

Comparison of efficiency and composition of ultrasonic extraction and conventional extraction of Chinese medicine formula particles

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Abstract: The purpose of this paper was to compare and analyze the application of ultrasonic extraction and conventional extraction methods in Chinese medicine formula particles. By exploring the differences in extraction efficiency, component distribution, component stability and quality control, the advantages of ultrasonic extraction in improving extraction efficiency, optimizing component stability and enhancing the curative effect of traditional Chinese medicine were revealed. The results show that ultrasonic extraction can significantly improve the extraction efficiency through its unique cavitation effect, and effectively avoid the degradation of components caused by high temperature, and has good component selectivity and stability. Therefore, ultrasonic extraction technology has wide application potential in the modern production of traditional Chinese medicine.

1. Introduction

As an important form of modern Chinese medicine preparation, the extraction technology of Chinese medicine formula granule has a direct influence on its efficacy and quality. Although the traditional water extraction method and alcohol extraction method are widely used in the field of traditional Chinese medicine extraction, they have gradually failed to meet the requirements of modern Chinese medicine industry for extraction efficiency and component stability due to complex operation, low extraction efficiency and possible degradation of components. In recent years, ultrasonic extraction has gradually become an efficient and environmentally friendly alternative method because of its unique advantages. By comparing the performance of ultrasonic extraction and conventional extraction methods in Chinese medicine formula particles, the differences in extraction efficiency, composition and stability of the two methods were analyzed.

2. Overview and analysis of conventional extraction methods

2.1 Traditional application of water extraction and alcohol extraction

In the process of extracting Chinese medicine formula particles, water extraction and alcohol extraction, as the two most classic and widely used conventional extraction technologies, have become one of the core methods of extracting Chinese medicine components after years of development and practice. Water extraction, as the name suggests, mainly relies on water as a solvent to extract the active components of Chinese medicinal materials^[1]. The advantage of water as a solvent is that it is non-toxic, pollution-free and has good solubility, especially suitable for the extraction of water-soluble components. The traditional water extraction method takes decocting as the main means, and uses the high temperature action of water to release the effective components of the medicinal materials into the solution, so as to obtain the essence of the traditional Chinese medicine formula. Although this method is simple and low cost, its extraction time is long, and it can not effectively extract fat soluble components, especially when extracting complex components or high-efficiency components, there are certain limitations. The extraction efficiency of the water extraction method is significantly affected by factors such as water temperature, decocting time and drug particle size, and the control accuracy in the operation process is directly related to the extraction effect^[2].

In contrast, alcohol extraction focuses more on the use of alcohol solvents (such as ethanol or methanol) to extract fat-soluble components from traditional Chinese medicine. Alcohol extraction has significant advantages in the extraction of volatile oil, flavonoids, steroids and other components, especially for those compounds with poor water solubility or insoluble in water. The advantage of alcohol extraction is that it can efficiently extract the effective components of medicinal materials in a short time, and the extracted components are stable and easy to preserve. However, this method is not without disadvantages, the use of alcohol solvents often involves high operating costs, and the toxicity of alcohol solutions also need to be strictly controlled in practical applications. The extraction process of alcohol extraction is complicated, involving many factors such as the choice of solvent, concentration control and extraction temperature. If the operation is not proper, it will easily lead to the degradation of some components or the residue of solvent, which will affect the efficacy and quality of medicinal materials.

2.2 The efficiency and limitations of conventional extraction methods in TCM formula particles

Conventional extraction methods play an important role in the production process of Chinese medicine formula particles, but the extraction efficiency and limitations reflected in practical applications often become one of the key factors affecting the quality and effect of the final product^[3]. As the most common traditional extraction technology, water extraction and alcohol extraction are widely used in the production of Chinese medicine formula particles, but the efficiency of these methods is particularly prominent. Although water extraction method can extract some water-soluble components efficiently, there are significant deficiencies in the extraction of fat-soluble compounds. Since many important active ingredients in Chinese medicinal materials, such as volatile oils, steroids and some flavonoids, are often poorly soluble, the singularity of water extraction makes it difficult to fully extract these fat-soluble ingredients, which may affect the comprehensive efficacy of formula granules. Water extraction in some complex formulations, often can not meet the needs of comprehensive extraction.

