Research Progress on Processing and Processing Methods in *Salvia miltiorrhiza* Production Areas

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**Abstract**

*Salvia miltiorrhiza* is one of the 40 most commonly used traditional Chinese medicinal materials in clinics. It is effective in activating blood circulation, removing blood stasis, relieving pain through the meridian, clearing the heart and removing irritations, and cooling blood and eliminating blemishes. Each main production area has developed a unique production method and processing technology, in accordance with local conditions. The processed products included in Chinese Pharmacopoeia are purified and wine-fried *S. miltiorrhiza*. In addition, the Chinese province’s standards include the vinegar-fried and wine-fried types. *S. miltiorrhiza* is produced in more areas and is more extensively processed, with large variations in specifications. The challenge in establishing a uniform quality standard affects the clinical application of decoction pieces. This review has explored the books of the past dynasties, summarized the relevant literature published in the past three decades, discussed the processing methods of *S. miltiorrhiza*, and provided a basis for further research on the processing method of the original sample. In particular, we integrate fresh cut processing as the starting point for in-depth research, discuss the processing technology specifications, and formulate quality product standards.

**Keywords:** Chemical composition, processing technology, production area, *Salvia miltiorrhiza*

**Background**

*Salvia miltiorrhiza* (Dan-Shen, in Chinese) is the dried root and rhizome of *S. miltiorrhiza* Bge. It has bitter taste and soothing nature, mainly functioning on the heart and liver. It was first recorded in Shen-Nong-Ben-Cao-Jing (Shen Nong’s Herbal Classic, B. C. 100–200). Modern pharmacological research shows that *S. miltiorrhiza* is effective against cardiovascular diseases and peptic ulcers and is an antioxidant, antitumor, antibacterial, anti-inflammatory agent. The main medicinal components include ketones, phenolic acids, volatile oils, and trace elements. Its ability to promote blood circulation and remove blood stasis has earned *S. miltiorrhiza* a good position among medical scientists and is known as “single *Salvia miltiorrhiza*, with four traditional Chinese medicine (TCM).” Medical research shows cardiovascular disease as one of the main causes of human death. *S. miltiorrhiza* is among the 40 most commonly used Chinese herbal medicines (CHMs) clinically and plays an important role in cardiovascular disease. Several kinds of *S. miltiorrhiza* preparations exist in the clinic, with compound *S. miltiorrhiza* pills, compound *S. miltiorrhiza* tablets, and injectable *S. miltiorrhiza* polyphenolate, known as landmark products of the modernization of Chinese medicine. With the increase in clinical demand and the gradual shortage of natural resources, artificial cultivation has become the main growth and production source of *S. miltiorrhiza*.

Origin processing (Chan-Di-Jia-Gong, in Chinese) and processing (Pao-Zhi, in Chinese) are two connected links in the production and processing chain of TCM. The target product of the former is Chinese medicinal materials (Zhong-Yao-Cai, in Chinese) and the latter is the CHMs piece (Yin-Pian, in Chinese). Although different, both are closely related. The processing of TCM materials not
only removes the nonmedicinal parts to achieve purification but can also terminate the physiological state and facilitate drying. Through appropriate processing methods, Chinese medicinal materials can promote the maximum retention of effective substances in medicinal parts, thereby affecting the quality of Chinese medicinal pieces. Therefore, investigating the chemical and pharmacological changes of CHM before and after processing is key for understanding underlying mechanisms. The Chinese Pharmacopoeia (CP, 2015 edition) has a relatively simple record on \textit{S. miltiorrhiza} processing and harvesting, that is, “harvesting in spring and autumn, removing sediment, and drying.” The specific processing parameters are not clearly indicated or requested for [Figure 1]. Differences in processing parameters such as the amount of auxiliary materials, processing temperature, processing time, and processing degree have a certain impact on the clinical application of the decoction products. Due to complex and unique processing methods of different origins, large differences exist in output and clinical efficacy, and industrial production fails to meet uniform and controllable quality. Establishing a scientific and standardized integrated processing and production method to avoid the loss caused by the repeated moisturizing, soaking and water washing of \textit{S. miltiorrhiza} in during processing, reducing the content reduction caused by transportation and storage during market circulation, and effectively ensuring the salvia quality will be of great significance to the quality assurance and clinical application of decoction products. Therefore, by reviewing older literature, and searching the Web of Science, PubMed, and CNKI databases, we summarized the research progress of the processing and modern processing of \textit{S. miltiorrhiza} and conducted a comprehensive analysis of relevant literature published in the past three decades. It provides reference for the in-depth study of the integrated production and processing technology based on manufacturing.

