REVIEW

The scientific elucidation of daodi medicinal materials

Xindan Liu1*, Ying Zhang1, Menghua Wu1, Zhiguo Ma1, Zihan Huang1, Fang Tian1, Sihan Dong2, Simin Luo2, Yu Zhou2, Jinju Zhang2, Nanxin Li2, Xiaofang He2 and Hui Cao1*

Abstract

Daodi medicinal materials (DMMs), with unique characteristics and specific ecological growing environments, are recognized as high-quality medicinal products of Chinese medicinal materials (CMMs). The quality evaluation of CMMs is fundamental for standardization. The concept and application of DMMs have a long history as described in records in ancient books and rooted in practice and experience over generations. DMM is the specific term for pure, superior medicinal herbs with the following characteristics: optimum harvest season (reflecting the appropriate developmental stage of the plant), scrupulous processing, traditional preparation technology, etc. As DMM and high-quality medicinal products are traditionally thought to be closely related, modern scientific studies that confirm the association of these products are described. This article aims to clarify the scientific elucidation of DMMs.

Keywords: Daodi medicinal materials, Chinese medicinal materials, Ecological environment, Chemical components, Pharmacological functions

Background

In recent years, as the use of Chinese medicinal materials (CMMs) has increased, the international attention paid to the safety, stability and efficacy of CMMs has increased. Some authentic and superior CMMs that are grown in specific regions and widely recognized as having better therapeutic effects are called daodi medicinal materials (DMMs) [1]. DMMs, based on the theory, origin, processing, and prominent curative effect of CMMs, are the essence of Chinese cultural heritage [2]. DMMs were first recorded in Zhen Zhu Nang Yao Xing Fu (Precious Drus in Rhyme), a book written 700 years ago. The term “daodi medicinal material” is widely found in Ben Cao Pin Hui Jing Yao (Essentials of Materia Medica Distinctions), a book compiled by the Imperial Hospital during the Ming Dynasty (1368–1644 A.D.), in which 268 medicinal herbals are listed. The entry “original source” was formally listed under each medicinal herb heading, specifying daodi production regions. It has been suggested that the quality of CMMs is highly correlated with their geographical origins. In ancient times, the identification of DMMs was commonly carried out based on the characteristics of the superfi cies, and this approach depended to a certain extent on empirical experiences and assumptions. Currently, modern scientific analytical techniques may be applied to confirm the validity of associations between high-quality medicinal products and DMM to ensure their utility, clarifying the scientific understanding of daodi medicinal materials.

The word “dao” (in “daodi”) is an ancient Chinese unit of measurement used to divide administrative districts, and this term can be retraced to the Eastern Han Dynasty (25–220 A.D.) as described in Hou Han Shu (Book of Later Han, 432–445 A.D.) [3]. In the Tang Dynasty (618–907 A.D.), the nation was divided into 15 “dao” according to landscapes in the Zhenguan Period, and then the number was increased to 15 “dao” in the Kaiyuan Period. Currently, “dao” is conceptually similar to the modern organizational system of provinces. The word “di” (in
“daodi” refers to regions and geography. Nowadays, “daodi medicinal materials” refers to the distinctively higher quality of the medicinal materials that grow in a certain area.

The establishment of DMMs is related to resources, agricultural technology and CMM development. In ancient China, due to agriculture production, rich experience along with advanced technology in growing and processing medicinal herals was accumulated, which resulted in the exchange of resources around the world [4]. In addition, the vast territory of China, including plains, hills, mountains, lakes, rivers and seas with different climates, sunshine, soils and ecological environments, provides favorable conditions for the growth of medicinal herbs. Through meticulous selection over the course of production and continuous clinical tests, DMMs have been proven to be definitely curative in medical treatments and therefore have been handed down from generation to generation [5].

DMM can be very effective if proper consideration is given to the characteristics of the original sources, growth and seasonal changes of the material; however, the same medicinal herb grown in different areas does not have the same effectiveness even if they are the same plant. In China, traditional Chinese medicine doctors usually select a superior populations or variety to prescribe based on geographical features. In addition, different harvest times or processing methods can greatly influence the quality and chemical components of closely related populations. Modern experimental research, especially molecular biological identification, has validated that the different production areas of CMMs are closely related to the quality and DNA sequence divergence of CMMs [6–8]. For example, as the dominant constituents, patchoulol and pogostone are the basis for the anti-inflammatory activity of Pogostemon cablin (Blanco) Benth. [9]. And it has been found that pogostone also exhibits potent anti-fungal [9], antiapoptotic [10], antioxidant [11], and immunosuppressive [12] properties. In our previous study, P. cablin produced in Shipai (in Guangzhou city, Guangdong province, SP) and Gaoyao (in Zhaoqing city, Guangdong province, GY) differed from P. cablin cultivated in Hainan province (HN) and Zhanjiang city (in Guangdong province, ZJ) not only in the total amount of volatile oil but also in genotype [13–15]. According to the composition of the volatile oil, P. cablin is divided into two chemotypes: SP and GY cultivars belong to the patchoulol-type, while the HN and ZJ cultivars belong to the patchoulol-type (Fig. 1). Moreover, we have demonstrated that the sequence divergence of both the matK and 18S rRNA genes among 6 samples of P. cablin from different locations was well correlated with the regions of cultivation and intraspecific essential oil chemotypes (Fig. 2) [16]. The same is true for other medicinal herbs. The major pharmacological components in Cnidium monnieri (L.) Cuss. are coumarins.

