *et al.* [11] employed a pressurized wine steaming method (120 ℃ for 60 min), which significantly reduced the processing time. Xiao Xiaoyan *et al.* [12] applied the AHP-comprehensive scoring method, considering polysaccharides, saponins, and physical property indicators, and determined that soaking in yellow wine for 10 h followed by steaming over water for 20 h was the optimal procedure. Shi Shuanghui *et al.* [13] employed the AHP-entropy weight method combined with the Box-Behnken design-response surface methodology to identify optimal processing techniques, which included soaking for 5 h, steaming for 1 h at 0.06 MPa, and stewing for 7 h. Notably, the process parameters reported across different studies exhibit considerable variability; for instance, the proportion of yellow wine used ranges from 10% to 30%, steaming durations vary between 1 and 20 h, and temperatures span from 80 to 130 ℃. These discrepancies likely arise from differences in raw material species (such as *P. sibiricum*, *P. kingianum*, or *P. cyrtonema*), geographic origin, and evaluation criteria. Therefore, there is a critical need to establish standardized processing techniques through comprehensive validation across multiple origins and varieties.

Zhang Yubo *et al.* [14] developed a novel wine roasting processing technique conducted at 220 ℃ for 7 min, which significantly reduced the processing time. Zhou Gailian *et al.* [15] compared various processing methods of *P. cyrtonema* and concluded that the wine processing method was superior to those involving black bean and honey. Contemporary research indicates that the processing of Polygonati Rhizoma does not require strict adherence to the traditional "nine steaming and nine processing cycles". Luo Xin *et al.* [16], using *P. cyrtonema* sourced from Jiuhua Mountain, found that the overall quality improved after six processing cycles, with polysaccharide and total saponin contents stabilizing. Based on correlation analyses of color, polysaccharide content, and antioxidant activity, Dong Ning *et al.* [17] reported that the highest comprehensive quality score for Polygonati Rhizoma was achieved after six steaming and six processing cycles; at this stage, the numbing sensation on the tongue disappeared, and the taste was characterized by a slight sweetness and bitterness, aligning with the traditional standards for high-quality Polygonati Rhizoma. However, the taste quality declined after seven cycles of steaming and processing. These findings suggest that the optimal number of processing cycles for Polygonati Rhizoma should be determined through a comprehensive evaluation of variety, processing techniques, and quality indicators, with the traditional "nine cycles" serving more as a symbolic guideline.

3 Changes in chemical components before and after wine processing

3.1 Polysaccharides Polysaccharides are the primary active components of Polygonati Rhizoma and serve as quality evaluation indicators as specified in the *Pharmacopoeia of the People's Republic of China*. The total polysaccharide content tends to decrease following wine processing[18-19], but the pattern of variation is complex. Cai Chunyan *et al.* [20] reported that the polysaccharide content in the ninth processing cycle was relatively higher than that observed in the sixth to eighth cycles, suggesting that moderate processing may induce a rebound in polysaccharide content due to cell wall disruption and the subsequent release of bound polysaccharides. Luo Xin *et al.* [16] observed an initial decrease in polysaccharide content followed by stabilization. These discrepancies may be attributed to differences in raw material species (*P. cyrtonema* versus *P. kingianum*) and variations in analytical methods (total sugar determination via the phenol-sulfuric acid method versus molecular weight distribution analysis by high-performance gel permeation chromatography). Such findings highlight the limitations of relying solely on "total polysaccharide content" as a quality indicator. Comprehensive investigations into the transformation mechanisms demonstrated that wine processing induced significant structural remodeling of polysaccharides. Specifically, regarding monosaccharide composition, the contents of fructose, arabinose, and mannose decreased, whereas glucose content increased[21]. Concerning molecular weight distribution, Sun *et al.* [22] reported an increase in the average molecular weight of polysaccharides from 4.01 to 14.2 kDa following 6 h of wine steaming. Wan Xiaoying *et al.* [21] observed an increased proportion of fractions with molecular weight below 50 kDa in wine-processed Polygonati

Rhizoma, accompanied by enhanced immunological activity, suggesting that polysaccharide fractions of different molecular weights may exhibit distinct biological activities. Zhang Yanxue *et al.* [23] confirmed that oligosaccharides underwent hydrolysis into monosaccharides and disaccharides during processing. Zeng Linyan *et al.* [24] reported that reducing sugars peaked at 16 h of processing (4 – 27 times higher than raw products). These findings indicate that during wine processing, polysaccharides experience a dynamic transformation characterized by "macromolecular degradation, enrichment of small molecules, and monosaccharide release". This structural remodeling, rather than a mere alteration in content, may be pivotal in enhancing the pharmacological efficacy of the drug.