\textbf{Processing in Production Spot}

Dynamic accumulation of active components and plant growth and development are two important indexes to determine the harvesting and processing of root Chinese medicine. \textit{S. miltiorrhiza} can grow to 3 years or more in the wild state. \textit{S. miltiorrhiza} has different effects on the quality and internal chemical composition of medicinal materials under different harvest years, harvest times, and processing methods.

\textbf{Sources of collection}

We referred to the past indigenous knowledge of famous herbs, including \textit{S. miltiorrhiza} harvesting and processing. More records such as Tai-Ping-Yu-Lan (Taiping Royal View, B. C. 977–983) were reviewed, which indicated May as the best period to harvest roots and to dry the roots in the dark. Further, a book (Ben-Hui-Jing-Yao, B. C. 1505) mentions that good harvest quality is observed in winter and poor harvest quality in summer. According to the ancient seasonal description of spring (from March to May) and autumn (from September to November), the harvesting and processing regulations for \textit{S. miltiorrhiza} in the 2015 edition of the CP (spring, autumn two-season digging, sediment removal, and drying) basically followed the collection methods recorded in the past dynasties. In the modern study, the content of active components of \textit{S. miltiorrhiza} was taken as the index to investigate the rationality of the collection period of \textit{S. miltiorrhiza}. Zhao studied the changes in the content ratio of dry matter in the roots of \textit{S. miltiorrhiza}, i.e., phenolic acids and tanshinones, at different growth stages. The results showed that the ratio of salvianolic acid B, cryptotanshinone, and tanshinone IIA in the entire growth period was stable at the beginning of August and remained stable until the 2nd year. To comprehensively consider the harvest period of \textit{S. miltiorrhiza} and content of active ingredients, it was indicated that this should be done before spring germination. Deng et al. used Yu \textit{S. miltiorrhiza} in Henan City as the research goal. By examining the dry weight of \textit{S. miltiorrhiza}, the alcohol-soluble extract of \textit{S. miltiorrhiza}, and the content of salvianolic acid B, the optimal harvest period of \textit{S. miltiorrhiza} was determined to be late October. Another survey concluded that the best harvest period of \textit{S. miltiorrhiza} was October.

\textit{S. miltiorrhiza} is a perennial herbaceous plant with different harvesting time limits in different regions. In the wild, a single plant of \textit{S. miltiorrhiza} can grow up to 3 years or longer. Liu et al. used high-performance liquid chromatography (HPLC) to determine the content of fat-soluble components and water-soluble components in \textit{S. miltiorrhiza} at different growth years. White flower \textit{S. miltiorrhiza} had better quality for 1 year, and purple flower had better quality for 2 years. Following Zhou et al.’s analysis of economic yield and effective chemical composition content, 2-year-old \textit{S. miltiorrhiza} is superior to 1-year-old one. Studies have shown that \textit{S. miltiorrhiza} yield in 2 years is significantly higher, compared to the yield after 1 year of planting; salvianolic acid B is higher after 2 years, while tanshinone content is higher after 1 year. Aging and decay are severe. Some scholars compared the relationship between the trace elements and chemical components of Yu’s \textit{S. miltiorrhiza} in different periods and found that the content of active ingredients in \textit{S. miltiorrhiza} in 1 year positively correlated with the trace elements, making it suitable for harvest. Investigation in actual production found that most cultivated \textit{S. miltiorrhiza} was harvested 1 year after planting, and it was difficult to distinguish the specific age of the root system during the mining process.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{image.png}
\caption{Processing process of \textit{Salvia miltiorrhiza}}
\end{figure}
Processing
The processing methods of *S. miltiorrhiza* aim at throwing away the soil after excavation, removing impurities, and dividing the size into the thick and dry forms. Many production areas exist for *S. miltiorrhiza*, and different regional environments and climatic environments lead to different processing methods. See Table 1 for details. The quality of medicinal materials is easily affected by the external environment, which affects the loss of active ingredients. Drying methods are the key factors affecting quality. *S. miltiorrhiza* drying methods include shade drying (Yin-Gan), sunlight drying (Shai-Gan), oven drying (Hong-Gan), and sweating (Fa-Han). Several scholars have reported different drying methods, but there is no unified consensus on the ancient and modern research on the specific processing methods of freshly cut *S. miltiorrhiza*.