![Fig. 1 Structures of the pogostone and patchoulol in Pogostemon cablin](image1.png)
**Fig. 2** Volatile oil composition in the leaves (a), comparison of the variable sites in the \textit{matK} sequence (b), comparison of the variable sites in the 18S rRNA sequence (c) and cluster trees of both the \textit{matK} and 18S rRNA gene sequences (d) of \textit{Pogostemon cablin} (Blanco) Benth. from 6 different locations. The top number indicates the nucleotide position upstream of the \textit{matK} (b) and the 18S rRNA (c) sequence, an asterisk (*) indicates the same nucleotide as the P1 sequence, and a hyphen (—) indicates an alignment gap (c).
Similarly, according to the coumarin chemotypes, C. monnieri has been classified into three chemotypes, the osthol-linear furanocoumarins-type (chemotype I), principally cultivated in regions of Jiangsu and Hunan provinces; the angular furanocoumarins-type (chemotype II), mainly produced in Heilongjiang province; and the transition-type (chemotype III), largely came from Henan and Hebei regions [18]. It was found that there were 12 variable sites in the matK gene sequence of C. monnieri from different populations. A phylogenetic tree constructed by the neighbor-joining (NJ) method showed that the phylogenetic relationship of 6 C. monnieri cultivars was well correlated with their geographical distribution and intraspecific coumarin chemotypes of (Fig. 3) [19]. Likewise, Laboratory research showed a clear correlation between the rDNA ITS sequence and the phenotype of Dendrobium officinale Kimura et Migo from different populations [20]. The phylogenetic relationship predicted by the 5S rRNA spacer region data correlated well with the essential oil chemotype of Acorus calamus L. collected from various locations [21]. However, the difference in the alkaloid content of Fritillaria thunbergii Miq. from various habitats did not result from variation in the 5S rRNA sequence but from the microenvironment [22]. It’s reported that 5S rRNA is highly-conserved across all species [23], thus, different environments did not produce changes in 5S rRNA of different F. thunbergii populations, but produced differences in secondary metabolites. In these cases, it can be concluded that genetic diversity existed among different populations is relevant to the cultivation regions except some highly-conserved DNA markers.

Harvest time
CMMs harvested during different growing periods contain different plant metabolites. For instance, the content of essential oil increased as the age of P. cablin increased: patchoulol, α-bulnesene and other sesquiterpenes accumulated to high concentrations at 210 days after maturation [24]. According to the report from Jin et al. [25], Chaenomeles speciosa (Sweet) Nakai produced the highest quality yields when harvested in early July. In the case of Desmodium styracifolium (Osb.) Merr., the best collection season was early October, when the highest concentrations of polysaccharides, flavonoids and schaftoside were measured [26].

Sunshine
Sunshine is an important factor for the formation of DMMs. For example, the content of volatile components in Houttymia cordata Thunb. was closely related to light intensity: monoterpenoids and nonterpenoids were positively and negatively associated with light intensity, respectively [27]. In Viola yedoensis Makino, the content of flavonoids and coumarins was positively correlated with light intensity [28]. Although it has been demonstrated that higher concentrations of total patchoulol corresponded to lower light intensity in P. cablin, there was no statistically significant correlation between patchoulol content and shade [29]. In recent years, circadian clocks that temporally organize many aspects of growth and metabolism have even been found in numerous plant species [30–32]. For example, in Antirrhinum majus L., monoterpene synthase mRNA levels and corresponding monoterpane emission, which followed diurnal rhythms, were controlled by a circadian clock [33]. A similar daily fluctuation was found in the endogenous level of geranyl acetate and in the expression of its biosynthetic gene, alcohol acetyl transferase in Rosa rugosa Thunb. [31].

Soil
Soil is also important for the identification of DMMs and for the evaluation of quality. Modern pharmacologic studies have proven that the specific composition of soil has a large influence on the quality and quantity of the chemicals in medicinal herbs. For example, soil available iron (Fe) could promote the accumulation of flavonoids, while soil available manganese (Mn), total potassium (K), and available K had an inhibitory effect on flavonoid content in Spatholobus suberectus Dunn [34]. In Citrus grandis ‘Tomentosa’, the content of soil available copper (Cu), zinc (Zn), Mn, boron (B), and molybdenum (Mo) was positively associated with flavonoid concentrations and naringin concentrations [35]. There was a positive correlation between soil total nitrogen (N), available K and emodin in Polygonum cuspidatum Sieb. et Zucc. [36]. Soil Mn was a favorable factor for accumulating schisantine A in Schisandra sphenanthera Rehd. et Wils., as a significant correlation was also found between these factors [37].
Water
Another matter regarding DMMs that warrants attention is water. As shown in Aconitum carmichaelii Debx., the heavy metals cadmium (Cd), arsenic (As), mercury (Hg), and lead (Pb) concentrations in it were positively associated with the water in Fujiang River \((p < 0.05)\) [38]. This result indicates that the quality of CMMs can also be affected by water. To meet the growing demand of DMMs, additional detailed studies should be undertaken in this field.

