REVIEW

School of Pharmaceutical Sciences[1], Shandong University of Traditional Chinese Medicine; The Affiliated Hospital of Shandong University of Traditional Chinese Medicine[2]; Shandong University of Traditional Chinese Medicine[3], Jinan, PR China

A review about industrialization of Chinese materia medica decoction pieces

Z. Chao[1,#], S. Xiaochen[1,#], W. Shuyue[1], S. Xiao[1], Y. Yaohui[1], G. Fei[2,*], S. Lei[3,*]

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**Corresponding authors: Fei Guo, The Affiliated Hospital of Shandong University of Traditional Chinese Medicine, Jinan 250011, PR China*
wenxianjiansuotcm@126.com
Lei Shi, Shandong University of Traditional Chinese Medicine, Jinan 250355, PR China
843061724@qq.com
[#]Chao Zhang and Xiao-Chen Sun contributed equally to this paper.

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Chinese materia medica decoction pieces (CMMDPs), one of the three pillars of the Chinese materia medica industry, are a key link in the Chinese materia medica industrial chain. Industrialization is the only way for the modernization of CMMDPs. This review mainly summarizes the characteristics, history, current situation and prospect of CMMDPs industry, providing a new reference for promoting the flourishing development of the industrialization of CMMDPs and for serving massive health industry. The literature was collected from databases including Web of Science, PubMed, Elsevier and CNKI (Chinese). CMMDPs industry has the characteristics of regionalism, resource dependency, customer diversity and low industrial concentration. Deeply processed products include traditional Chinese medicine (TCM) formula granules, small-packed decoction pieces, ultrafine decoction pieces, puffed decoction pieces, compressed decoction pieces and instant decoction pieces. Integration of treatment and processing at the place of origin is emerging. However, there is still room for improvement, for example, the manufacturing technologies of CMMDPs industry need to be continually improved. The management of CMMDPs' normalized production also needs to be strengthened. The quality of CMMDPs should be strengthened supervision and it should establish the objective and feasible quality evaluation system for CMMDPs. At present, China has attached unprecedented importance to the development of TCM, and issued a number of supporting policies, sparing no effort to support its development.

1. Introduction

Chinese materia medica decoction pieces (CMMDPs), one of the three pillars of the Chinese materia medica industry, are a key link in the Chinese materia medica industrial chain (Wu et al. 2001) and play an important role in the Chinese materia medica industry as well as in the entire traditional Chinese medicine (TCM) industry. CMMDPs are not only the important raw material for TCM clinical medication and Chinese patent medicine production, but also are a strategic key link in the development of the entire TCM massive health industry, as well as the basis to ensure the clinical efficiency of TCM and to improve the quality of national health (Xiao et al. 2016b). Industrialization is the only way for the modernization of CMMDPs. China has listed the processing technology of CMMDPs (Sheridan et al. 2015) and the decoction pieces industry as one of the key areas of the modern science and technology industry of Chinese materia medica. Therefore, this review summarizes the characteristics, history, current situation and prospect of CMMDPs industry, providing a new reference for promoting the flourishing development of the industrialization of CMMDPs.

2. The characteristics of CMMDPs industry

2.1. Regionalism

The medicinal materials are genuine (Zhao et al. 2012; Yang et al. 2018). However, differences in natural resources, medication habits, living customs, and cultural traditions in assorted clinical applications, and even different processing techniques for the same medicinal material (He et al. 2018), lead to processed products with distinct regional characteristics (Zhao et al. 2010). Considering the obvious regionalism of the CMMDPs industry, the "one-size-fits-all" management way should not be adopted during the circulation and supervision, which may obliterate these special processing techniques and products.

2.2. Resource dependency

The industry of CMMDPs is highly associated with the farm production and breeding industries of the Chinese medicinal materials in the upstream, making itself a typical medicinal material resource-dependent industry (Guo 2006). Changes in the resource reserves and output of Chinese medicinal materials could impose a direct and rapid impact on CMMDPs and related products in downstream industries. Only through the scientific protection, rational development and sustainable use of Chinese materia medica resources can the sustainable development of the CMMDPs industry be guaranteed. Otherwise, the excessive development and utilization of Chinese medicinal resources will lead to the crisis of the CMMDPs industry.

2.3. Customer diversity

The downstream industry of CMMDPs covers a wide range of pharmaceutical fields, including Chinese patent medicine factories, hospitals (TCM hospitals and TCM departments), and retail pharmacies. In addition, CMMDPs are also widely used in health products (Fu et al. 2014; Lu et al. 2020), medicated diet (Tan et al.

2017), cosmetics (Wang et al. 2006), medicinal foot baths (Vagedes et al. 2018) and other massive health and massive Chinese medicine fields. Some medicinal and food homogeneous decoction pieces directly enter the shopping mall, supermarket or the catering service industry. The CMMDPs industry is characterized by extensive downstream uses, multiple application industries, and various terminal consumption channels. This diversity requires the manufacturers of CMMDPs to formulate individual marketing strategies in response to the different needs of pharmaceutical companies, hospital pharmacies, pharmacies, and individual consumers, so as to fulfill the needs of different customers in the market.