3.2 Saponins and flavonoids Zhang Hongkun *et al.* [25] investigated the effects of nine steaming and nine processing cycles of Polygonati Rhizoma steamed in clear soup and wine, finding that the changes in saponin content were consistent across both processing methods. However, products steamed in wine reached the culmination of their properties more rapidly than those steamed in clear soup, suggesting that yellow wine accelerates the processing. Luo Xin *et al.* [16] reported that the total saponin content increased progressively from approximately 3% in the raw product to 6.92% after six processing cycles, showing more than a twofold increase. However, findings regarding the specific saponin dioscin are inconsistent: Zhao Qiuhua *et al.* [26] observed a decrease in dioscin content following processing of Polygonati Rhizoma from Debao, Guangxi; Liu Shaohuan *et al.* [27] reported an increase in dioscin content in Polygonati Rhizoma cultivated in Guizhou after processing; and Sun Tingting *et al.* [28] found that the dioscin content in Polygonati Rhizoma from Shaanxi steamed in wine was lower than that steamed in clear soup. The observed regional differences may be attributed to variations in the accumulation of saponin precursors, influenced by the genetic background (variety) and environmental factors (soil and climate) of Polygonati Rhizoma across different production areas, suggesting the necessity of establishing an integrated "three-in-one" quality standard encompassing origin, variety, and processed products. Ren Hongmin *et al.* [29] identified 38 compounds (15 steroidal saponins, 6 alkaloids, and 3 flavonoids) in wine-processed products of *P. cyrtonema* using UPLC-Q-TOF-MS technique, and subsequently screened 16 differential markers related to processing, such as kingianoside Z, which may serve as potential indicators for quality control in wine processing. Lin Yu *et al.* [30] demonstrated that the increase in total flavonoid content following wine processing was positively correlated with enhanced antioxidant activity, thereby supporting the hypothesis that "compositional changes contribute to enhanced efficacy".

3.3 Maillard reaction products and volatile components 5-Hydroxymethylfurfural (5-HMF) is a significant product of the Maillard reaction occurring during the processing of Polygonati Rhizoma and serves as an indicator of the processing extent. Chang Liang *et al.* [31] reported that the 5-HMF content peaked at approximately 16 h. Zeng Linyan *et al.* [32] identified two novel compounds, DDMP and 5-HMF. Li Detian *et al.* [9] proposed a consistency evaluation strategy based on variations in 5-HMF content. Through gas chromatography-mass spectrometry (GC-MS) analysis, Liu Minmin *et al.* [33] showed that the enhancement of the "fragrant" taste correlated with an increase in aldehyde components, whereas the reduction of the "raw" taste was associated with a decrease in volatile compounds such as hexaldehyde. Du Liji *et al.* [34] observed a significant increase in aldehyde and ester components following wine processing, which were identified as the primary contributors to the characteristic aroma of wine-processed Polygonati Rhizoma.

Fan Shumiao[35] demonstrated that the amino acid content of wine-processed Polygonati Rhizoma decreased, whereas the mineral content increased. Liang Zehua *et al.* [36] identified 127 differential metabolites associated with multiple pathways, including glucose metabolism and amino acid metabolism. Ren Cuijiao *et al.* [37] reported significant alterations in the components of steroidal saponins, flavonoids, and organic acids following processing.

4 Changes in the pharmacological efficacy after wine processing

4.1 Changes in antioxidant activity The antioxidant activity of Polygonati Rhizoma is markedly enhanced following wine processing. Sun Tingting *et al.* [38] reported an increase in the antioxidant activity of water-soluble polysaccharides subsequent to wine processing. Cai Chunyan *et al.* [20] observed that antioxidant activity progressively increased with the number of processing cycles, stabilizing after seven cycles. Shi Yang *et al.* [39] demonstrated that the extract of *P. sibiricum* subjected to wine processing exhibited significantly greater activity compared to dried and steamed extracts. These findings indicate that the antioxidant capacity of wine-processed Polygonati Rhizoma surpasses that of the unprocessed raw material.