On the other hand, alcohol extraction does show high efficiency in the extraction of fat soluble components, but its limitations should not be ignored. Although the use of alcohol solvents improves

the extraction rate of some components, due to the particularity of solvent properties, the extraction of many alcohol-soluble substances is often accompanied by the risk of solvent residue, especially in large-scale production. How to avoid the pollution of solvents to the finished products has become an urgent problem to be solved^[4]. Alcohol extraction requires precise control of solvent concentration, extraction temperature and time in the operation process, which has high requirements for equipment and process, and a slight mistake may lead to the degradation of components or the decline of extraction efficiency, further affecting the quality and stability of particles. More importantly, the efficiency of conventional extraction methods is often limited by time and human resources, especially in the case that some Chinese medicinal materials need to be decocted for a long time or extracted several times, the complexity and cost of the extraction process rise significantly, making the entire production cycle elongated, production efficiency and economic benefits limited.

2.3 The influence of conventional extraction on the selectivity and stability of traditional Chinese medicine ingredients

Conventional extraction methods, especially water extraction and alcohol extraction, have a profound influence on the selectivity and stability of medicinal ingredients in the production process of Chinese medicine formula granules. From the point of view of selectivity, these traditional extraction methods often have a bias to specific compounds when extracting the active ingredients of medicinal materials. Taking water extraction as an example, it mainly relies on the polar dissolution characteristics of water, and can efficiently extract water-soluble components such as polysaccharides and amino acids, but the extraction effect is relatively weak for fat-soluble components, especially volatile oil and steroid components^[5]. As a result, water extraction is often difficult to fully extract all possible active ingredients in Chinese medicine formulations, resulting in the breadth of its efficacy is limited. Similarly, although alcohol extraction can extract fat soluble components well, the extracted components usually have selective rejection of water-soluble compounds, which further aggravates the problem of composition imbalance in the extraction process. This selective extraction not only affects the comprehensiveness of the drug, but also may lead to the absence of some key ingredients, affecting the therapeutic effect of the traditional Chinese medicine formula.

Conventional extraction methods also have significant effects on the stability of the components. In the process of traditional water extraction and alcohol extraction, especially under the conditions of high temperature and long time frying or soaking, some sensitive ingredients are easily degraded or transformed. For example, in water extraction, long-term high temperature frying may lead to the loss of certain heat-sensitive components such as volatile oils, phytosterols, etc., or chemical reactions occur during the extraction process of active substances, reducing their efficacy. Alcohol extraction also has similar problems, especially in the use of high concentration of alcohol solvents, some components may be strongly affected by the solvent, resulting in changes in their structure, which in turn affects their pharmacological activity. More complicated is the residual problem of alcohol solvents, which not only affects the stability of the ingredients, but also may bring safety risks, seriously affecting the quality and efficacy of the final product.

3. Comparison of ultrasonic extraction efficiency with conventional extraction efficiency

3.1 Comparison of the influence of extraction time, temperature and solvent

In the efficiency comparison between ultrasonic extraction and conventional extraction, extraction time, temperature and solvent selection play a crucial role. The influence of extraction time is particularly prominent between the two. Traditional water extraction methods and alcohol extraction

methods usually require a long extraction time, especially in the process of frying or soaking, and the extraction efficiency is often gradually improved with the extension of time, but at the same time, it is also accompanied by energy consumption and component degradation risk. In general, the extraction time of water extraction can reach several hours, alcohol extraction usually takes 1-2 hours to complete effective extraction, and ultrasonic extraction method greatly reduces this time, and its extraction time is usually 10-30 minutes. This significant difference is not only reflected in the time efficiency, but also reduces the possible degradation of the active ingredient at high temperatures and maintains the stability of the ingredient.