2.4. Low industrial concentration

Chinese materia medica can be categorized into herbal medicines, animal medicines and mineral medicines (Liu 2015). Herbal medicines can be further divided into medicines of roots and rhizomes, stems and woods, skins, leaves, flowers, fruit seeds and whole grasses according to the medicinal parts. In addition, there are different processing methods for the same medicine, resulting in the various, complicated and changeable specifications and categories of CMMDPs (Zhang et al. 2018). At present, most manufacturers of decoction pieces do not have a large scale, while the production efficiency is low and the manufacturing costs are high, attributed to the various categories and batches of decoction pieces produced. Besides, the industrial chain of the Chinese materia medica medicine decoction pieces is relatively long, involving multiple processes, such as the selection and planting of medicinal materials, medicinal material collection, processing, decoction piece packaging, storage, sales and use, which span multiple industries and have higher operating costs. There is no real leading company in the decoction pieces industry. The market share of the industry leader is less than 2%, and merging and reorganization will be the trend in the future.

3. The history of CMMDPs industry

Before the Tang Dynasty (AD 618–907), medical practitioners could not communicate due to geographical and traffic limitations, and they had different understandings on the disease's etiology and pathogenesis, medication's efficacy and compatibility, so they carried the medications around while practicing medicine. During spare time, the medical practitioners sold the medicinal materials collected and the prepared medicine. People involved in the area of Chinese materia medica were actually medical practitioners who collected, manufactured and sold medication, as well as practiced medicine, who did not have a fixed place for business. In the Tang Dynasty, business places called "pharmaceutical markets" and "pharmaceutical houses" appeared. In the Song Dynasty (AD 960–1279), TCM and Chinese materia medica began to be set apart. As Xu Lingtai of the Qing Dynasty (AD 1636–1912) said in *On the Origin of Medicine*, "Since Song Dynasty, there have been doctors who only made up prescriptions but sold no medications which were bought in herbal medicine shops, like what we did today."

In the Song Dynasty, the most attention was paid to pharmaceutical industry. In order to contend against the monopolies of private business, a state-operated drug bureau was set up. First, a drug office was set up in the Bureau of Imperial Doctors, and then a Drug Processing Center was established to specialize in the preparation and processing of medicinal materials, both of which were independent from the Bureau of Imperial Doctors (Yang 1989). The former was renamed the Drug Bureau of Benevolence, a place for drug-selling and disease-curing, and the latter was called the Drug Bureau for Compounding and was in charge of medication preparation. Through the inheritance and extension in the Jin Dynasty (AD 1115–1234) and the Yuan Dynasty (AD 1271–1368), the system of the official drug bureau started to decline in the middle of the Ming Dynasty (AD 1368–1644). There was no Bureau for Compounding in the early Ming Dynasty. The pattern of shop front and workshop rear was adopted by the Bureau of Benevolence, which was in charge of medication preparation and selling. Some Bureaus of Benevolence had no workshop for medication preparation at all, only functioning as health charities, delivering medications to the public for free in the presence of natural disasters and plagues (Jin 2007).

Under the influence of the official drug bureau, private Chinese medicine shops in the Song Dynasty also developed greatly. Both the number and scale of drugstores in the city increased compared to the Tang Dynasty. Drugstores specialized into certain categories of drugs appeared, and TCM associations were formed. Drugstores in the Song Dynasty could be divided into practice medicine stores and raw medicine stores. The former sold prepared medications, like CMMDPs and Chinese patent medicines in the form of pastes, pellets, pills, powders, medicinal liquors, syrup and so on, whereas the latter sold raw medications (Jin et al. 2014). As for the former kind of stores, generally medication was sold in the front hall and processed in the back hall, with doctors in the store practicing medicine. Medication preparation, drug selling and doctor practicing medicine were accomplished in one place, and such pattern was still used in modern times. Raw medication stores mainly purchased and then processed medicinal materials, and finally sold them to drug-preparation workshops or drugstores. Private Chinese medicine stores in the Yuan Dynasty were not limited to the coastal areas of Zhejiang and gradually developed to inland areas. In the Ming Dynasty, private Chinese medicine stores developed in the whole country and moved from big cities to small towns. The division of labor was more refined and improved, and the degree of goods socialization was greatly enhanced. In the past, private drugstores were mainly set up by doctors, while in the Ming Dynasty, some were set up by businessmen who did not know TCM, such as stores named "Chen Liji" and "Guangshenghao"(Sun 2003), which utilized genuine medicinal materials, effective processing techniques and superb medical skills, and therefore quickly occupied the market.

In the Qing Dynasty, many private drugstores had the ability to process medicinal materials and manufacture a variety of patent medicines. The front shop of the store sold Chinese medicines, and in the workshop in the back workers were organized to work on the steaming, frying, cauterization and calcination of patent medications in the form of pills, powders, pastes and pellets. The drugstore integrated production and sale, whose major business included purchasing, transporting, storing, processing, manufacturing, packaging and selling medicinal materials. By the late Qing Dynasty, many large private drugstores were no longer shops employing only three or four assistants, but developed into new industrial and commercial enterprises with the simple cooperative nature of capitalism.