Shade drying (Yin-Gan)
Drying in the shade is called the blinding method. The Chinese medicinal materials are placed indoors or in a cool place, and the flowing air is used to reduce the moisture of the medicinal materials, to achieve the purpose of natural drying. Qi used fresh *S. miltiorrhiza* as the research object and discussed the changing rules of 13 kinds of active ingredients during the process of drying and water loss. The results showed that the total content of fat-soluble components was the highest when dried in the shade with 30% water content, while the highest total content of water-soluble components was 15% water content. The fat-soluble tanshinone is called tanshinone-type diterpene quinone and is mainly concentrated in the root cork tissue. The root after passing through shade drying is redder than other methods. By comparing the effects of different processing methods on the quality of Shan-Dong *S. miltiorrhiza*, the study found that drying in the shade is most beneficial to the retention of active ingredients. There was no significant difference between the shaded part and the whole content.

Sunlight drying (Shai-Gan)
This method of drying using the thermal energy of sunlight is referred to as sunlight drying. Sunlight drying does not require a special equipment, is simple and easy to operate, and has a low cost, but is unsuitable for large-scale industrial production because it takes a long time. This experiment proved that the tanshinone components, cryptotanshinone and tanshinone IIA, are sensitive to temperature. It easily decomposes and deteriorates the color of and reduces the curative effect of medicinal materials. High temperature (80°C–100°C) drying has little effect. The volatile components are sensitive to sunlight and temperature. Exposure to sunlight for a long time can easily damage the components. However, the water-soluble component salvianolic acid B increased in proportion to the other components, in drought stress. Hou found that the content of salvianolic acid B was the highest after sun drying.

Oven drying (Hong-Gan)
Oven drying uses the method of external heating to dry the medicinal materials in a short time. Because not only the temperature can be controlled, but also the work efficiency is high, so it is widely used in industry. Some researchers showed that with the increase of the drying and dehydration rate of fresh *S. miltiorrhiza*, the content of phenolic acid positively correlated with the dehydration rate, and the content of tanshinone components was not vastly altered. The oven drying at 50°C was better than sun drying. Blast drying uses the principle of physical air drying to drain the internal moisture of the medicinal materials. Infrared blast drying is used to treat *S. miltiorrhiza*. Compared with the dry product, the dried products have a higher content of salvianolic acid B and tanshinone IIA.

Sweating (Fa-Han)
“Sweating” is a unique origin processing technology. Conventionally, “sweating” is conducive to the drying of medicinal materials, making them easy to store and improving their quality. “Sweating” will change the *S. miltiorrhiza* to purple-red. Under the action of active enzymes, the lighter-colored cryptotanshinone component is converted into the darker-tanshinone IIA component, to increase the content. The composition and content of phenanthrenequinone are closely related. The study found that the content of rosmarinic acid in *S. miltiorrhiza* after “sweating” was reduced, there was no significant difference in the composition of salvianolic acid B, and the content of cryptotanshinone and tanshinone IIA increased significantly. Conventional processing methods of medicinal materials have a profound connotation. The science and rational of the “sweating” process should be combined with in-depth clinical efficacy to further reveal its principle.