The difference of extraction temperature also shows the advantages of ultrasonic extraction technology. Conventional extraction methods, such as water extraction, usually require higher temperatures (about 80 °C-100 °C) to achieve higher extraction efficiency, although high temperatures help to increase the solubility of components, but at the same time may cause the loss of some heat-sensitive components. In contrast, ultrasonic extraction can be carried out at lower temperatures (usually 30 °C-60 °C), which not only improves the extraction efficiency, but also promotes the release of components at lower temperatures due to its unique mechanical vibration, reducing the risk of thermal degradation.

The influence of solvent selection on the two extraction methods is also different. While conventional extraction methods usually rely on water or alcohol solvents, ultrasonic extraction is more flexible and can use a variety of media such as water, alcohol solutions or even mixed solvents to achieve the best results in the extraction of different components. This diversified solvent selection enables ultrasonic extraction to accurately select the most suitable solvent according to the needs of different traditional Chinese medicine formulations, further improving the efficiency and selectivity of extraction.

The following are comparative data on the effects of extraction time, temperature, and solvent selection on the efficiency of ultrasonic extraction versus conventional extraction, See Table 1:

Table 1: Comparison of ultrasonic extraction efficiency with conventional extraction efficiency: influence of extraction time, temperature and solvent.

Extraction Method	Extraction Time	Extraction Temperature	Solvent Type	Extraction Efficiency
Ultrasonic Extraction	10-30 minutes	30 °C-60 °C	Water, Alcohol Solvents	High
Conventional Water Extraction	2-3 hours	80 °C-100 °C	Water	Medium
Conventional Alcohol Extraction	1-2 hours	60 °C-80 °C	Alcohol Solvents	Medium-High

3.2 Differences in extraction efficiency and component distribution

The differences in extraction efficiency and composition distribution between ultrasonic extraction and conventional extraction methods directly affect the final quality and curative effect of TCM formula granules. First, from the point of view of extraction efficiency, ultrasonic extraction, with its unique mechanical fluctuations, can significantly improve extraction efficiency in a short period of time. Through the cavitation effect produced by ultrasound, the interaction between solvent molecules and the cell wall of medicinal materials is stimulated, and the cell structure is rapidly destroyed, thus accelerating the release of active ingredients. This process not only greatly reduces the time required by traditional extraction methods, but also achieves efficient extraction at lower

temperatures, avoiding the thermal degradation of some components under high temperature conditions, and ensuring the stability of the extract. In contrast, conventional extraction methods such as water extraction and alcohol extraction often take a longer time and are often accompanied by high temperature treatment, which limits the full extraction of components to a certain extent, especially for heat-sensitive or volatile components, the extraction effect of traditional methods is significantly lower than ultrasonic extraction.

From the perspective of component distribution, ultrasonic extraction can not only improve the extraction efficiency, but also extract the active components in medicinal materials more uniformly. This is because the effect of ultrasound can promote the penetration and diffusion of solvents in medicinal materials particles, so that various components in medicinal materials are evenly distributed in the extract. In contrast, during the extraction process of conventional extraction methods, the contact between solvent and medicinal materials is not as uniform as that of ultrasonic extraction, resulting in some components may not be fully extracted due to incomplete solvent penetration, resulting in uneven distribution of components.

3.3 Comparison of the performance of ultrasonic extraction and conventional extraction in different Chinese medicine formula particles

In the comparative study of ultrasonic extraction and conventional extraction technology, the performance difference of different Chinese medicine formula particles revealed their respective advantages and limitations. First, ultrasonic extraction technology has shown higher efficiency and more uniform composition distribution in the extraction of many TCM formula particles. For example, for Chinese medicinal materials with complex components, such as ginseng, Astragalus, etc., ultrasonic extraction can break the plant cell wall through its unique cavitation effect and acoustic transmission, so that the effective ingredients are quickly dissolved and released, thus greatly improving the extraction rate and extraction efficiency. In contrast, the conventional water extraction method and alcohol extraction method have low extraction efficiency when dealing with these complex ingredients, especially when dealing with ginseng and Astragalus, which contain a large number of insoluble ingredients, the conventional method often takes a longer time, and the extracted ingredients are not as uniform as ultrasonic extraction. Especially in the extraction of flavonoids, saponins and other compounds, ultrasonic extraction can be more efficient and accurate to achieve full spectrum extraction, while conventional methods often have problems of incomplete extraction or composition deviation.