Comprehensive ecological factors
Comprehensive research on the relationship between different ecological environment factors and the quality of CMMs has also been recorded. For example, in Scutellaria baicalensis Georgi, most of the chemical constituents were negatively correlated with latitude and positively correlated with temperature. Generally, the contents of 21 chemical constituents were higher at low latitudes than at high latitudes. By gradual regression analysis, it was found that the content of baicalein in S. baicalensis was negatively correlated with latitude. Similarly, the content of inorganic elements in soil was excessively high (magnesium (Mg) and calcium (Ca) excluded), which had a negative effect on the accumulation of chemical constituents in S. baicalensis [39, 40]. Taking the well-known antioxidant herb Panax ginseng C. A. Mey. as another example, low temperature was a favorable factor for the accumulation of ginsenosides, as a negative correlation was found between temperature and ginsenoside contents within a certain temperature range, while the levels of soil available B, effective Fe and available N were positively correlated to ginsenoside contents [41]. In recent years, due to overexploitation, the destruction of the ecological environment and the lack of proper cultivation practices, the geographical distributions of most DMMs may undergo large changes. For example, although the Changzhi region of Shanxi province and provinces of north-east China was P. ginseng’s original production center, the present production center of it is in Xiaoqianling region (in Heilongjiang province) and Changbaishan region (in Jilin province) [42]. Similarly, Panax notoginseng (Burk.) F. H. Chen historically came from the Tianzhuo region (in Guangxi province), but now the dominant medicinal material comes from Wenshan region (in Yunnan province) [43]. In these cases, predicting the geographical distribution of CMMs is important for resource conservation and regional management. Therefore, a geographic information system based on a computer program (TCMGIS) was developed to predict the distribution of CMMs. By integrating geographic location, climate and soil type databases, TCMGIS was able to determine the impacts of environmental components and predict the large-scale distribution of target medicinal herbs such as P. cablin [44], Artemisia annua L. [45], Polygonum multiflorum Thunb. [46], Morinda officinalis How [47], Aquilaria sinensis (Lour.) Gilg [48], Rheum tanguticum Maxim. ex Balf. [49], Amomum villosum Lour. [50], etc.

Traditional descriptions of daodi medicinal materials by famous physicians in ancient China
In the use of CMMs, a large emphasis has been placed on the identification of DMMs since ancient times. As recorded in Shen Nong Ben Cao Jing (The Divine Shennong’s Classic of Materia Medica, 25–220 A.D.) [51], “each medicinal material has laws for its production region, authenticity, and freshness.” In various chapters of that book, locations in ancient kingdoms and regions, such as mountain valley, river valley or marshes, were mentioned for the first time as medicinal herbs sources. This record indicates that different CMMs come from certain specific areas. In his immense book Ben Cao Jing Ji Zhu (Collection of Commentaries on the Classic of the Materia Medica, 480–498 A.D.) [52], Tao Hongjing, a well-known physician in the Northern and Southern Dynasties (420–589 A.D.), used such terms “good”; “quite good”, “fairly good”, “excellent” and “best” to describe the effects of over 40 medicinal herbs commonly used in medical treatment. Moreover, correlations between the sources, developmental stages and efficacy of these medicinal herbs were described. Sun Simiao, a famous physician and pharmacologist of the Tang Dynasty (618–907 A.D.), stated the following in his book Qian Jin Yi Fang (Formulas Worth a Thousand Gold Pieces, 682 A.D.) [53]: “Medicinal herbs used by ancient physicians were always from designated original sources, which accounted for their great effectiveness in medical treatment”. In that book, he comprehensively sorted 519 DMMs and systematically stipulated 133 regions of production. According to Kou Zongshi, a famous physician of the Song Dynasty (960–1279 A.D.), in his book Ben Cao Yan Yi (Extension of the Materia Medica, 1116 A.D.), “in prescribing medicinal herbs, care should always be taken to select those from proper sources to ensure their effectiveness”; greatly emphasizing the designated original sources of medicinal herbs [54]. During the Jin and Yuan Dynasties (1115–1368 A.D.), the text Yong Yao Fa Xiang (Medication Method, 1249 A.D.) also suggested that one could achieve excellent treatment results only by using DMMs with proper production regions and harvest time. Then, the Ming Dynasty (1368–1644 A.D.) document Ben Cao Meng Quan (Materia Medica Companion, 1565 A.D.) stated that “the effect will be definitely different if medicinal materials are produced in a different environment” [55]. The record in Yi Xue Yuan Liu Shi
attached similar importance to the use of DMMs collected from certain original sources [56]. All of this historical literature showed that the use of DMMs has been a practice since ancient times.