Fresh cutting (Xian-Qie)
The fresh-cutting technology greatly reduces the burden on the process flow and production cost. The freshly cut pieces processed by this method can maximize the quality; hence, it is a suitable processing method and has a good promotion prospect. The fresh *S. miltiorrhiza* was processed into decoction pieces, and comprehensive evaluation was made based on the decoction appearance, moisture, water-soluble extract, alcohol-soluble extract, and active ingredient content. Compared with other drying methods, fresh cut scores were higher. The production areas of traditional Chinese medicinal materials are cut fresh, which can again effectively shorten the medicinal material infiltration processing procedure. Zhao et al. explored the feasibility of replacing the traditional cutting method by the traditional medicinal material cut production method. The color of the cut section remains unchanged. After drying at 40°C, the cut section becomes flat and white. The content of the most active ingredients here is significantly higher than that in sections obtained by the traditional methods.
### Ancient and Modern Processing Methods

#### Historical evolution of ancient processing

Historically, *Salvia miltiorrhiza* processing methods include purifying, wine-frying, and pig-blood-mixing. The preparation of *S. miltiorrhiza* was first recorded in a Tang Dynasty book called “Preparation of Thousands of Gold” (Bei-Ji-Qian-Jin-Yao-Fang, in Chinese). In this book, it is described as “crushed into rough or unfinished.” Another ancient book records the method as “cut.” By the arrival of the Song Dynasty, there had been further development which began to stir up speculation. *S. miltiorrhiza* for the first time appeared in the official regulations of the Taiping Huimin Heyao Administration (Tai-Ping-Hui-Min-He-Ji-Ju-Fang, in Chinese): “Go to head and prepare it carefully.” There were many methods of processing the material in the Ming Dynasty, with different forms, including “removing the reeds and filing,” “removing the yellow skin,” and “removing the reeds.” The wine-fried method (Jiu-Zhi, in Chinese) appeared for the first time in Liang Chao’s “Compendium of Materia Medica” (Ben-Cao-Jing-Ji-Zhu, in Chinese): “Slowly soak with wine” and “Wash with wine.” However, during the Qing Dynasty, the book “Bi Hua Medical Mirror” (Bi-Hua-Yi-Jing, in Chinese) recorded “wine-steamed” and “wine-fried.” The wine-fried *S. miltiorrhiza* has been used to date. The specific principles are not described in detail. More prominently, a book called “Ben Cao Haru” (Ben-Cao-Hai-Li, in Chinese) in the Qing Dynasty recorded stir-fried *S. miltiorrhiza* with pig’s blood.

#### Modern processing rules

The modern processing methods of *S. miltiorrhiza* include purifying and wine-frying. After a summary investigation, according to the CP and the regulations of various provinces and cities, regulations on the processing of *S. miltiorrhiza* were found to be different, with no standard technical parameters. As indicated in Table 2 the differences mainly exist in the thickness of the pieces, the amount of auxiliary materials, the firepower, and the degree of processing.

### Summary of Research on Processing Technology

The application of modern research to *S. miltiorrhiza* processing technology is summarized. Several differences were observed in the drying mode, time, and temperature.

#### Purifying process

Through the orthogonal experimental design, our group investigated the effects of different softening and cutting processes on the extract and content of *S. miltiorrhiza* and optimized the processing conditions by comprehensive scoring. The best softening processing conditions were obtained as follows: the amount of water added was 1.2 times of water, the soaking time was 8 h, and the drying temperature was 60°C. The cutting process of Radix Salviae Miltiorrhizae is simple and feasible, which provides a basis for the study of *S. miltiorrhiza*. Song used HPLC and an orthogonal experimental design to take the fat-soluble and water-soluble components in Gansu *S. miltiorrhiza* as indexes. The results showed that the water extraction of pure *S. miltiorrhiza* had little practical significance on the transfer rate of fat-soluble components of 2.4%. It had a significant effect on the content of the water-soluble component – salvianolic acid B.