In the Ming and Qing Dynasties, drugs and medicines were further separated, and the Chinese drug industry moved closer to economic and trade activities and became more commercialized and industrialized. In some places, there were a lot of businessmen engaged in the medicinal industry, and also plenty of drugstores specialized in thousands of kinds of Chinese drugs, leading to the natural appearance of drug capitals. In the Ming dynasty, Zhangshu, the drug capital, has become the center of processing and distributing of medicinal materials in southern China. Drugstores here had front cabinet for drugs selling and back cabinet for decoction pieces' processing, where wholesale and retail were both possible, as well as agency trading. In the course of hundreds of years of development, a unique processing style was formed, requiring cut products "as thin as paper, capable of being blown up, neat section, pretty shape", and requiring processed products with perfect combinations of color, fragrance, shape, taste and effect (Gong et al. 2007). In the drug capital Anguo (known as Qizhou in ancient times), the rise and development of the industry of decoction pieces also mobilized the development of local industry of medicinal planting. At the end of the Ming Dynasty, some local farmers began to plant Chinese herbs. With the farmers' careful operation, the medicinal materials produced were of high-quality and with good effects. Hence, *Coicis semen* (Yiyiren), *Menthae haplocalycis herba* (Bohe), *Artemisiae argyi folium* (Aiye), *Angelicae dahuricae radix* (Baizhi), *Chrysanthemi flos* (Juhua), *Rhei radix et rhizoma* (Dahuang), *Aucklandiae radix* (Muxiang), and other drugs produced in Qizhou were given names, such as QiYimi, QiBohe, QiAi, QiBaizhi, QiJuhua, QiDahuang, and QiMuxiang, and earned great reputations across the country.

In the period of the Republic of China, Chinese medicinal stores throughout the country basically followed the pattern of "shop front and workshop rear". In the early 1950s, the policy of national planned management was implemented for the Chinese medicinal industry. The primary and intermediate merchandise consignments, orders for processing and exclusive sales, processing, retailing and distribution were developed into individual public-private joint management. In this period, the production and selling of the decoction pieces were operated by individuals with manual work, following the "shop front and workshop rear" pattern. There were large variations in seasonal processing, the processing methods were not unified, and the production scale was limited, far from meeting the people's needs for disease prevention and treatment. By the 1960s, all of the private-owned drugstores had become state-owned. Some retail drug stores were merged into hospitals as Chinese medicine pharmacies, and some were combined into pharmaceutical companies specializing in decoction pieces and Chinese patent medicines (Wang et al. 2000). With TCM's rapid development, the consumption of CMMDPs has been greatly increased. For this reason, pharmaceutical companies have successively established factories or processing departments of decoction pieces. Some Chinese medication pharmaceutical factories even built pre-treatment workshops. Production became mechanized and the production capacity of decoction pieces increased significantly (Yang and Zhang 2010). Until the 1990s, the production enterprises of decoction pieces were still in a state with small-scale, simple equipment, outdated technology and manual workshops, which restricted the modernization of the production of CMMDPs (Li 2008).

4. The current situation of CMMDPs industry

4.1. Emerging integration of treatment and processing at the place of origin

The finished products after treatment at the place of origin are raw materials for the processing of CMMDPs. Treatment at the place of origin and the processing of decoction pieces are two continuous links, during which sorting out, cutting, and drying of the medicinal materials are repeated. In the 1980s, experts (Chen 1988) put forward that "Chinese medicinal materials should be processed into decoction pieces at the place of origin" and called on the industry of CMMDPs to extend upstream. In recent years, in consideration problems like the overlapping during the process of the treatment at the place of origin and the processing of decoction pieces, complex operations of processing, and likely occurrence of the loss of active ingredients, the notion of the integration of the treatment of medicinal materials at place of origin and the processing of decoction pieces was put forward (Yang and Zhang 2005; Huang et al. 2018; Zhang et al. 2018), which advocated that medicinal materials should be processed into decoction pieces at the place or origin after being harvested. The original rough treatment at the place of origin was replaced with the fine treatment, and decoction pieces were directly manufactured at the place of origin. The National Administration of Traditional Chinese Medicine performed a research project on the key technical specifications for the integration of treatment at the place of origin and processing of 30 CMMDPs (Yang et al. 2018). It integrated the related processes of treatment at the place or origin and the processing of decoction pieces, came up with key technologies, specifications and processing equipment involving the integration of the treatment at the place of origin and the processing, with the advantages of optimized processes, reduced costs, and being easy to store and transport, which raised the technological level of the CMMDPs industry, promoted its transformation and upgrading, and benefited for its development.