4.2 Changes in immunoregulatory effects Immunoregulation is the most significant pharmacological activity contributing to the enhanced efficacy of wine-processed Polygonati Rhizoma. Zhong Lingyun *et al.* [40] displayed that the dichloromethane extract of wine-processed Polygonati Rhizoma significantly increased both the carbon particle clearance index and the phagocytic coefficient in mice, indicating an enhancement of non-specific immune function. A comprehensive study conducted by Wan Xiaoying *et al.* [21] elucidated the underlying mechanism: under normal physiological conditions, the polysaccharide fraction of wine-processed Polygonati Rhizoma with a molecular weight below 50 kDa exhibited a stronger stimulatory effect on macrophage secretion of TNF-α compared to raw polysaccharides; under LPS-induced inflammatory conditions, the inhibitory effects of wine-processed Polygonati Rhizoma polysaccharides on TNF-α and IL-1β surpassed those of the raw material; and *in vivo* experiments confirmed that the fraction of wine-processed Polygonati Rhizoma with a molecular weight below 50 kDa most effectively recovered spleen and thymus atro-

phy in cyclophosphamide-induced immunosuppressed mice. Through molecular-level investigations, Sun *et al.* [22] reported that the immune-stimulating capacity of Polygonati Rhizoma polysaccharides was significantly enhanced following wine processing. Tian Xin *et al.* [41] observed that four cycles of steaming and processing rather than the traditional nine cycles exerted the most potent regulatory effect on immunosuppressed mice. This finding corroborates the conclusion of Luo Xin *et al.* [16], who identified six cycles of steaming and processing as optimal for overall quality, thereby supporting the scientific principle of "moderate processing". Excessive steaming may result in the over-degradation of active polysaccharides, consequently diminishing immune activity. Shi Shuanghui *et al.* [13] confirmed that although wine-processed Polygonati Rhizoma enhanced immunity, its stimulatory effect on mucous membranes was significantly reduced, illustrating the dual benefits of wine processing in "enhancing efficacy while maintaining safety".

4.3 Hypoglycemic effect and stimulating changes Shi Shuanghui *et al.* [13] confirmed that the hypoglycemic effect of wine-processed Polygonati Rhizoma was more potent than that of the raw form. Liu Lumei *et al.* [42] further enhanced this hypoglycemic effect through process optimization. Yu Huanying *et al.* [43] reported that wine-processed Polygonati Rhizoma exhibited the most significant improvement in symptoms associated with kidney yin deficiency. Regarding irritation, wine processing leads to the destruction of phlegmatic temperament and the disintegration of calcium oxalate needle crystal morphology[44]. Lin Yu *et al.* [30] confirmed that the needle crystals transform from sharp to blunt forms, which directly contributes to the reduction in irritation.

4.4 Anti-aging effects The concept of anti-aging is a contemporary scientific interpretation of the traditional effects attributed to Polygonati Rhizoma, which is believed to lighten the body and prolong life with long-term use. Fan Shumiao[35] employed *Caenorhabditis elegans* as an experimental model and demonstrated that the anti-aging efficacy of Polygonati Rhizoma polysaccharides surpassed that of its alcohol extracts, notably extending the lifespan of nematodes without impairing their reproductive capacity. More notably, Zhang *et al.* [45] isolated a low-molecular-weight homogeneous polysaccharide, PSP-1 (approximately 2.7 kDa, mainly composed of galactose), from nine-steamed and nine-sun-dried Polygonati Rhizoma. Their findings indicate that PSP-1 delays aging through a multi-target synergistic mechanism involving the remodeling of intestinal microbiota composition (enriching beneficial bacteria such as *Lactobacillus* that produce short-chain fatty acids), enhancement of short-chain fatty acid metabolism, and regulation of host energy metabolism-related gene expression, including glycolytic pathways. This study, utilizing *in vitro* human fecal bacterial fermentation and *C. elegans* models, provides direct experimental evidence elucidating the anti-aging mechanism of processed Polygonati Rhizoma products from the perspective of "intestinal microecology, metabolic regulation, and host health". These results suggest that the low-molecular-weight polysaccharides generated during the steaming process may be the principal functional components responsible for anti-aging effects. Furthermore, this research identifies a critical target for the development of functional foods derived from Polygonati Rhizoma (particularly nine-steamed and nine-sun-dried products).

