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## Methods of Extraction: Maceration, Percolation and Decoction

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### ABSTRACT

Today, natural medicines not only provide the primary healthcare needs for the majority of the population in developing countries but have attracted more and more attention in developed countries due to soaring healthcare costs and universal financial austerity. In the USA, approximately 49% of the population has tried natural medicines for the prevention and treatment of diseases. Chemicals known to have medicinal benefits are considered to be “active ingredients” or “active principles” of natural medicines. Natural products have provided the primary sources for new drug development.

### 1. Introduction

Today, natural medicines not only provide the primary healthcare needs for the majority of the population in developing countries but have attracted more and more attention in developed countries due to soaring healthcare costs and universal financial austerity. In the USA, approximately 49% of the population has tried natural medicines for the prevention and treatment of diseases.<sup>1</sup> Chemical known to have medicinal benefits is considered to be an “active ingredient” or “active principle” of natural medicines. Natural products have provided the primary sources for new drug development. From the 1940s to the end of 2014, nearly half of the FFDA-approved chemicals for the treatment of human diseases were derived from or inspired by natural products.<sup>2,3</sup> Natural products offer more drug-like features to molecules from combinatorial chemistry in

terms of functional groups, chirality, and structural complexity.<sup>4,5</sup> The amounts of active ingredients in natural medicines are always fairly low. The lab-intensive and time-consuming extraction and isolation process have been the bottleneck of the application of natural products in drug development. There is an urgent need to develop effective and selective methods for the extraction and isolation of bioactive natural products. This review intends to provide a comprehensive view of a variety of methods used in the extraction and isolation of natural products.

### Extraction

Extraction is the first step to separating the desired natural products from the raw materials. Extraction methods include solvent extraction, distillation method, pressing, and sublimation according to the extraction principle. Solvent extraction is the most

widely used method. The extraction of natural products progresses through the following stages: (1) the solvent penetrates into the solid matrix; (2) the solute dissolves in the solvents; (3) the solute is diffused out of the solid matrix; (4) the extracted solutes are collected. Any factor enhancing the diffusivity and solubility in the above steps will facilitate the extraction. The properties of the extraction solvent, the particle size of the raw materials, the solvent-to-solid ratio, the extraction temperature, and the extraction duration will affect the extraction efficiency.<sup>6-10</sup> The selection of the solvent is crucial for solvent extraction. Selectivity, solubility, cost, and safety should be considered in the selection of solvents. Based on the law of similarity and intermiscibility (like dissolves like), solvents with a polarity value near to the polarity of the solute are likely to perform better and vice versa. Alcohols (EtOH and MeOH) are universal solvents in solvent extraction for phytochemical investigation. Generally, the finer the particle size is, the better result of the extraction achieves. The extraction efficiency will be enhanced by the small particle size due to the enhanced penetration of solvents and diffusion of solutes. Too fine particle size, however, will cost the excessive absorption of solute in solid and difficulty in subsequent filtration. High temperatures increase solubility and diffusion. Temperatures that are too high, however, may cause solvents to be lost, leading to extracts of undesirable impurities and the decomposition of thermolabile components. The extraction efficiency increases with the increase in extraction duration in a certain time range. Increasing time will not affect the extraction after the equilibrium of the solute is reached inside and outside the solid material. The greater the solvent-to-solid ratio is, the higher the extraction yield is; however, a solvent-to-solid ratio that is too high will cause excessive extraction solvent and requires a long time for concentration. The conventional extraction methods, including maceration, percolation, and reflux extraction, usually use organic solvents and require a large volume of solvents and a long extraction time. Some modern or greener extraction methods

such as supercritical fluid extraction (SFC), pressurized liquid extraction (PLE), and microwave-assisted extraction (MAE), have also been applied in natural products extraction, and they offer some advantages such as lower organic solvent consumption, shorter extraction time and higher selectivity. Some extraction methods, however, such as sublimation, expeller pressing, and enfleurage are rarely used in the current phytochemical investigation and will not be discussed in this review. A brief summary of the various extraction methods used for natural products is shown in Table 1.

### **Maceration**

This is a very simple extraction method with the disadvantage of long extraction time and low extraction efficiency. It could be used for the extraction of thermolabile components. Ćujić et al. achieved high yields of total phenols and total anthocyanins from chokeberry fruit at an optimized condition with 50% ethanol, a solid-solvent ratio of 1:20, and particle size of 0.75 mm, which suggested that maceration was a simple and effective method for the extraction of phenolic compounds from chokeberry fruit.<sup>11</sup> A study on the extraction of catechin<sup>1</sup> from *Arbutus unedo* L. fruits using maceration, microwave-assisted, and ultrasound extraction techniques showed that microwave-assisted extraction (MAE) was the most effective, but a lower temperature was applied in maceration with nearly identical extraction yields, which can be translated into economic benefits.<sup>12</sup> Jovanović et al. evaluated the extraction efficiency of polyphenols from *Serpylli herba* using various extraction techniques (maceration, heat-assisted extraction, and ultrasonic-assisted extraction). Based on the content of total polyphenols, ultrasonic-assisted extraction produced the highest total flavonoids yield and no statistically significant differences were found between maceration and heat-assisted extraction.<sup>13</sup> *Cajanus cajan* leaves are used in Chinese folk medicine for the treatment of hepatitis, chickenpox, and diabetes. Flavonoids are bioactive compounds. Jin et al. compared extraction rates of

orientoside<sup>2</sup>, luteolin<sup>3</sup>, and total flavonoids from *C. cajan* leave by microwave-assisted method, reflux extraction, ultrasound-assisted extraction, and maceration extraction. The extraction efficiency of orient side, luteolin, and total flavonoids were found to be the lowest in the extract from the maceration method.<sup>14</sup>