4.1.1. Advantages of the integration of treatment at the place of origin and processing

4.1.1.1. Connection to a national GAP plan for Chinese medicinal materials

The implementation of a national Good Agricultural Practice (GAP) plan for Chinese medicinal materials has laid foundation for the integration. The national standardized planting base for Chinese medicinal materials can provide high-quality raw materials for the processing and manufacturing of CMMDPs (Liu 2017). The combination of integration and standardized planting base is in line with the trend of designated large-scale manufacturing of high-quality Chinese medicinal materials, which can not only clarify and stabilize the source of medicinal materials, but also ensure the quality of the decoction pieces.

4.1.1.2. Quick connection of the treatment of Chinese medicinal materials at the place of origin, the manufacturing of decoction pieces and the market

Integration allows the direct entry of decoction pieces into the market, which are processed from Chinese medicinal materials at the place of origin, so as to accelerate the process of medicinal materials becoming the final consumer products of prescription medicines in the market, shorten the distance between the place of origin of medicinal materials and consumer markets, strengthen the interaction among treatment of medicinal materials at their place of origin, processing of decoction pieces and consumer markets, avoid the blindness of herb planting and manufacturing of decoction pieces, and promote the effective, healthy and stable development of the industry of CMMDPs after getting out of the outdated dilemma.

4.1.1.3. Ensuring the quality of decoction pieces from the source

The implementation of integration can effectively address the problems of scattered processing at the place of origin and market confusion, and prohibit CMMDPs of low quality entering the market. During the integration, the processing basis for medicinal materials is built into the place of origin of the genuine medicinal materials, where genuine medicinal materials of high quality are used as raw materials. At the best harvesting time season or period, medicinal materials are processed intensively at right time, so as to ensure the quality of the decoction pieces (Yue et al. 2017; Zhang et al. 2018). Integration can also reduce the loss of medicinal ingredients caused by intermediate processing and storage, and improve the quality of the decoction pieces. Traditionally, medicinal materials that have been dried at the place of origin are moistened, softened, cut and dried again, during which active ingredients of the medicinal materials are likely to be lost. Meanwhile, active ingredients are also easy to lose during the storage period before being processed into the decoction pieces(Yang JJ et al. 2016). Specifications for part of freshly cut decoction pieces have been included in the 2020 edition of the *China Pharmacopoeia*.

4.1.1.4. Creating premium brands of genuine CMMDPs

At the place of origin of common medicinal materials, the manufacturers of CMMDPs build processing bases in accordance with the requirements of Good Manufacturing Practice (GMP) to implement the integrating of the treatment at the place of origin and processing, which can change the situation of scattered processing by small farmers at origin place with natural and outdated economy, improve the chaos where the treatment of medicinal materials at their place of origin are not united, promote the formation of the centralized, mass, and large-scale production and operation model. Through the integration of manufacturing and marketing resources, a number of premium brands of genuine decoction pieces will be established nationwide (Wang et al. 2005).

4.1.1.5. Reducing manufacturing costs and increasing economic benefits

If medicinal materials are freshly processed into decoction pieces at their place of origin, the intermediate process can be shortened, saving both labor and time, and reducing the manufacturing cost (Duan et al. 2009; Li et al. 2016). Decoction pieces processed at

the place of origin increase the added value of medicinal materials. Not only herbalist at the place of origin can benefit a lot, but also enterprises involved in the integration, therefore promoting industrial reconstructing at the place of origin. In addition to manufacturing CMMDPs, parts not being used in medicine can be used as raw materials for pharmaceutical (Xu 2012), food (Zhao and Yi 2009) and fodder manufacturing (Liu et al. 2013), by which the utilization efficiency of medicinal resources can be improved and full utilization can be realized.

4.1.2. Matters needing attention during the implementation of integrating treatment at the place of origin and processing

At present, the integration of treatment at the place of origin and processing has received great attention from the industry of CMMDPs, and some accomplishments have been achieved, which are not limited to the integration of fresh cutting of medicinal materials, but also the integration of treatment at the place of origin and heating processing or excipient processing. However, not all medicinal materials are suitable for the integration of treatment at the place of origin and processing, and basic researches on the feasibility of the integration of specific medicinal materials need to be strengthened. According to the characteristics and application features of medicinal materials, techniques for the integration are explored, and procedures and technical parameters are determined. In addition, comparative studies on external properties, chemical components, and pharmacological and toxic effects are carried out between treatments at the place of origin and with traditional methods, so as to comprehensively evaluate the scientificity and feasibility of processing at the place of origin and integration for certain medicinal materials. Besides, it is necessary to improve the construction of a standardized system for the integration of treatment at the place of origin and processing, and to include treatment at the place of origin into the supervision scope of the pharmaceutical industry. During the implementation of integration, there have been cases that finished products are packaged after simple cutting and drying at the place of origin, or raw decoction pieces purchased from scattered farmers are packaged. As the final product of integration is decoction pieces, GMP-certified factories or pharmaceutical manufacturers of decoction pieces should take the lead in constructing workshops to meet the requirements of GMP at the place of origin to implement integration.