The scientific elucidation of daodi medicinal materials

DMMs are the subset of CMMs that meet the highest quality criteria. DMMs are not only associated with specific geographic regions (Fig. 4) but also linked to the chemical components and pharmacological function of CMMs.

Chemical components

As we described above, ecological environments such as topography, sunshine, soil, and water directly influence the secondary metabolites (many of which are bioactive components) in medicinal herbs. The many names of DMMs reflect the connotations of production regions; for instance, “qin pi” (Fraxinus chinensis Roxb.), “fen qi” (Astragalus membranaceus (Fisch.) Bge.), “huai di huang” (Rehmannia glutinosa Libosch.) and “ba dou” (Croton tiglium L.), where “qin”, “fen”, “huai”, and “ba” refer to the names of regions used over the course of ancient Western Zhou Dynasty (1046–771 B.C.) [1]. Modern experimental research has validated that DMMs growing in a certain production region are often of high quality (Table 1). For example, the ancient Chinese medicine book Xin Xiu Ben Cao (Newly Revised Materia Medica, 659 A.D.) [57] said that “Fraxinus chinensis Roxb., which can change the color of water to a fluorescent color after soaking, is thought to be superior in quality” (Fig. 5). Currently, scientific evidence supporting the rational for such description is available. *F. chinensis* produced from Shaanxi province has a higher content of aesculin and aesculetin than that produced in Sichuan province and Liaoning province, and its stronger fluorescence reaction is consistent with the description written in ancient times [58, 59]. The same observation is true for *Astragalus membranaceus* (Fisch.) Bge. This herb is principally cultivated in a region in Shanxi province, and the cultivar produced in this region contains more astragaloside than do cultivars produced in Shandong, Inner Mongolia, Hebei and Jilin provinces [60]. It is generally recognized that *Rehmannia glutinosa* Libosch. cultivated in Henan province is of particularly high quality. Modern experimental studies have demonstrated that higher levels of the active constituent catalpol content are present in *R. glutinosa* grown in this region than in cultivars grown in areas of Xianyang (in Shaanxi province) and Dali (in Shaanxi province) [61]. Similarly, *A. villosum* cultivated in Yangchun (in Guangdong province) is believed to be
Table 1 The contents (%) of active constituents in different Chinese medicinal materials in daodi production region and non-daodi production regions

| No. | CMM                          | Active constituents     | Daodi production region | Non-daodi production region | References |
|-----|------------------------------|-------------------------|-------------------------|-----------------------------|------------|
| 1   | Fraxinus chinensis Roxb.     | Aesculin, aesculetin    | Shaanxi: aesculin (4.37%), aesculetin (1.92%) | Sichuan: aesculin (1.10%), aesculetin (0.21%) | [58, 59]   |
| 2   | Astragalus membranaceus (Fisch.) Bge. | Astragaloside          | Shanxi: 0.37% | Shandong: 0.12% | Inner Mongolia: 0.11% | Hebei: 0.29% | Jilin: 0.32% | [60] |
| 3   | Rehmannia glutinosa Libosch. | Catalpol               | Henan: 0.76%         | Xianyang, Shaanxi: 0.34% | Dali, Shaanxi: 0.33% | [61] |
| 4   | Amomum villosum Lour.        | Bornyl acetate         | Yangchun, Guangdong: 65.82% | Gaoyao, Guangdong: 55.95% | Guangxi: 61.75% | Hunan: 50.92% | Burma: 60.71% | [62–64] |
| 5   | Pogostemon cablin (Blanco) Benth. | Pogostone              | Shipai, Guangzhou, Guangdong: 68.43% | Gaoyao, Zhaoqing, Guangdong: 26.15% | Leizhou, Zhanjiang, Guangdong: 4.78% | Wuchuan, Zhanjiang, Guangdong: 5.20% | Hainan: 8.97% | [65–70] |

CMM Chinese medicinal material

Fig. 5 The herbal classic Xin Xiu Ben Cao (Newly Revised Materia Medica) describes the metachromatism-based quality evaluation of “qin pi” (Fraxinus chinensis Roxb.)
superior in quality. The effective medicinal elements in *A. villosum* is bornyl acetate. Modern experimental research has validated that Yangchun-cultivated *A. villosum* has the highest effective component content among different populations [62–64]. In other example, *P. cablin* cultivated in Shipai (in Guangzhou city, Guangdong province) is of particularly high quality. It produced higher levels of the active constituent pogostone than that cultivated in Gaoyao (in Zhaoqing city, Guangdong province), Leizhou (in Zhanjiang city, Guangdong province), Wuchuan (in Zhanjiang city, Guangdong province) and Hainan province [65–70]. Interestingly, the same is true for toxicology. *A. carmichaelii* produced from plantation sites at Jiangyou county of Sichuan province is believed to be superior in quality. The proportions of the major bioactive constituents monoester alkaloids to toxic constituents diester alkaloids among 5 samples of *A. carmichaelii* from different localities were well correlative with their regions of cultivation. The highest proportion occurred in cultivar Jiangyou (in Sichuan province), followed by cultivars Hanzhong (in Shaaxi province), Butuo (in Sichuan province), Weishan (in Yunnan province), and Anxian (in Sichuan province) [71].