5 Conclusions and prospects

This article provides a systematic review of research advancements concerning "toxicity reduction and efficacy enhancement" in wine-processed Polygonati Rhizoma around three key dimensions: process optimization, chemical component transformation, and changes in pharmacological efficacy. Furthermore, it develops a "three-in-one" theoretical framework integrating "process parameters, component transformation, and efficacy enhancement". The principal conclusions are as follows.

(i) Process dimension: existing research has established that the parameters for wine processing exhibit considerable variation, including a range of 10% to 30% for yellow wine concentration, steaming durations from 1 to 20 h, and temperatures between 80 and 130 ℃. Variations in grape variety and geographic origin are primary factors contributing to these parameter differences. The wine roasting method, conducted at 220 ℃ for 7 min, offers a novel approach for rapid processing. Furthermore, the traditional practice of nine steaming and nine processing cycles can be optimized to six steaming and six processing cycles, thereby embodying the scientific connotation of "moderate processing".

(ii) Component dimension: during wine processing, polysaccharides undergo dynamic transformations characterized by "macromolecular degradation, enrichment of small molecules, and the release of monosaccharides". The enhancement of immune activity within the fraction of molecular weight less than 50 kDa is a central synergistic mechanism. Saponin content increases significantly, and total flavonoid levels exhibit a positive correlation with antioxidant activity. Maillard reaction products, including 5-HMF and DDMP, may serve as potential markers for assessing the extent of processing.

(iii) Efficacy dimension: the mechanism of toxicity reduction involves three pathways: the degradation of phlegmatic temperament, the passivation of calcium oxalate needle crystal morphology, and the reduction of volatile irritating components. The synergistic mechanism is closely associated with the enrichment of low-molecular-weight polysaccharides, the enhanced dissolution of glycoside components, and the multi-component synergistic effect. This review demonstrates that the fundamental nature of wine-processed Polygonati Rhizoma lies in the selective enrichment and structural optimization of active components, facilitated by the combined influence of heat, water, and chemical forces mediated by yellow wine, rather than a mere "addition or subtraction of components".

Despite considerable advancements in current research, the field of wine processing of Polygonati Rhizoma continues to encounter challenges at both methodological and theoretical levels.

In terms of process research, most process optimizations have relied on single-factor or orthogonal experimental designs. A comprehensive optimization model that integrates multidimensional variables such as variety, origin, and season remains undeveloped, and there is a notable absence of pilot-scale and industrial-scale validation. In terms of mechanism interpretation, the majority of studies have focused on describing correlations between "changes in component content and drug efficacy", without clearly elucidating the causal pathways by which specific component alterations mediate enhancements in drug efficacy through defined molecular targets. Notably, there is a deficiency of systems biology evidence supporting multi-omics integration in this context. Regarding quality standards, the *Pharmacopoeia of the People's Republic of China* currently utilizes characteristics and total polysaccharide content as primary indicators. However, these measures inadequately capture the comprehensive extent of wine processing and its intrinsic quality. Therefore, it is imperative to establish a "component-activity-clinical" association evaluation system grounded in quality markers (Q-markers). Based on this foundation, future research should prioritize the following directions: (i) Analysis of multi-omics-driven processing mechanisms. By integrating metabolomics, proteomics, and intestinal metagenomics technologies, the complete regulatory network encompassing "components, targets, pathways, and phenotypes" involved in wine processing can be elucidated from a systems biology perspective, with particular emphasis on immune regulation and anti-aging mechanisms mediated by the intestinal microecology of low-molecular-weight polysaccharides. (ii) Artificial intelligence-assisted precise process control: a predictive model linking "raw material attributes, process parameters, and product quality" is developed using machine learning algorithms. By integrating process analytical technologies such as near-infrared spectroscopy (PAT), this approach enables intelligent determination of processing endpoints, thereby facilitating a paradigm shift from "experience-based practices" to "data-driven methods". (iii) Construction of a quality standard system based on Q-markers: by selecting differential processing markers, including kingianoside Z, polysaccharide fractions with molecular weight less than 50 kDa, and 5-HMF, as candidate Q-markers, a multi-index quality evaluation standard linked to pharmacodynamic activity has been established to address the lack of specificity in current pharmacopoeial standards. (iv) Clinical evidence-based research and industrial transformation: randomized controlled clinical trials (RCTs) investigating the effects of wine-processed Polygonati Rhizoma on immune deficiency, disorders of glucose and lipid metabolism, and aging-related indicators have been conducted, resulting in the accumulation of high-quality evidence-based medical data. Concurrently, the industrial application of wine-processed Polygonati Rhizoma in functional foods, specialized medical foods, and nutritional interventions for the elderly is being actively promoted. This review offers a systematic literature foundation and theoretical framework to support the advancement of these research areas.