4.2. Deeply processed products

4.2.1. TCM formula granules

Single-ingredient CMMDPs are granules manufactured by concentrating water extracts (Li et al. 2016). Its essence is a single-ingredient extract granule, which is a supplement to conventional decoction pieces. TCM formula granules are convenient to take and ready-to-take after being dissolved. They are beneficial for the normalization and standardization of the industry of CMMDPs and its upstream industries and the realization of intelligent prescriptions and promotion of the construction of modern TCM pharmacies. It can also meet the international needs for herbal extract, to increase the economic value added of CMMDPs. The decoction prepared with conventional decoction pieces is a combined decoction, with special treatment, such as being decocted first or later. During the decoction process, complex physical and chemical changes may occur among different ingredients, which may involve solubilization, hydrotropy, adsorption, precipitation, and acid-base neutralization, substitution, hydrolysis, oxidation, and condensation. TCM formula granules are a combination of decoctions of various single prescriptions, whose effects are not necessarily equivalent to those of the decoction prepared by combined decoction. Pharmacodynamic and/or toxicological comparison should be made between formula granules and corresponding doses in the original decoction pieces. In addition, uniform quality standards should be developed for TCM formula granules.

4.2.2. Small-packed decoction pieces

The qualified CMMDPs after processing will be packaged with packaging materials according to the clinical dose of commonly use. There is no need for weighing with the utilization according to the number of packages (Li and Shi 2012). In 2008, the National Administration of Traditional Chinese Medicine published the "Guidelines on the Application of Small-Packed CMMDPs for Medical Institutions" to promote the use of small-packed decoction pieces, changing the traditional prescription mode and improving the working environment of pharmacists. The small-packed decoction pieces are accurately measured, and the prescription efficiency is high, which is conducive to the storage and preservation and also the quality improvement of the decoction pieces (Wan 2019). However, the lack of dosage specifications limits the flexibility of clinically prescribed dosages, which is not conducive to the preparation of clinical prescriptions (Zhou 2015). At the same time, each small pack is packaged with plastic bags and printed, increasing manufacturing costs and exacerbating plastic pollution (Liang 2018; Liu 2018).

4.2.3. Ultrafine decoction pieces

The ultrafine powder technology is used to pulverize the CMMDPs into powders with certain particle sizes. The ultrafine powder of herbs has a high wall-broken rate, also known as wall-broken decoction pieces, such as wall-broken decoction pieces of *Astragali radix* (Huangqi) (Rao et al. 2019) and *Panacis quinquefolii radix* (Xiyangshen) (Chen et al. 2016). The ultrafine decoction pieces inherited the advantages of powders and boiling powders of the TCM, and retained all components of the TCM or compound medicines and their pharmacodynamic material basis. Ultrafine decoction pieces can increase the dissolution of active ingredients, especially the poorly soluble ingredients, and meanwhile increase the specific surface area of the medication, improve bioavailability, reduce the dosage, and save resources. The quality of the preparations can be improved using ultrafine powder as the materials, so as to promote the development of innovative forms of TCM. However, researches on homogeny evaluation between the ultrafine decoction pieces and the original decoction pieces are needed, to confirm its safety, effectiveness and stability and controllability (Shen et al. 2017).

4.2.4. Puffed decoction pieces

During the processing of Chinese materia medica, new decoction pieces are prepared through the puffing technology. When the TCM is put into the extruder, due to mechanical extrusion and frictional heat generation, the temperature inside the machine cavity increases, so does the pressure, and the water in the medicine is in an overheated state. When the high pressure suddenly drops to normal pressure, the water vapor inside the medicine experiences instant expansion, breaking the cell wall and forming a hollow texture with loose texture (Zhang et al. 2007). Puffed decoction pieces of *Ginseng radix et rhizoma* (Renshen), *Lycii fructus* (Gouqi), *Dioscoreae rhizoma* (Shanyao), and *Paeoniae radix alba* (Baishao) have been reported. Experiments have confirmed that usual pieces have a crisp texture after expansion, which is conducive to dissolution.

4.2.5. Compressed decoction pieces

Flowers, whole grasses, leaves and some light or irregular decoction pieces are compressed into decoction pieces in certain shapes and certain dosages (Lin 2018). Compression is realized by physical methods, without the addition of any auxiliary materials, or changes in the intrinsic quality of the decoction pieces. After mechanized quantitative packaging with certain packaging materials, the resulting products can be directly used for prescription preparation. The compressed decoction pieces showed great reduction in its volume, which has the advantages of being easy to carry, transport, store, and adjust, but it is impossible to intuitively identify the goodness and inferiority of the decoction pieces.