Pharmacological functions
Pharmacological functions are actually the outside manifestations of CMMs. In the case of DMMs, the conditions in a certain region are thought to confer clinical superiority, and for this reason, DMMs are considered the most efficacious among CMMs [72]. Scientific evidence supporting the alleged clinical superiority of DMMs is the subject of ongoing research. For example, *Dendrobium huoshanense* C. Z. Tang et S. J. Cheng produced in Huoshan (in Anhui province) is considered to be superior in quality. Accordingly, the hepatoprotective effect is the best for the Huoshan cultivar, second for the Yunnan cultivar, and last for the other region cultivars [73]. *P. cablin* has been classified into two chemotypes, the patchoulol-type, including cultivars HN and ZJ, and the pogostone-type, including cultivars SP and GY. Accordingly, this cultivars produced in GY are more potent than those from ZJ in terms of promoting digestion [74] and antibacterial [75] effects. In addition, the toxicity of DMMs is often less potent than that of non-DMMs. For instance, *P. multiflorum* is principally cultivated in region Deqing county of Guangdong province, which has the largest output and the longest history of medicinal use. Accordingly, cultivar Deqing showed less potent cytotoxicity than cultivar Chongqing in HepG2 and LO2 cells [76]. These studies show considerable promise for explaining the scientific mechanism of DMM superiority.

**Daodi medicinal materials are the basis of the medicinal industry and clinical practice**
CMMs are the materials processed into decoction ingredients or used to produce proprietary drugs. The identification of DMMs is important in quality evaluation and disease treatment. In addition to the optimum harvest season, the processing and standard prescription of CMMs produce the unique characteristics of DMMs, and a plausible production chain of CMMs is hypothesized in Fig. 6. The production chain of CMMs is based on the content we described above, including populations, designated growing regions (*daodi*), and harvest season, as well as the extensive quality control knowledge accumulated for CMMs by Liu et al. [77–80]. Compared to previous production chain of CMMs [77–80], factors such as populations, designated growing regions and

---

**Fig. 6** A putative production chain for CMMs
harvest time directly influenced the quality of CMMs were emphasized. Every procedure in the production chain should be standardized to guarantee the prominent curative effect of medicinal materials. For example, the manufacturing procedure for *Pinellia ternata* (Thunb.) Breit. was standardized by orthogonal design [81]. In addition, modern analytical methods have revealed the processing mechanism of many CMMs, including *Coptis chinensis* Franch. [82–84], *Xanthium sibiricum* Patr. [85–87], *Siegesbeckia orientalis* L. [88, 89], *Descurainia sophia* (L.) Webb. ex Prantl. [90, 91], *Cassia obtusifolia* L. [92, 93], etc. Additionally, cooperation among universities, research institutes and pharmaceutical manufacturers should be strengthened to communicate information regarding CMMs.

**Conclusions**

DMMs have long maintained, currently have, and will continue to maintain a good reputation on the basis of their excellent curative effects. In our review, DMM is the specific term for pure, superior medicinal herbs with the following characteristics: optimum harvest season (reflecting the appropriate developmental stage of the plant), scrupulous processing, traditional preparation technology, etc. Historical literature, modern phytochemical and pharmacological methods have provided additional scientific data and a theoretical basis to validate the mechanisms of DMMs. In addition, every procedure in the production chain of CMMs should be standardized to guarantee the prominent curative effect of medicinal materials. Effectively establishing a correlation among the active components, clinical efficacy and identity of DMMs is an important aspect in the quality evaluation of CMMs. The core scientific elucidation of DMMs should be continuously carried out, and multidisciplinary measures should be adopted to explore scientific and practical methodologies for the further research of DMMs.

**Abbreviations**

DMMs: daodi medicinal materials; CMMs: Chinese medicinal materials; SP: Shipai (in Guangzhou City, Guangdong province); FN: Gaoyao (in Zhaoqing City, Guangdong province); NJ: neighbor-joining; Fe: iron; Mn: manganese; K: potassium; Cu: copper; Zn: zinc; B: boron; Mo: molybdenum; N: nitrogen; Cd: cadmium; As: arsenic; Hg: mercury; Pb: lead; Mg: magnesium; Ca: calcium; TCMGIS: geographic information system based on a computer program.

**Acknowledgments**

Not applicable.

**Authors' contributions**

HC and XL conceived, designed and wrote the review; YZ, MW and ZM collected the data; YZ, ZH, FT, SD, SL, YZ, JZ, NL and XH revised the paper. All authors read and approved the final manuscript.

**Funding**

This work was supported by the 6th National Academic Experience Inheritance Program of Famous Chinese Medicine Experts (Prof. Hui Cao) (No. 176-2017-XM2C-0166-01).

**Availability of data and materials**

Not applicable.

**Ethics approval and consent to participate**

Not applicable.

**Consent for publication**

Not applicable.

**Competing interests**

The authors declare that they have no competing interests.