References

[1] National Pharmacopoeia Commission. Pharmacopoeia of the People's Republic of China: Part I[M]. Beijing: China Medical Science Press, 2025: 319 – 320. (in Chinese).

[2] CHEN H, FENG SS, SUN YJ, *et al.* Advances in studies on chemical constituents of three medicinal plants from *Polygonatum* Mill. and their pharmacological activities[J]. Chinese Traditional and Herbal Drugs, 2015, 46(15): 2329 – 2338. (in Chinese).

[3] ZHENG N, LI Y, LIU JF, *et al.* Optimization of honey-frying process and evaluation of *in vitro* and *in vivo* activities of Polygonati Rhizoma[J]. Chinese Traditional and Herbal Drugs, 2025, 56(4): 1171 – 1183. (in Chinese).

[4] YANG MH, ZHOU X, QIAO ZW, *et al.* Recent advances in Polygonatum Polysaccharides: Extraction, isolation, purification and bioactivities [J]. Science and Technology of Food Industry, 2022, 43(12): 407 – 416. (in Chinese).

[5] JIANG CX, ZHANG TJ, CHEN CQ, *et al.* Research progress in Polygonati Rhizoma and predictive analysis on Q-marker[J]. Chinese Traditional and Herbal Drugs, 2017, 48(1): 1 – 16. (in Chinese).

[6] LIN Y, LIU JJ, XU LC. Study on the changes of morphology and content of calcium oxalate crystal before and after processing Mount Tai *Polygonatum sibiricum* Red[J]. Journal of Li-Shizhen Traditional Chinese Medicine, 2023, 34(4): 892 – 894. (in Chinese).

[7] WANG WK, WANG XT, WANG ZM. Study on wine used for processing traditional Chinese medicine[J]. China Journal of Chinese Materia Medica, 2006, 31(3): 259 – 262. (in Chinese).

[8] CHEN XL, XU Z, QIAN HL, *et al.* Historical evolution and modern research progress of processing of Huangjing (Polygonati Rhizoma)[J]. Chinese Archives of Traditional Chinese Medicine, 2024, 41(11): 150 – 157. (in Chinese).

[9] LI DT, FENG L, JIA XB, *et al.* Processing principle and process optimization strategy of Polygonati Rhizoma[J]. Chinese Traditional and Herbal Drugs, 2024, 55(20): 7110 – 7121. (in Chinese).

[10] FENG Y, TIAN YH, WANG Y, *et al.* Optimization of processed techniques and quality in Huangjing braised with wine[J]. Journal of Sichuan of Traditional Chinese Medicine, 2010, 28(3): 35 – 37. (in Chinese).

[11] ZHANG J, JIN CS, WU DL, *et al.* Optimization of pressurized wine-steaming process for Rhizoma Polygonati by orthogonal test[J]. Journal of Anhui University of Chinese Medicine, 2014, 33(1): 72 – 74. (in Chinese).

[12] XIAO XY, SU LP, CHEN P, *et al.* Optimization of processing technology of wine-processed Polygonati Rhizoma based on orthogonal test and AHP-comprehensive scoring method and comparison of immunomodulation functions of Polygonati Rhizoma processed with different methods [J]. China Journal of Chinese Materia Medica, 2022,47(23):6391 – 6398. (in Chinese).

[13] SHI SH, WANG ML, WEI XT, *et al.* Optimization of processing technology of wine-processed Polygonati Rhizoma by combination of Box-Behnken design-response surface method and AHP-entropy weight method and comparison of efficacy before and after processing[J]. Chinese Traditional and Herbal Drugs, 2023, 54(14): 4467 – 4480. (in Chinese).

[14] ZHANG YB, CHEN XJ, JIA ZL, *et al.* Study the new wine processing technology of Polygonati Rhizoma based on immunomodulatory effect [J]. China Medical Herald, 2025, 22(5): 24 – 28. (in Chinese).

[15] ZHOU GL, LI J, XU MY, *et al.* Study on different processing techniques of Guangxi *Polygonatum cyrtonema*[J]. Chinese Journal of Ethnomedicine and Ethnopharmacy, 2018, 27(10): 34 – 37. (in Chinese).