4.2.6. Instant decoction pieces

On the basis of traditional processing, the ready-to-take CMMDPs are manufactured through modern technologies, such as quick freezing, freeze-drying, fermentation and non-thermal physical sterilization (Jia 2019), which have the characteristics of reliable curative effects, high safety, easy to take, delicious, portable and easy to popularize. They can meet the growing needs for health products under the trend of massive health, and are mainly used for preventive healthcare and health rehabilitation. Since the ready-to-take decoction pieces can be directly put into mouth, their manufacturing environment is the same with that of oral preparations. The development of ready-to-take decoction pieces requires that processing methods should be selected according to the medicine's characteristics. For example, sometimes crispness needs to be improved, or taste needs to be improved or the appearance needs to be beautified. Edible TCM is most suitable for the preparation of ready-to-take decoction pieces, such as dairy *Astragali Radix* and freezing-dried *Gastrodiae rhizoma* (Tianma), which not only increases the decoction pieces' economic value added, but also improves their poor images.

At present, the total market value of TCM formula granules will reach 30 billion yuan in 2020. Ultrafine decoction pieces and small-packed decoction pieces also have a certain scale. However, puffed decoction pieces, compressed decoction pieces and Instant decoction pieces are still in the conceptual stage, and have not been approved by the regulatory authorities to move towards industrialization.

4.3. Needing improvement in manufacturing technologies

During the seventh and eighth period of the five-year plan, the national scientific research department and the production department, based on the production reality of CMMDPs, increased the investment on its scientific research, conducted researches on the key technologies and developed key equipment for its production, therefore, significantly improving the production conditions for CMMDPs. Taking *Curcumae rhizoma* (Ezhu) as an example, traditionally, it was processed by soaking moistening or piling moistening, which has low efficiency, and the components were easily lost. Through the vacuum steaming moistening method, the efficiency of softening can be improved, and the moistening would be more even, making the products more easily to cut (Wang et al. 2019). However, most of the traditional decoction pieces' processing and production was empirical. The production processes lacked normalized and standardized technical parameters (Wu et al. 2018). The next step is to increase the development and application of various new types of mechanized, automated, and intelligent processing equipment, such as electrical dual-use medicinal steaming cabinets, automatic drug-moistening machines, temperature-controlled calcining furnaces with energy-saving and emission-reduction programs and so on. The automated and intelligent control of the CMMDPs production process was gradually realized. In addition, information-based process control technology, like color difference meters and electronic noses, were used for production monitoring. What's more, common herbs of rhizomes, tubers and flowers were processed at the place of origin with a set of interlocking equipment integrating washing, cutting and drying, and new technologies such as hot-air drying, microwave drying, and infrared drying were also under exploration, in order to save energies like water, electricity and gas, so as to reduce production costs and increase efficiency. Through increasing the transformation of the research results of processing principles, parameters for the production of decoction pieces were made more objective and through the continuous updating and development of processing equipment, the technical level of its production were also continuously improved, resulting in normalization, automation and large-scale production.

4.4. Strengthening management of CMMDPs' normalized production

With the formulation and implementation of relevant production management policies for CMMDPs (Liu et al. 2009), especially the implementation of GMP certification for CMMDPs, great improvement has been made in the plant facilities, processing equipment, quality control system, and personnel quality of pharmaceutical enterprises. These improvements enhanced the production conditions of CMMDPs, and thus, promoted the advancement of the overall management of pharmaceutical enterprises (Zeng and Li 2014).

In 2002, the former Safety Department of State Food and Drug Administration entrusted the China Association of Traditional Chinese Medicine (CATCM) to organize experts for the preparation of GMP certification for CMMDPs. On January 30, 2003, the "GMP Supplementary Provisions for CMMDPs" was officially published. The "Guidelines for GMP Inspection of Pharmaceutical Products – CMMDPs" was issued in April 2003. In June of the same year, one Chinese herbal medicine manufacturer passed GMP certification for the first time. In October 2004, the former State Food and Drug Administration issued a "Notice on Promoting the Implementation of GMP in the Supervision of Drugs in CMMDPs and Other Drugs", and required that the provincial Food and Drug Administrations was responsible for the GMP certification of manufacturers of CMMDPs in their jurisdictions since January 1, 2005. The notice also stipulated that since January 1, 2008, all manufacturers of CMMDPs must manufacture in accordance with GMP (Zhao et al. 2010). Subsequently, the "GMP Certification Inspection Project for CMMDPs" was formulated to further clarify the goals of GMP certification for the manufacturers of CMMDPs. On February 5, 2008, the former State Food and Drug Administration issued the "Notice on Strengthening the Supervision and Management of the Manufacturing of CMMDPs", which once again emphasized that since January 1, 2008, companies that have not obtained a "GMP Certificate" were not allowed to be engaged in the manufacture and operation of CMMDPs. By September 2017, more than 1,800 manufacturers have passed GMP certification for CMMDPs. Since 2008, China has comprehensively implemented GMP management in the manufacturing of CMMDPs. After more than a decade, GMP management has become routine and also the most fundamental requirement for decoction pieces manufacturers. Today, GMP certification has changed from a high threshold that needed to be passed to a basic requirement, which has greatly promoted the development of the industry of CMMDPs.