**Author details**

1 Research Center for Traditional Chinese Medicine of Lingnan (Southern China), Jinan University, Guangzhou 510632, China. 2 College of Pharmacy, Jinan University, Guangzhou 510632, China.

Received: 12 May 2020   Accepted: 13 August 2020

**Published online:** 20 August 2020

**References**

1. Zhao ZZ, Guo P, Brand E. The formation of daodi medicinal materials. J Ethnopharmacol. 2012;140(3):476–81.
2. Xiao XH, Chen SL, Huang LQ, Xiao PG. Survey of investigation on daodi Chinese medicinal materials in China since 1980s. China J Chin Mater Med. 2009;34(5):519–23.
3. Fan Y. Hou Han Shu (漢書). Beijing: Zhonghua Book Company; 1965.
4. Cao H, Liao G. “One Belt, One Road” Chinese Medicine Cultural Relics Collection (中國“一帶一路”中藥文物圖錄集). Guangzhou: Jinan University Press; 2016.
5. Gao XM. Lectures on Chinese pharmacology-genuine and high-quality drugs. J Tradit Chin Med. 1994;14(2):147–51.
6. Cao H, Zhang Y. The latest progress in study of DNA molecular marker used in quality evaluation of Chinese medicinal materials. World Sci Technol Tradit Chin Med. 2003;4(1):39–47.
7. Cao H, Yang MS, Xiao PG. Recent advances in gene technology for identification of genuineness of Chinese herbal drugs. Acta Pharm Sin. 2005;40(7):577–84.
8. Cao H, Shaw PC, But PH. Molecular Identification of Chinese Medicinal Materials: Technology and Application (中藥分子鑒定技術與應用). Beijing: People’s Medical Publishing House; 2016.
9. Xu W, Wu YQ, Ding HF, Xie YF. Research progress on pharmacological effects and mechanism of Herba Pogostemonis. Shanghai J Tradit Chin Med. 2017;51:103–6.
10. Chen XY, Chen HM, Liu YH, Zhang ZB, Zheng YF, Su ZQ, et al. The gastroprotective effect of pogostone from Pogostemonis Herba against indomethacin-induced gastric ulcer in rats. Exp Bio Med. 2016;241:193–204.
11. Wang XF, Huang YF, Wang L, Xu LQ, Yu XT, Liu YH, et al. Photo-protective activity of pogostone against UV-induced skin premature aging in mice. Exp Gerontol. 2016;77:76–86.
12. Su JY, Luo X, Zhang XJ, Deng XL, Su ZR, Zhou L, et al. Immunosuppressive activity of pogostone on T cells: blocking proliferation via S phase arrest. Int Immunopharmacol. 2015;26:328–37.
13. Luo JP, Liu YF, Feng YF, Cao H. Two chemotypes of Pogostemon cablin and influence of region of cultivation and harvesting time on volatile oil composition. Acta Pharm Sin. 2003;38(4):307–10.
14. Zhang Y, Chen Y, Zhang JC, Yang MS, Cao H, Xiao PG. Correlation between ITS genotype and geographical distribution of Pogostemon cablin. Acta Pharm Sin. 2007;42(1):93–7.
15. Zhang Y. Study on Guangdong authentic and superior medical material Pogostemon cablin by GC-Ms fingerprinting and DNA molecular markers analysis. Beijing: Beijing University of Chinese Medicine, 2007.
16. Liu YP, Luo JP, Feng YF, Guo XL, Cao H. DNA profiling of Pogostemon cablin chemotypes differing in essential oil composition. Acta Pharm Sin. 2002;37(4):304–8.

17. Li YM, Jia M, Li HQ, Zhang ND, Wen X, Rahman K, et al. Cnidium monnieri: a review of traditional uses, phytochemical and ethnomedicinal properties. Am J Chin Med. 2015;43(5):835–77.

18. Cai JN, Zhang L, Wang ZT, Xu LS, Du F, Xu GJ. Variation and regularity of conjugates in Fructus Cnidii collected from different regions of China. Acta Pharm Sin. 1999;34(10):767–71.

19. Cao H, Cai JN, Liu YP, Wang ZT, Xu LS. Correlative analysis between geographical distribution and nucleotide sequence of chloroplast matK gene of Cnidium monnieri fruit in China. Chin Pharm J. 2001;36(6):373–8.

20. Ding XY, Wang ZT, Xu LS, Xu H, Zhou KY, Shi GX. Study on sequence difference and SNP phenomenon of rDNA ITS region in F type and H type population of Dendrobium officinale. China J Chin Mater Med. 2002;27(2):85–9.

21. Sugimoto N, Kiuchi F, Mikage M, Mori M, Mizukami H, Tsuda Y. DNA profiling of Acorus calamus chemotypes differing in essential oil composition. Biol Pharm Bull. 1999;22(5):481–5.

22. Cai CH, Li P, Li SL, Dong TX, Zhan HQ. Sequences of SS-rRNA gene spacer region and comparison of alkaloid content in Fritillaria thunbergii from different habitats. J Chin Med Mater. 2001;24(3):157–9.