Furthermore, the adaptability of ultrasonic extraction in different solvent systems is also excellent. For example, when processing some medicinal materials that require alcohol solvents, ultrasonic extraction can not only reduce the amount of solvent, but also significantly improve the extraction efficiency of alcohol components, which effectively reduces cost and time consumption. However, the conventional alcohol extraction method is often carried out at a higher temperature, the amount of solvent and extraction time are relatively long, and the stability of the components can not be effectively guaranteed at a lower temperature. In addition, ultrasonic extraction can also maintain a relatively stable extraction effect in the extraction process of different medicinal materials due to its efficient delivery mechanism, while the conventional method is easy to cause component loss in the extraction of some volatile components, affecting the stability of extraction results.

The following is the comparative data about the performance of ultrasonic extraction and conventional extraction in different Chinese medicine formula particles, see Table 2:

Table 2: Comparison of ultrasonic extraction and conventional extraction in different Chinese medicine formula particles

TCM Granule	Extraction Method	Extraction Efficiency	Component Uniformity	Extraction Time	Solvent Usage
Ginseng	Ultrasonic Extraction	High	High	30 minutes	Small Alcohol Solvent
Ginseng	Conventional Alcohol Extraction	Medium	Medium	2 hours	Large Alcohol Solvent
Astragalus	Ultrasonic Extraction	High	High	20 minutes	Small Water or Alcohol
Astragalus	Conventional Water Extraction	Medium	Low	3 hours	Large Water
Reishi Mushroom	Ultrasonic Extraction	High	High	40 minutes	Small Alcohol Solvent
Reishi Mushroom	Conventional Alcohol Extraction	Medium	Medium	1.5 hours	Large Alcohol Solvent

4. Component analysis and comparison between ultrasonic extraction and conventional extraction

4.1 Quantitative and qualitative analysis of the main active ingredients in the extract

In the component analysis of ultrasonic extraction and conventional extraction, the quantitative and qualitative analysis of the main active components in the extract provides an important basis for evaluating the extraction effect of both. Qualitative analysis through chromatography, mass spectrometry and other technologies, can identify the types and structures of various chemical components in the extracts. With its efficient energy transfer mechanism, ultrasonic extraction technology can release chemical components in medicinal materials more comprehensively, especially in the extraction of fat-soluble components. Through the analysis of ultrasonic extract, it was found that it had high component diversity and richness in the extraction of volatile oil, flavonoids, steroids and other components. This is because the cavitation effect produced by ultrasound can effectively destroy the cell wall, promote solvent penetration and quickly release the active components in the cell, thus making the spectrum of chemical components in the extract more comprehensive and complex. In contrast, conventional extraction methods such as water extraction and alcohol extraction, due to the longer extraction time and relatively simple operating conditions, extract fewer components, and in the process of extraction of heat-sensitive components, high temperature treatment often leads to the degradation or transformation of some components, thus affecting the composition and activity of the extract.

Quantitative analysis was mainly conducted by means of high performance liquid chromatography (HPLC) and gas chromatography (GC) to determine the content of the main active ingredients in the extract. Due to its high extraction efficiency, the concentration of active ingredients in ultrasonic extraction is usually significantly higher than that of conventional extraction methods. Taking flavonoids as an example, ultrasonic extraction can extract more flavonoids in a short period of time,

and its extraction amount is less dependent on the solvent concentration. In contrast, conventional water extraction method lacks in extraction efficiency and stability. Ultrasonic extraction method has shown advantages in the extraction of some fat-soluble components, such as ginsenosides and ganoderma lucidum polysaccharide, especially at low temperature, which can still maintain high extraction efficiency, while conventional extraction often causes the degradation of components due to high temperature for a long time, thus affecting their activity and curative effect.