However, some companies that have passed the GMP certification are still engaged in OEM (Original Equipment Manufacturer), amateur performance and affiliation. Due to frequent quality problems, since the implementation of the new version of GMP certification in 2014, the GMP certificates of some companies were recovered, especially CMMDPs manufacturers. In 2015, a total of 144 certificates were recovered across the country, 82 of which were recovered from CMMDPs manufacturers, accounting for 56.9%. In 2019, a total of 114 GMP certificates were recovered across the country, 60 of which were recovered from CMMDPs manufacturers, accounting for 52.6%. Differences in the specific implementation of GMP for different decoction pieces manufacturers were observed, which more or less affected the development of the entire industry. In the future, it is necessary to combine the characteristics of CMMDPs and current manufacturing reality and thus, improve the relevant provisions of GMP for CMMDPs, enhance the management efficiency of CMMDPs manufacturing, strengthen the self-discipline of the entire industry, and ensure that manufacturers develop in an orderly manner in accordance with market economic laws.

4.5. Strengthening supervision and establishing the objective and feasible quality evaluation system for CMMDPs

The quality of CMMDPs is directly related to the clinical efficacy and the quality of Chinese patent medicine. The state should strengthen supervision and steadily promote a series of policies, such as pollution-free planting and the establishment of the traceability system, which makes manufacturers pay much more attention to the quality of decoction pieces and continuously improve the quality of CMMDPs. For example, starting from the farming

of Chinese herbal medicines and the manufacturers of decoction pieces, a quality traceability system should be established, into which data, such as planting, harvesting, processing in the place of origin, processing, quality inspection reports, and warehousing should be imported. After the product is assigned a code in the system, we can track the quality of the decoction pieces through the whole processes in the circulation and utilization according to the two-dimensional code on the package, thereby improving the supervision efficiency (Li et al. 2019).

The objective and feasible quality evaluation system for CMMDPs is an important guarantee for the manufacturing of qualified, safe and effective decoction pieces. In the past, the indexes for quality test quality were simple, and the test technology was outdated, so the quality of the decoction pieces was not controllable. As the national quality standard of TCM, the *China Pharmacopoeia* attaches great importance to the quality standards of Chinese medicinal materials and TCM prescription preparations, in which Chinese herbal decoction pieces (processed products) and medicinal materials are often confused. The 2010 edition of the *China Pharmacopoeia* clearly states the differences between decoction pieces and medicinal materials, in which 822 standards for decoction pieces are included, basically covering all commonly used clinical decoction pieces, and generally establishing a standard system of CMMDPs with quality standards from the *China Pharmacopoeia* as the main body, and *Specifications on the Processing of CMMDPs* of various provinces, municipalities and autonomous regions as the complementary part. The 2015 edition of the *China Pharmacopoeia* focuses on strengthening and improving the safety evaluation items for CMMDPs, including heavy metals and harmful elements, pesticide residues, sulfur dioxide residues and mycotoxins. The improvement of these safety-related quality standards will effectively prohibit pesticide abuse during plantation, sulfur fumigation abuse during processing and storage at the place of origin, and mildew and deterioration during storage. The 2020 edition of the *China Pharmacopoeia* further supplements scientific quality control methods based on intrinsic objective indicators. Based on the characteristics that the overall composition of TCM matters, fingerprint and multi-component content determination studies were conducted and a standard was established, to improve the control of the effectiveness of CMMDPs. According to the composition changes before and after processing, more attention was paid to compositions of CMMDPs that were different from those of Chinese medicinal materials, such as toxicity, and different actions of the same decoction piece in the raw or processed form, for specific identification and content determination. Identification methods for raw and processed decoction pieces with unique characteristics were investigated and established. The establishment of the quality standard for CMMDPs is a dynamic, constantly updating process. It is necessary to continue to deepen basic research on Chinese materia medica, improve in scientific and technological levels and interpret of the scientific connotation of processing principles, so as to continuous updated quality standards and to make them more scientific, complete, reasonable and controllable.

5. The prospect of CMMDPs industry

5.1. Establishing an integration alliance between the bases of medicinal materials and manufacturers of decoction pieces

In recent years, the establishment of GAP planting bases of medicinal materials and large-scale planting cooperatives has provided stable and high-quality raw medicinal materials for the processing and manufacturing of CMMDPs. In order to reduce the costs and ensure the source and quality of medicinal materials, manufacturers of decoction pieces may establish a qualified GAP planting base of medicinal materials, or form an industrial alliance with existing GAP planting bases of medicinal materials, so as to realize the integration of medicinal material bases and decoction pieces. On the basis of standardized processing techniques and controllable quality, genuine medicinal materials with large varieties and high-quality are preferred for the creation of premium brands of CMMDPs.