### Percolation

Percolation is more efficient than maceration because it is a continuous process in which the saturated solvent is constantly being replaced by fresh solvent. Zhang et al. compared the percolation and refluxing extraction methods to extract *Undaria pinnatifid*. They found that the contents of the major component, fucoxanthin<sup>4</sup>, from the percolation extraction method were higher than that from the refluxing method while there was no significant difference in extract yield between the two methods.<sup>15</sup> Goupil patch is a compound Chinese medicine preparation consisting of 29 Chinese medicines. Fu et al. used the whole alkaloids content determined by acid-base titration as the index and optimized the ethanol percolation method by soaking the medicine with 55% alcohol for 24 h and then percolating with 12 times the amount of 55% alcohol.<sup>16</sup> When using the extracting rate of sinomenine<sup>5</sup> and ephedrine hydrochloride<sup>6</sup> as the index, Gao developed another optimized percolation method: soaking the medicine with 70% ethanol for 24 h and then percolating with 20 times the amount of 70% ethanol. The transfer rates of sinomenine and ephedrine hydrochlorides were 78.23 and 76.92%, respectively.<sup>17</sup>

### Decoction

The extract from decoction contains a large number of water-soluble impurities. A decoction cannot be used for the extraction of thermolabile or volatile components. The ginsenosides<sup>7-31</sup> in ginseng encounter hydrolysis, dehydration, decarboxylation, and addition reactions during decocting.<sup>18</sup> Zhang et al. investigated the chemical transformation of a famous TCM preparation, *Danggui Buxue Tang*, an herbal

decoction containing *Astragali Radix* and *Angelicae Sinensis Radix*. They found that two flavonoid glycosides, calycosin-7-O- $\beta$ -D-glucoside<sup>32</sup> and ononin<sup>33</sup>, in *Astragali Radix*, could be hydrolyzed to form calycosin<sup>34</sup> and formononetin<sup>35</sup>, respectively, during decocting. The hydrolysis efficiency was strongly affected by pH, temperature, and the number of herbs.<sup>19</sup> Two compounds of TCM, *Sanhuang Xiexin Tang* (SXT) and *Fuzi Xiexin Tang* (FXT), have been used in China for the treatment of diseases such as diabetes for thousands of years. SXT is composed of *Rhei Radix et Rhizoma*, *Scutellariae Radix*, and *Coptidis Rhizoma* while FXT is produced by adding another TCM, *Aconiti Lateralis Radix Preparata*, in SXT. Zhang et al. applied a UPLC-ESI/MS method to monitor 17 active constituents in SXT and FXT decoctions and macerations. The decoction process might enhance the dissolution of some bioactive compounds compared with the maceration process. The contents of 11 constituents [benzoylaconine<sup>36</sup>, benzoylhypaconine<sup>37</sup>, benzoylmesaconine<sup>38</sup>, berberine<sup>39</sup>, coptisine<sup>40</sup>, palmatine<sup>41</sup>, jatrorrhizine<sup>42</sup>, aloe-emodin<sup>43</sup> and emodin<sup>44</sup>, baicalin<sup>45</sup>, wogonoside<sup>46</sup>] in decoctions of SXT and FXT were significantly higher than those in macerations of SXT and FXT. The  $\beta$ -glucuronidase in herbs could catalyze the hydrolysis of the glucuronic acid group from glycosides (baicalin and wogonoside) to transfer into aglycones [baicalein<sup>47</sup> and wogonin<sup>48</sup>]. The high temperature in the decoction process deactivated the activity of the  $\beta$ -glucuronidase and prevented the transformation of glycosides to their aglycones, which led to the discovery of the higher contents of baicalin and wogonoside in decoctions as well as the higher contents of baicalein and wogonin in macerations. The interaction between chemicals from different herbs was also observed. The diester-diterpenoid alkaloids were not detected in the decoction and maceration of FXT, but diester-diterpenoid alkaloid hypaconitine<sup>49</sup> was found in the decoction of the single herb *Aconiti Lateralis Radix Preparata*. The constituents of the other three herbs in FXT might promote the

transformation from diester-diterpenoid alkaloids in Aconiti Lateralis Radix Preparata to other less toxic monoester-diterpenoid alkaloids, which might explain

the mechanism of toxicity reduction and efficacy enhancement of TCM by formulation.<sup>20</sup>

Table 1. A brief summary of various extraction methods for natural products

Method	Solvent	Temperature	Pressure	Time	The volume of organic solvent consumed	The polarity of natural products extracted
Maceration	Water aqueous and non-aqueous solvent	Room temperature	Atmospheric	Long	Large	Dependent on extracting solvent
Percolation	Water aqueous and non-aqueous solvent	Room temperature occasionally under heat	Atmospheric	Long	Large	Dependent on extracting solvent
Decoction	Water	Under heat	Atmospheric	Moderate	None	Polar compounds

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