#### Wine-processing

After wine-frying, the types and contents of the chemical components change significantly; some tanshinones and salvianolic acids underwent qualitative or quantitative changes. It is speculated that the enhanced blood circulation effect after the processing of *S. miltiorrhiza* is related to the conversion of its ingredients into more easily absorbable active ingredients, in the body. Li et al. studied the processing technology of *S. miltiorrhiza* by orthogonal experimentation. The contents of water extract, alcohol extract, tanshinone IIA, and salvianolic acid B in different process samples were determined, and a comprehensive scoring method was used to analyze the results. The optimum processing conditions of *S. miltiorrhiza* were obtained as follows: stir-fried for 12 min. The processing method is simple and feasible.

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**Table 1: Processing methods and characteristics of *Salvia miltiorrhiza* in producing area**

<table>
<thead>
<tr>
<th>Area</th>
<th>Sweated</th>
<th>Processing of producing areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shan-Dong, China</td>
<td>No</td>
<td>Sunlight dried: Cut off the stump after picking fresh <em>Salvia miltiorrhiza</em>. Cut the root strips above the diameter of 0.8 cm at the mother root, arrange them in order, expose them to the sun, turn them from time to time, tie them into small handfuls when they are 70%-80% dry, then air-dry them to dry, and box them into “strips”</td>
</tr>
<tr>
<td>Si-Chuan, China</td>
<td>Yes</td>
<td>Sweated: Dig up fresh <em>Salvia miltiorrhiza</em> root strips and dry them until semi-dry or 70%-80% dry. When the root strips become soft, pile them together or put them directly into a white plastic bag and seal them. After sweating for 5 days, spread them out for 1-2 days and pile them up. After repeated operation until the whole pile of “sweating” is uniform, when the core of the root strip changes from white to purple-black, spread out and dry to remove the rash, and cut off the fine tail to become the finished product of Radix Salviae Miltiorrhiza</td>
</tr>
<tr>
<td>Shan-Xi, China</td>
<td>No</td>
<td>Dried in the shade/sun-dried: After mining, <em>Salvia miltiorrhiza</em> used to remove the soil, remove the part of the root, air-dry to semi-dry, and then accumulate and air-dry. Pile it into a pile about 2 m wide and 10 m long outside, dry in the sun, open it when the weather is good, and then collect it into a pile, repeated many times until dry</td>
</tr>
<tr>
<td>He-Nan, China</td>
<td>No</td>
<td>Dried in the wind/dried in the shade: After the excavation, remove the impurities from the soil, place the <em>Salvia miltiorrhiza</em> in a clean field for drying in the shade, lay the air with a thickness of about 6 cm, and turn it for a long time to dry</td>
</tr>
<tr>
<td>An-Hui, China</td>
<td>No</td>
<td>Mainly dried in a drying room: Collect fresh <em>Salvia miltiorrhiza</em> to remove the miscellaneous stems and parts on the ground, evenly spread it on the drying room, and bake the Kang, with a thickness of about 10 cm, and bake it at 50°C-55°C until dry</td>
</tr>
</tbody>
</table>
Table 2: Details of Salvia miltiorrhiza processing methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Specific records</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purified (净制)</td>
<td>Remove impurities and residual stems, wash, smooth, slice thick, dry</td>
<td>The Chinese Pharmacopoeia (2015 edition)[1]</td>
</tr>
<tr>
<td></td>
<td>Take the original medicinal materials, remove impurities and residual stems,</td>
<td>The 2008 Edition of “Beijing” Traditional Chinese Medicine Pieces</td>
</tr>
<tr>
<td></td>
<td>and wash them quickly for 2-4 h, until the internal and external humidity is</td>
<td>Processing Standards[44]</td>
</tr>
<tr>
<td></td>
<td>the same; cut into 5-10 mm thick pieces, dry them, and sieve out the debris</td>
<td>The 2008 Edition of “Shanghai” Traditional Chinese Medicine Pieces</td>
</tr>
<tr>
<td></td>
<td>Remove the impurities such as residual stems from the original medicine,</td>
<td>Processing Standards[31]</td>
</tr>
<tr>
<td></td>
<td>wash, moisten, cut into thick slices, dry, and sieve out the ashes</td>