5.2. Establishing modern manufacturing system

The modern manufacturing system of CMMDPs relies on the GAP medicinal material planting bases. Modern equipment and scientific detection methods should be adopted, and the manufacturers should strictly follow the processing requirements and quality standards. GMP management of CMMDPs is to be implemented to effectively control the whole manufacturing process, making the whole process to be scientific and data-based, thus ensuring the stability and controllability of the decoction pieces' quality (Tang et al. 2018). Enterprises should be actively guided to appropriately reduce their manufacturing varieties according to their own conditions, and expand the manufacturing scale of single decoction pieces, in order to realize the integration of small and medium-sized enterprises (SMEs), thereby completely changing the multiple, small, and scattered industrial structure. On the basis of lessons from the experience of relevant pharmaceutical and food industries, we are supposed to develop processing equipment with specificity, universality and informatization, quantify relevant parameters in combination with research results on processing techniques, ensure the consistency of the quality specifications of CMMDPs, and integrate key equipment for the standardization and industrialization of the manufacturing of CMMDPs by utilizing online control technologies. These measures will establish integrated equipment and production lines in accordance with manufacturing characteristics of CMMDPs, as well as realize the standardized, automated and large-scale manufacturing of CMMDPs. The whole manufacturing process is to be effectively controlled, that is to formulate corresponding quality-control indicators for every manufacturing procedure, including indicators for the quality control of raw materials control of processing excipients, control of processing techniques, quality control of semi-finished products, quality inspection on finished products, storage quality control, quality control in circulation. The quality control of the whole-process manufacturing should be better than the control of the processing results emphasized in the past, which can ensure the quality of decoction pieces more comprehensively and effectively.

5.3. Normalization of quality supervision

Improvement of the normalized supervision mechanism allows the supervision for CMMDPs to be standardized and normalized (Xiao et al. 2016a). Things that could be done in the near future include: to improve the national drug regulatory system; truly to implement the management system of the manufacturing approval number for CMMDPs; to promote the creation of a number of full-scale enterprises and brand enterprises in the industry; to reverse the low-profit situation of the industry of decoction pieces by utilizing the scale effect and brand effect; to increase the concentration of the industry to meet the needs of great circulation in the market; to establish a quality traceable system covering the entire industrial chain of TCM; to encourage enterprises to record information of decoction pieces in every procedure by information-based means; to complete the records of decoction pieces in each processing link; to realize the tracking and supervision of the decoction pieces throughout the entire process to ensure the quality of CMMDPs.

5.4. Establishing an information system for the manufacture, sale and application of decoction pieces

The establishment of an information system for the manufacture, sale, and application of CMMDPs can realize the information management of the marketing system of CMMDPs, as well as accelerate and ensure their circulation. Through internet and online trading platforms for CMMDPs and e-commerce, online display of a large amount of real-time information is possible, including Chinese medicinal material resource reserves, annual output, annual collection amounts, processing methods at the place of origin and storage conditions, processing specifications, processing capacity, manufacturing costs, grade classification, product name, market capacity of decoction pieces, customer types, price trends, logistics mode, trading methods and so on.

Thus, the exchange between domestic and aboard markets is accelerated, and the healthy development of the industry of decoction pieces is promoted.

5.5. Inheriting traditional processing techniques

Inheriting traditional processing techniques has both historical, cultural and economic promotion values. Through the inheritance of the traditional processing techniques, the role of Chinese medicinal processing with independent intellectual property rights can be enhanced in the TCM industry, thereby promoting the development of the industry of CMMDPs and better benefiting human health (Yang et al. 2016).

Traditional processing techniques should not only be inherited in terms of technique, but also in personnel. First of all, the inheritance of traditional processing techniques should be promoted, and systematic inheritance research should be supported by government project, in order to exploit and sort out academic ideas of traditional processing techniques, processing experience, processing theories and processing techniques, explore the social and cultural background created by traditional processing techniques, and summarize the formation rules and technical characteristics of the processing techniques, thus providing reference for the processing of Chinese medicines and TCM development. Secondly, at grassroots, there are still some ancestral TCM families that hold on to the medication model of 'one method for one prescription', which involves many special traditional processing techniques that can produce special effects. While their medical qualifications are certified, the traditional service pattern of "shop front and workshop rear, with TCM practitioners practicing medicine in the hall" should be explored and supported, and researches on this pattern's scientific principles should also be strengthened, in order to build a research platform for special processing techniques (Xiao et al. 2009). Finally, an inheritance model combining processing experts and veteran workers is to be implemented (Li 2018), allowing experts and scholars who are good at summarizing to conduct a general survey of the existing veteran workers and their processing experience in the country, establishing a relevant technical file. Corresponding policies and regulations should be formulated to encourage the experienced veteran workers to train the younger generation, so as to form a handing-down inheritance system. Meanwhile, it is good to seek talented personnel for processing, thus laying a talent base for the inheritance of TCM processing techniques.

6. Conclusions

At present, China attaches unprecedented importance to TCM's development, and has issued a number of supporting policies, sparing no effort to support its development, and even implemented super drug treatment for CMMDPs, such as the strict prohibition of foreign investments in the processing of CMMDPs and the production of unique Chinese patent medicines. The prohibition of CMMDPs in the bidding for the centralized procurement of drugs in all provinces, out of the range of drug price reductions. And the selling of CMMDPs still enjoying the policy of drug price addition. The revitalization and development of the industry of CMMDPs ushered in the right time, geographical convenience and favorable opportunities.

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