23. Huang SJ, Aleksashin NA, Loveland AB, Klepacki D, Reier K, Kefi A, et al. Ribosome engineering reveals the importance of SS-rRNA autonomy for ribosome assembly. Nat Commun. 2020;11(1):2900.

24. Chen Y, Wu YG, Xu Y, Zhang JF, Song XQ, Zhu GP, et al. Dynamic accumulation of flavonoids content of Ziqiu (Chaenomeles speciosa) with active officinal principles. Ecol Environ. 2008;17(3):1179–83.

25. Jin LN, Liu YM, Xiong YX, Chen KL. Study on the best harvesting period of Panax notoginseng a review of traditional uses, phytochemical and ethnopharmacological: Dendrobium officinale. Chin Med. 2010;5(1):18.

26. Huang LF, Xie CX, Duan BZ, Chen SL. Research mapping the potential distribution of high artemisinin-yielding Artemisia annua L. (qing-hao) in China with a geographic information system. Chin Med. 2010;5(1):18.

27. Shi WT, Wu XJ, Wang X, Liang YZ. Analysis of effect of light intensity on metal elements and inorganic elements of Schisandra sphenanthera. Sci China Life Sci. 2017;55(2):406–9.

28. Cai CH, Li P, Li SL, Dong TX, Zhan HQ. Sequences of 5S-rRNA gene spacer region and comparison of alkaloid content in Fritillaria thunbergii from different habitats. J Chin Med Mater. 2001;24(3):157–9.

29. Ji SG, Cai JL, Lu HJ, Zheng ZT. Effect of different light intensity on the distribution of mid- and main components of Viola yedoensis. Sci China Life Sci. 2013;56(11):1047–56.

30. Su J. Xin Xiu Ben Cao (新修本草). Anhui: Anhui Science & Technology Publishing House; 1990. p. 144.

31. Xu DC, Wan F, Yi Xue Yuan Liu Shi (醫學源流史). Beijing: People's Medical Publishing House; 1984.

32. Mcclung CR. Defence at dawn. Nature. 2011;470:44–5.

33. Hendel-Rahmanim K, Masci T, Vainstein A, Weiss D. Diurnal regulation of ribosome assembly. Nat Commun. 2020;11(1):2900.

34. Li MM, Liu JM, Luo DH, Zhan RT. Correlation of flavonoids content of Viola yedoensis. J Chin Med Mater. 2001;24(3):157–9.

35. Sun SM. Qian Jin Ji Fang (千金翼方). Beijing: People's Medical Publishing House; 1997. p. 45.

36. Xu J, Cai JL, Lu HJ, Zheng ZT. Effect of different light intensity on the distribution of mid- and main components of Viola yedoensis. Sci China Life Sci. 2013;56(11):1047–56.

37. Zhang XD, Deng HS, Zhu SM, Cheng M. Effect of soil factors on secondary metabolites and inorganic elements of Scutellaria baicalensis and analysis of geoherbism. Sci China Life Sci. 2013;56(11):1047–56.

38. Huang LF, Xie CX, Duan BZ, Chen SL. Research mapping the potential distribution of high artemisinin-yielding Artemisia annua L. (qing-hao) in China with a geographic information system. Chin Med. 2010;5(1):18.