4.2 The correlation between the difference of component composition and the efficacy of traditional Chinese medicine

In the component analysis of ultrasonic extraction and conventional extraction, the difference of component composition has a key effect on the curative effect of traditional Chinese medicine. Ultrasonic extraction through efficient acoustic energy transfer and cavitation effect, so that the effective ingredients in Chinese medicinal materials can be released more quickly and comprehensively, which not only significantly improves the extraction efficiency, but also ensures that more active ingredients are retained. Compared to traditional water and alcohol extraction methods, ultrasonic extraction is often able to extract a wider range of chemical components in a shorter period of time, especially those present in cell walls or other hard-to-reach locations. Therefore, the composition spectrum of ultrasonic extraction in Chinese medicine formula granules is more abundant, covering more pharmacologically active ingredients. This difference in composition directly affects the overall efficacy of traditional Chinese medicine. The extract obtained by ultrasonic extraction not only has more comprehensive components, but also has more full synergies between components, which enhances its therapeutic effect, especially in the process of conditioning and treatment of complex diseases, and can play a more significant comprehensive effect.

In contrast, conventional extraction methods such as water extraction and alcohol extraction, due to their long extraction time and high temperature, often lead to the degradation or loss of some heat-sensitive components, which affects the integrity and stability of components. For example, when using the water extraction method to extract certain herbs, although a certain amount of water-soluble components can be extracted, it is often impossible to extract the volatile oil and fat-soluble components in them, which are often crucial to the overall efficacy of the traditional Chinese medicine. Although alcohol extraction method can extract more fat soluble components, but the extraction effect of water soluble components is relatively poor. Due to the incomplete extraction of components, conventional extraction methods often lead to the efficacy of traditional Chinese medicine is not as comprehensive and efficient as ultrasonic extraction.

The difference in composition also affects the stability and persistence of the drug effect. Due to its low operating temperature and short extraction time, ultrasonic extraction can effectively avoid thermal degradation and ingredient loss, so as to maintain a higher component stability and ensure the continuous efficacy of traditional Chinese medicine formulations. However, the conventional extraction method may cause degradation and oxidation of components due to high temperature and long-term soaking during the extraction process, thus affecting the stability and durability of the therapeutic effect.

4.3 Stability and quality control of components

In the component analysis of ultrasonic extraction and conventional extraction methods, the stability and quality control of components are one of the key factors affecting the efficacy and safety of TCM formula particles. Due to its short time and low temperature operation characteristics, ultrasonic extraction can effectively avoid the degradation of some heat-sensitive components at high temperatures in the extraction process, so as to maintain a high component stability. The volatile oils,

polysaccharides, phenolic acids and other components of some traditional Chinese medicines are prone to chemical changes under high temperature conditions, resulting in reduced efficacy. By using low temperature and high penetrating power of sound wave, ultrasonic extraction can minimize the loss of these components and maintain the integrity and stability of their chemical structure while ensuring efficient extraction. Ultrasonic extraction not only improves the extraction rate of components, but also provides a reliable guarantee for the quality control of Chinese medicine formula particles.

Conventional extraction methods, especially water extraction and alcohol extraction, often rely on higher temperatures and longer extraction time, and this high temperature and long exposure often lead to the degradation of some heat-sensitive components, which affects the quality and efficacy of the extract. For example, water extraction often requires frying at high temperatures, and alcohol extraction often relies on high concentrations of alcohol solvents, which pose a potential threat to the stability of the ingredients. In the operation process of conventional extraction methods, the control of extraction temperature, time, solvent concentration and other factors is more complicated, if the improper operation, it is easy to trigger the oxidation, degradation and other reactions of the components, affecting the quality and consistency of the final extract.

5. Conclusions

Ultrasonic extraction technology has shown remarkable advantages in the production of Chinese medicine formula particles. Compared with traditional extraction methods, ultrasonic extraction can not only significantly shorten the extraction time, but also improve the extraction efficiency and optimize the stability of components. By reducing the damage caused by high temperatures, ultrasonic extraction can improve the selectivity and uniformity of the ingredients while ensuring the integrity of the ingredients. Although the conventional extraction method is still widely used, ultrasonic extraction technology has become a powerful tool for the modern production of traditional Chinese medicine with its characteristics of high efficiency, accuracy and environmental protection, and has broad application prospects..

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