[16] LUO X, HU Y, NI XT, *et al.* Effects of steaming and drying for nine

times on the quality of *Polygonatum cyrtonema* from Jiuhua Mountain [J]. China Brewing, 2025, 44(2): 144 – 151. (in Chinese).
[17] DONG N, CHEN Y, LI XB, *et al.* Exploring quality variations of Polygonati Rhizoma during nine-steaming and nine-drying process through color-polysaccharides-antioxidant activity linkages[J]. Chinese Traditional and Herbal Drugs, 2025, 56(2): 476 – 486. (in Chinese).
[18] XU SC, JI YH, LI SH, *et al.* Determination on the polysaccharide contents of Rhizoma Polygonati (*Polygonatum sibiricum*) before and after processing and their yield on extraction[J]. Chinese Traditional and Herbal Drugs, 1993, 24(12): 629 – 630. (in Chinese).
[19] SUN TT, ZHANG H, LIU JF, *et al.* Analysis of polysaccharide content in different processed products of *Polygonatum* from Shaanxi[J]. China Pharmacist, 2016, 19(2): 232 – 234. (in Chinese).
[20] CAI CY, CHEN X, LIU SJ, *et al.* Comparative study on intrinsic quality and *in vitro* antioxidant activity of *Polygonatum cyrtonema* Hua at different processing stages[J]. Journal of Li-Shizhen Traditional Chinese Medicine, 2022, 33(11): 2665 – 2669. (in Chinese).
[21] WAN XY, LIU ZL, SONG ZQ, *et al.* Comparison of relative molecular weight distribution and immune activity of Polysaccharides in Polygonati Rhizoma before and after processing[J]. Chinese Journal of Experimental Traditional Medical Formulae, 2021, 27(15): 83 – 90. (in Chinese).
[22] SUN TT, ZHANG H, LI Y, *et al.* Physicochemical properties and immunological activities of polysaccharides from both crude and wine-processed *Polygonatum sibiricum*[J]. International Journal of Biological Macromolecules, 2020, 143: 255 – 264.
[23] ZHANG YX, ZHOU Q, ZHANG XL, *et al.* Content change and transformation mechanism of oligosaccharides and monosaccharides before and after processing in *Polygonatum cyrtonema*[J]. Journal of Chinese Medicinal Materials, 2020, 43(2): 318 – 322. (in Chinese).
[24] ZENG LY, WEI Z, CAO YN, *et al.* Content variations of low molecular weight saccharide from Rhizoma Polygonation during processing[J]. Chinese Journal of Experimental Traditional Medical Formulae, 2012, 18(11): 69 – 72. (in Chinese).
[25] ZHANG HK, WU GF, HUANG YY, *et al.* Study on the process of *Polygonatum sibiricum* Red. in different nine fold processing[J]. Journal of Li-Shizhen Traditional Chinese Medicine, 2019, 30(3): 602 – 605. (in Chinese).
[26] ZHAO QH, HUANG YH, PAN QD, *et al.* Study on HPLC chromatogram changes of *Polygonatum sibiricum* from Debao, Guangxi before and after processing[J]. Chinese Journal of Ethnomedicine and Ethnopharmacy, 2021, 30(12): 39 – 41. (in Chinese).
[27] LIU SH, HONG DQ, WANG SQ. Determination of diosgenin content in cultivated *Polygonatum sibiricum* from Guizhou[J]. Chinese Journal of Ethnomedicine and Ethnopharmacy, 2010, 19(5): 44 – 45. (in Chinese).
[28] SUN TT, ZHANG H, LI Y, *et al.* Analysis of diosgenin content in different processed products of *Polygonatum* from Shaanxi[J]. China Pharmacist, 2017, 20(1): 158 – 160. (in Chinese).
[29] REN HM, ZHANG JL, DENG YL, *et al.* Analysis of chemical constitutions of *Polygonatum cyrtonema* dried rhizomes before and after processing with wine based on UPLC-Q-TOF-MS[J]. Chinese Journal of Experimental Traditional Medical Formulae, 2021, 27(4): 110 – 121. (in Chinese).
[30] LIN Y, SHE L, WEI XY, *et al.* Study on chemical constituents, detoxification and synergism of Polygonati Rhizoma before and after processingg[J]. Journal of Chinese Medicinal Materials, 2021, 44(6): 1355 – 1361. (in Chinese).