<td>The 2012 Edition of “Tianjin” Traditional Chinese Medicine Pieces</td>
</tr>
<tr>
<td></td>
<td>Remove impurities and residual stems, wash, moisten, slice, and dry</td>
<td>Processing Standards[34]</td>
</tr>
<tr>
<td></td>
<td>Remove the impurities, clean the soil, take out, moisten thoroughly, cut 1.5</td>
<td>The 1986 Edition of “Jilin” Province Traditional Chinese Medicine</td>
</tr>
<tr>
<td></td>
<td>mm pieces, and dry in the sun</td>
<td>Pieces Processing Standards[17]</td>
</tr>
<tr>
<td></td>
<td>Pick up the impurities, remove the residual stems, wash, moisten, slice, dry,</td>
<td>The 1986 Edition of “Liaoning” Province Traditional Chinese Medicine</td>
</tr>
<tr>
<td></td>
<td>sift away the ash</td>
<td>Pieces Processing Standards[48]</td>
</tr>
<tr>
<td></td>
<td>Remove impurities and residual stems, wash, moisten, slice, and dry</td>
<td>The 2005 Edition of “Henan” Province Traditional Chinese Medicine</td>
</tr>
<tr>
<td></td>
<td>Take the original medicinal materials, remove the impurities and residual</td>
<td>Pieces Processing Standards[49]</td>
</tr>
<tr>
<td></td>
<td>stems, wash, moisten them thoroughly, cut them into thick slices, dry them,</td>
<td>The 2005 Edition of “Anhui” Province Traditional Chinese Medicine</td>
</tr>
<tr>
<td></td>
<td>and sift away the debris</td>
<td>Pieces Processing Standards[46]</td>
</tr>
<tr>
<td>Stir-fried (切制)</td>
<td>Remove impurities and residual stems, wash, moisten, slice or slice, dry</td>
<td>The 2010 Edition of “Hunan” Province Traditional Chinese Medicine</td>
</tr>
<tr>
<td></td>
<td>Remove impurities and residual stems, wash, moisten, cut into thick slices,</td>
<td>Pieces Processing Standards[31]</td>
</tr>
<tr>
<td></td>
<td>dry, sift out dust</td>
<td>The 2015 Edition of “Sichuan” Province Traditional Chinese Medicine</td>
</tr>
<tr>
<td></td>
<td>Take the original medicine, remove the impurities and residual branches and</td>
<td>Pieces Processing Standards[42]</td>
</tr>
<tr>
<td>Wine-fried (酒制)</td>
<td>leaves, and screen out the ashes</td>
<td>The 1984 Edition of “Guangdong” Province Traditional Chinese Medicine</td>
</tr>
<tr>
<td></td>
<td>Take the original medicine, remove the impurities such as fibrous roots and</td>
<td>Pieces Processing Standards[43]</td>
</tr>
<tr>
<td></td>
<td>residual stems, wash them, moisten them, cut them into thick slices, dry them,</td>
<td>The 2005 Edition of “Guizhou” Province Traditional Chinese Medicine</td>
</tr>
<tr>
<td></td>
<td>if they have been sliced in the production area, sift out the debris</td>
<td>Pieces Processing Standards[44]</td>
</tr>
<tr>
<td></td>
<td>Stir fry raw Salvia miltiorrhiza until it is slightly scorched. Sift out the</td>
<td>The 2015 Edition of “Zhejiang” Province Traditional Chinese Medicine</td>
</tr>
<tr>
<td></td>
<td>ashes</td>
<td>Pieces Processing Standards[45]</td>
</tr>
<tr>
<td></td>
<td>Take the pure Salvia miltiorrhiza tablet, stir fry it gently until it is purple</td>
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</tr>
<tr>
<td></td>
<td>brown with scorching spots</td>
<td></td>
</tr>
<tr>
<td>Pig’s blood mixed</td>
<td>Take Salvia miltiorrhiza tablets, stir fry with yellow wine according to the</td>
<td></td>
</tr>
<tr>
<td>(猪心血制)</td>
<td>wine roasting method until the color deepens</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Take the ginseng tablets, according to the wine burning method fried dry</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Take raw Salvia miltiorrhiza and mix it with fresh pig heart blood and</td>
<td></td>
</tr>
<tr>
<td>Bran-fried (麦麸制)</td>
<td>yellow rice wine mixture to make it suck up. Dry. Blood was taken from</td>
<td></td>
</tr>
<tr>
<td></td>
<td>three fresh pig hearts. Add 30 g yellow rice wine and mix well</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Take slices and stir fry with wheat bran until yellowish</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Take the slices and fry them dry according to the blood roasting method of</td>
<td></td>
</tr>
<tr>
<td>Turtle blood mixed</td>
<td>turtle</td>
<td></td>
</tr>
<tr>
<td>(馴血制)</td>
<td>Vinegar stir-fry</td>
<td></td>
</tr>
<tr>
<td>Vinegar-fried (醋制)</td>
<td>Salt water fried</td>
<td></td>
</tr>
<tr>
<td>Salt-fried (盐制)</td>
<td>Salt water fried</td>
<td></td>
</tr>
</tbody>
</table>