39. Zhang XD, Deng HS, Zhu SM, Cheng M. Effect of soil factors on secondary metabolites and inorganic elements of Scutellaria baicalensis and analysis of geoherbism. Sci China Life Sci. 2013;56(11):1047–56.
67. Luo JP, Feng YF, Guo XL, Li XQ. GC-MS analysis of volatile oil of Herba Pogostemonis collected from Gaoyao county. J Chin Med Mater. 1999;22(1):25–8.
68. Feng YF, Guo XL, Luo JP. GC-MS analysis of volatile oil of Herba Pogostemonis collected from Leizhou county. J Chin Med Mater. 1999;22(5):241–3.
69. Guo XL, Feng YF, Luo JP. GC-MS analysis of volatile oil of Herba Pogostemonis collected from Wuchuan county. J Chin Med Mater. 2002;25(4):262–3.
70. Luo JP, Guo XL, Feng YF. Constituents analysis on volatile oil of Pogostemon cablin from different collection time cultivated in Hainan. J Chin Med Mater. 2002;25(1):21–3.
71. Zhang DK, Wang JB, Yang M, Peng C, Xiao XH. Exploring in integrated quality evaluation of Chinese herbal medicines: the integrated quality index (IQI) for aconite. China J Chin Mater Med. 2015;40(13):2582–8.
72. Yang X, Tian X, Zhou Y, Liu Y, He L. Evidence-based study to compare dioxid traditional Chinese medicinal material and non-dioxid traditional Chinese medicinal material. Evid Based Complement Alternat Med. 2018;2018:1–12.
73. Wang K, Sui DJ, Wang CS, Wei Y. Protective effects of five different types of Dendrobium on CCl4-induced liver injury in mice. China J Chin Mater Med. 2017;42(10):1945–50.
74. He B, Chen XX, Li XQ, Luo JP. Comparison of effects of Herba Pogostemonis from Gaoyao and Wuchuan on digestive system. J Chin Med Mater. 1999;22(4):201–3.
75. Liu HH, Luo JP, Lai PL. Studies on the anti-enteropathogenic bacteria action of Herba Pogostemonis extracts. J Chin Med Mater. 1999;22(8):408–11.
76. Rui W. Identification, activity evaluation and biosynthetic pathways analysis of the differential constituents in aqueous-methanol extracts of Polygonum multiflorum Thunb. Guangzhou: Southern Medical University; 2018.
77. Zhang L, Yan JB, Liu XM, Ye ZG, Yang XH, Meyboom R, et al. Pharmacovigilance practice and risk control of traditional Chinese medicine drugs in China: current status and future perspective. J Ethnopharmacol. 2012;140(3):519–25.
78. Liu Y, Nie Q, Chen J. Suggestions to strengthen quality management of herbal decoction pieces—based on production chain of herbal decoction pieces. China J Chin Mater Med. 2015;40(16):3319–22.
79. Yu WK, Dong L, Pei WX, Wang Y. Development of whole process quality control and management system of traditional Chinese medicine decoction pieces based on traditional Chinese medicine quality tree. China J Chin Mater Med. 2017;42(3):4488–93.
80. Zhang C, Liu Y, Xiao YQ. Strengthening production management of Chinese medicinal materials and stabilizing quality of traditional Chinese medicine products. Chin J Exp Tradit Med Form. 2017;23(15):1–4.
81. Su T, Zhang WW, Zhang YM, Cheng BCY, Fu XQ, Li T, et al. Standardization of the manufacturing procedure for Pinelliae Rhizoma Praeparatum cum Zingibere et Alumine. J Ethnopharmacol. 2016;193:663–9.
82. Huang P, Qian XC, Li JS, Cui XB, Chen LH, Cai BC, et al. Simultaneous determination of 11 alkaloids in crude and wine-processed Rhizoma Coptidis by HPLC-PAD. J Chromatogr Sci. 2015;53(1):73–8.
83. Qian XC, Zhang L, Tao Y, Huang P, Li JS, Chai C, et al. Simultaneous determination of ten alkaloids of crude and wine-processed Rhizoma Coptidis aqueous extracts in rat plasma by UPLC-ESI-MS/MS and its application to a comparative pharmacokinetic study. J Pharmaceut Biomed. 2015;105:64–73.
84. Yang CY, Guo FQ, Zang C, Li C, Cao H, Zhang BX. The effect of ginger juice processing on the chemical profiles of Rhizoma coticids. Molecules. 2018;23(2):1–14.
85. Su T, Cheng BCY, Fu XQ, Li T, Guo H, Cao HH, et al. Comparison of the toxicities, activities and chemical profiles of raw and processed Xanthii Fructus. BMC Compliment Altern M. 2016;16:1–8.
86. Jiang H, Yang J, Xing XD, Yan ML, Guo XY, Hou AJ, et al. A UPLC-MS/MS application for comparisons of the hepatotoxicity of raw and processed Xanthi Fructus by energy metabolites. Rsc Adv. 2019;9(5):2756–62.
87. Jiang H, Yang J, Xing XD, Yan ML, Guo XY, Yang BY, et al. Chemometrics coupled with UPLC-MS/MS for simultaneous analysis of markers in the raw and processed Fructus Xanthii, and application to optimization of processing method by BBD design. Phytomedicine. 2019;57:191–202.
88. Su T, Yu H, Kwan HY, Ma XQ, Cao HH, Cheng CY, et al. Comparisons of the chemical profiles, cytotoxicities and anti-inflammatory effects of raw and rice wine-processed Herba Siegesbeckiae. J Ethnopharmacol. 2014;156:365–9.
89. Li SJ, Liu DY, Liu P, Fu ZH, Sun ML, Zhang YH, et al. Comparison of attenuating renal ischemia/reperfusion injury effects of raw and honey wine-processed Herba Siegesbeckiae. Int J Clin Exp Med. 2017;10(1):524–31.
90. Luo HY, Yu XK, Zhang X, Wang ZJ. Determination of contents of five components in Descurainiae semen before and after being processed by HPLC. Chin J Exp Tradit Med Form. 2018;25(10):115–20.
91. Li HW, Shi YB, Tian LQ, Feng WS. Effects of five processing methods on compositions and contents of fatty oils in Descurainiae Semen. Chin Tradit Pat Med. 2017;39(8):1661–5.
92. Guo RX, Wu HW, Yu XX, Xu MY, Zhang X, Tang LY, et al. Simultaneous determination of seven anthraquinone aglycones of crude and processed Semen Cassiae extracts in rat plasma by UPLC-MS/MS and its application to a comparative pharmacokinetic study. Molecules. 2017;22(11):1–14.
93. Guo RX, Yu XK, Zhang X, Wang ZJ. Chemical study on Cassiae Semen processing procedure. China J Chin Mater Med. 2018;43(15):3145–9.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.