[31] CHANG L, CHEN ZZ, WANG D, *et al.* Contents of 5-HMF during the processing of three species of *Polygonatum* by HPLC and GC-MS[J]. China Pharmacist, 2015, 18(3): 387 – 390. (in Chinese).
[32] ZENG LY, SONG ZQ, WEI Z, *et al.* Isolation of chemical constituents produced in processing of Polygonati Rhizoma and their content changes [J]. Chinese Traditional and Herbal Drugs, 2013, 44(12): 1584 – 1588. (in Chinese).
[33] LIU MM, LIU Y, ZHANG T, *et al.* Effect of wine processing on odour formation of *Polygonatum cyrtonema* Rhizoma by GC-MS[J]. Chinese Journal of Experimental Traditional Medical Formulae, 2022, 28(17): 166 – 173. (in Chinese).
[34] DU LJ, CHEN RR, WANG K, *et al.* Changes of volatile substances in rhizome of *Polygonatum cyrtonema* processing by GC-MS[J]. Journal of Anhui Agricultural University, 2021, 48(6): 1035 – 1040. (in Chinese).
[35] FAN SM. Study on chemical constituents and metabolomics of *Polygonatum sibiricum*[D]. Zhengzhou: Henan Agricultural University, 2023. (in Chinese).
[36] LIANG ZH, PAN YJ, QIU LY, *et al.* Analysis on chemical components changes of Polygonati Rhizoma in processing of nine times steaming and nine times sunning by UPLC-Q-TOF-MS/MS[J]. Chinese Traditional and Herbal Drugs, 2022, 53(16): 4948 – 4957. (in Chinese).
[37] REN CJ, DING YF, LI JJ, *et al.* Differences in chemical composition of *Polygonatum cyrtonema* Rhizome before and after processing based on UPLC-Q-Exactive orbitrap MS analysis[J]. Chinese Journal of Experimental Traditional Medical Formulae, 2024, 30(24): 98 – 107. (in Chinese).
[38] SUN TT, LIU Y, WEI M, *et al.* Antioxidant activity of water-soluble polysaccharides from crude and wine-processed Huangjing(*Polygonatum sibiricum*)[J]. Chinese Archives of Traditional Chinese Medicine, 2023, 41(2): 78 – 84. (in Chinese).
[39] SHI Y, WANG LC, MA ZL, *et al.* Determination of components and activity of extractions of Polygonatum kingianum and evaluation of its cytotoxicity[J]. China Surfactant Detergent & Cosmetics, 2020, 50(11): 788 – 792. (in Chinese).
[40] ZHONG LY, ZHANG Y, HUO HJ, *et al.* Study on the composition and pharmacological function change of Rhizoma Polygonati before and after processing[J]. Journal of Chinese Medicinal Materials, 2011, 34(10): 1508 – 1511. (in Chinese).
[41] TIAN X, LIU Y, ZHANG JL, *et al.* Study on nine-steaming and nine-drying process of *Polygonatum sibiricum* and immunomodulatory effect of *Polygonatum sibiricum* polysaccharides on mice[J]. Journal of Huazhong Agricultural University, 2026: 1 – 15. (in Chinese).
[42] LIU LM, WANG N, CHEN D, *et al.* Optimization of wine-processed *Polygonatum sibiricum* processing technology based on hypoglycemic effect[J]. Journal of Li-Shizhen Traditional Chinese Medicine, 2021, 32(8): 1915 – 1918. (in Chinese).
[43] YU HY, GAO HY, JIN CS, *et al.* Effect of crude and processed products of *Polygonatum sibiricum* on a rat model of kidney-yin deficiency induced by glucocorticoid: A comparative analysis[J]. Journal of Anhui University of Chinese Medicine, 2021, 40(6): 58 – 62. (in Chinese).
[44] WANG JX, WANG F, LI QM, *et al.* Study on the numbing substance of Polygonatum Rhizoma based on steaming treatment[J]. Food and Machinery, 2024, 40(4): 165 – 171. (in Chinese).
[45] ZHANG C, LIN HR, WEI CM, *et al.* Anti-aging effects of low-molecular-weight polysaccharide PSP-1-1 from steamed *Polygonatum sibiricum* via gut microbiota modulation[J]. Carbohydrate Polymers, 2026, 381: 125225.