Hu et al.[53] studied the processing conditions for Radix Salviae Miltiorrhizae and determined the content of tanshinone-IIA in the processed samples by ultraviolet spectrophotometry, as an index. The four factors that affected the quality of wine-fried S. miltiorrhiza were selected by orthogonal design. The best processing conditions were basically consistent with the traditional wine moxibustion S. miltiorrhiza conditions: the best wine-fried condition is to add 20% of yellow rice wine and bake at 80°C for 2 h. Chang[54] selected two-year-old Salvia miltiorrhiza to compare the content of tanshinone IIA under four processing methods, and the results showed that the content of tanshinone IIA in alcoholic beverages was reduced. The results showed that wine-frying made S. miltiorrhiza removed the soothing effect and increased its medicinal properties. At the same time, the IIA content of tanshinone decreased although wine-steaming was the best processing technology.

**Vinegar-processing**

The orthogonal experiment was used as the design scheme, and
the content of tanshinone IIA was used as the evaluation index to investigate the three factors of vinegar quantity, processing time, and processing temperature of *S. miltiorrhiza* vinegar, so as to optimize the optimum technological conditions for the production of *S. miltiorrhiza* vinegar. The results showed that the best technological conditions for the preparation of *S. miltiorrhiza* vinegar were 30% vinegar, with a processing time of 60 min and a processing temperature of 60°C, which not only ensured the content of tanshinone-IIA but also saved costs and resources.[55]

**Effect of Processing on the Chemical Composition of Salvia miltiorrhiza**

The chemical constituents of *S. miltiorrhiza*, mainly divided into water-soluble components and fat-soluble components, change in content and structure after processing.[56] Many studies have evaluated the influence of different processing technologies by comparing the chemical composition of medicinal materials before and after processing.

**Tanshinone**

Tanshinone ingredients are more sensitive to light conditions, affect the color of medicinal materials, and reduce their efficacy.[57] Studies have reported that *S. miltiorrhiza* can reduce the content of tanshinone IIa under sun-dried, dark-dried, fried, and wine-fried conditions. Sunlight drying had the greatest impact, with a 43.8% tanshinone IIa loss rate. This was closely followed by the fried and wine-fried methods. The least impact was observed in those dried in the absence of light, with a 9.4% tanshinone IIa loss rate.[58] Therefore, *S. miltiorrhiza* is best to dry in the absence of light. Scholars[59] used tanshinone IIa as an internal standard to establish a one-test multi-evaluation HPLC method for the determination of four fat-soluble components of dihydrotanshinone I, tanshinone I, tanshinone IIa, and cryptotanshinone. The results showed that the content of these four components decreased after wine-frying. Wu et al.[60] used the HPLC-TOF/MS method to compare the number of ion peaks and peak area and main chemical components before and after wine-frying. After observing the wine-processed *S. miltiorrhiza*, the peak areas of cryptotanshinone, tanshinone IIa, and tanshinone decreased significantly, while the peak areas of dihydrotanshinone I and tanshinone I increased.

**Phenolic acids**

The content of salvianolic acid B in the processed products of *S. miltiorrhiza* was determined by the HPLC. Among them, the salvianolic acid B content in wine-fried *S. miltiorrhiza* was the highest. The content of salvianolic acid B in rice-processed salvia and fried salvia was negligible and that in vinegar-fried *S. miltiorrhiza* and raw *S. miltiorrhiza* was moderate. This indicates that salvianolic acid B has poor thermal stability. Studies have shown that ethanol and acidic additives increase the thermal stability of salvianolic acid B.[61] Fang et al.[62] investigated the changes and losses of salvianolic acid B during the production process of *S. miltiorrhiza*. Through the study of 10 batches of decoction pieces, the average content of salvianolic acid B at four sampling points of the original medicinal materials, washed medicinal materials, drenched medicinal materials, and slices was sequentially increased relative to that in the original medicinal materials that were washed directly. The final loss rate of salvianolic acid B was the highest, reaching 47.48%. It can be seen that the water washing process is strictly controlled in large-scale production to effectively retain the content of salvianolic acid B and improve the processing efficiency of *S. miltiorrhiza*.

**Polysaccharide**

Some studies[63] used traditional water extraction, alcohol precipitation and phenol sulfuric acid, and found that the polysaccharides in *S. miltiorrhiza* would increase after wine- fried, vinegar-fried or rice-fried. This indicates that different methods have different effects on the content of polysaccharides in *S. miltiorrhiza* decoction.

**Other**

Pig blood processing is a rare method in the processing of TCM. UPLC-Q-TOF/MS was used to analyze the changes in chemical composition before and after processing *S. miltiorrhiza*. Each ion peak was assigned using reference substance comparison, mass spectrometry data, database matching, and literature reference. The results showed that 59 components were identified before and after the preparation of *S. miltiorrhiza*, and the peak area of 25 chemical components changed significantly. The content of the ingredients changed significantly, among which the amino acid composition of *S. miltiorrhiza* had a quantitative change, which may be related to the effect of pig heart blood on promoting the treatment of cerebral ischemia by *S. miltiorrhiza*.[64]

**Effect of Processing on Pharmacological Effects**

Different products of *S. miltiorrhiza* show good pharmacological effects on prevention, treatment, or regulation of the body’s cardiovascular diseases, treatment of cerebrovascular and hematological diseases, and two-way regulation. Scholars around the world have conducted in-depth research on the pharmacological effects of *S. miltiorrhiza*, and summarized and analyzed the pharmacological mechanism of some active ingredients. However, the pharmacological changes of different processed products have not formed a system.[65,66]

**Cardiovascular diseases**

Wang[67] prepared the model of acute blood stasis in rats by the subcutaneous injection of epinephrine-ice water method and determined the pharmacological effects of *S. miltiorrhiza* ultrafine powder and decoction. It was found to significantly reduce the wet weight and dry weight of venous thrombosis in model rats and has anticoagulant and anti-thrombotic effects. The pharmacological effects of equal doses are similar. Jiang[68] studied the effects of wine-based *S. miltiorrhiza* and rhubarb on blood rheology in rats and verified that their
Regarding the effects of processing on the chemical composition of *S. miltiorrhiza*, the current research results do not align; the clinical aspect of wine-frying has a stronger clinical effect on promoting blood circulation and removing blood stasis but is weaker than raw *S. miltiorrhiza* in anticerar and anti-inflammatory effects. There are few studies on the mechanism of pharmacological action. Establishing an exclusive quality evaluation system for different pieces of *S. miltiorrhiza* to ensure the safety and effectiveness of clinical pieces is therefore essential. This will go in line with increasing the inspection of varieties, strengthening technical research, controlling the quality from the source, and deeply exploring local characteristics of technology. This will help increase the research on the processing technology of *S. miltiorrhiza*, systematically excavate and organize its processing methods and processes, and analyze its processing significance with modern research methods. Subsequently, these will tightly integrate demand, increase revenue, increase application value, provide production indicators for enterprises, and promote the sustainable use of resources.

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**Conflicts of interest**

There are no conflicts of interest.

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