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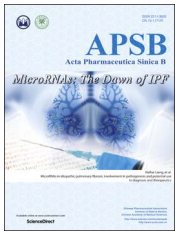

REVIEW

New sensor technologies in quality evaluation of Chinese materia medica: 2010–2015

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Abstract New sensor technologies play an important role in quality evaluation of Chinese materia medica (CMM) and include near-infrared spectroscopy, chemical imaging, electronic nose and electronic tongue. This review on quality evaluation of CMM and the application of the new sensors in this assessment is based on studies from 2010 to 2015, with prospects and opportunities for future research.

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1. Introduction

Quality evaluation of Chinese materia medica (CMM) is targeted at safety and effectiveness. Rapid analysis in quality control is focused on holistic characterization and measurement of active ingredients, and is of significant public concern. However, because of the diversity of ingredients and the multi-targets effects, the quality standard of CMM has not been universally acknowledged. A low quality standard also impedes the pace of modernization and internationalization of CMM. Thus, it is necessary to establish a reasonable and effective quality evaluation system. So far the development of quality assessment of CMM has gone through four stages: off-line analysis, on-line analysis, in-line analysis and on-site analysis[1]. With the development of analytical methodology, high performance liquid chromatography (HPLC), gas chromatography (GC) and other methods have been increasingly utilized. Although these conventional methods can provide accurate identification and quantitation of active pharmaceutical ingredients, they are unable to provide information about the spatial distribution of individual components, even making it difficult or impossible to trace the source of failures or anomalies. In this case, a new trend in the sensor field is to couple multidimensional sensors with advanced information processing strategies, such as near-infrared (NIR), electronic nose (EN), electronic tongue (ET) and chemical imaging (CI). These new sensors are fast, simple, and inexpensive, and have become an effective method for identification and quality control of CMM[2].

At present, the new sensors play a very critical role in the field of pharmaceutical analysis with regard to the evaluation of safety and effectiveness of CMM. A growing number of researchers have referred to the sensors, including the NIR, EN, ET, CI. Here we will review changes to quality evaluation of CMM and the application of the new sensors from 2010 to 2015. Furthermore, the development of NIR, CI, EN and ET for qualitative and quantification analysis of CMM will be discussed. Finally, the limitation of these new sensors and the future directions for research will be considered.

2. NIR spectroscopy

Online NIR sensors (NIRS), one of the most important technologies in the rapid quality evaluation of CMM, have become highly popular and are widely used in the fields of process control including extraction, concentration, alcohol precipitation and purification. Moreover, with the rapid development of information technologies and especially developments in chemometrics, online NIR sensors have increasing applications in quality analysis abroad[3–5].

2.1. Qualitative analysis of CMM

2.1.1. Identification and authentication

Identification and confirmation of the authenticity of CMM has mainly relied on experience, microscopic identification, physical identification, and chromatographic identification. But now, NIRS can rapidly identify multiple chemical components and is updating these traditional methods. Gao et al.[6] have characterized *Pinellia ternata* and spurious imposters. They reported that NIRS with cluster analysis was consistent with chromatographic analysis, providing a new method to confirm the authenticity of *Pinellia ternata* in a fast and stable method. Qu et al.[7] collected *Colla corii asini* from different sources and established a model to distinguish them by NIRS. Zhao et al.[8] extracted component information of Rhubarb and used the Fisher classifier to confirm its authenticity. Shao et al.[9] applied NIRS to qualitative recognition of extracts from *Anoderma lucidum* and *Coriolus versicolor*, providing a basic method for rapid identification of these extracts. Sun et al.[10] investigated *Semen Cuscutae* and its adulterants. They generated data for the authentic product from NIRS, choosing the optimum wavebands with the highest precision, and were able to make distinctions between three different pharmaceutical materials.

2.1.2. Determination of geographical origins

It has been proposed that the main components of CMM, even when from the same location, are influenced by different factors (for example, climate and growth conditions), which leads to variations in quality. Compared with the traditional methods, NIRS can authenticate the CMM regardless of origin.

To investigate the effect of geographical origin on pharmaceutical content, many researchers have utilized NIRS. For example, Guo et al.[11] established a NIRS method for the identification of *Citri reticulata*, which is well known as a non-destructive and green technology. Additionally, Wang et al.[12] measured and analyzed the NIR data of 102 batches *Cordyceps sinensis* samples from different habitats. In this case, the accuracy of the results has reached 100%. Liu et al.[13] gathered 269 batches of Radix Angelicae and 350 batches of *Salvia miltiorrhiza* to characterize these samples by geographical origins. It suggested that the accuracy of cross validation was 99% and 95%, respectively. Sun et al.[14] assembled the Cortex Phellodendri and its adulterants. They established a discriminant model which has been verified by a triple cross-validation method. Recently, Bai et al.[15] built an analysis method on NIRS of Radix Rehmanniae from three producing fields, offering a new technology for the further identification.

2.1.3. Characterization of processing

Processing is responsible for the change of chemical components under the theory of CMM. After processing, these changes can be identified by NIR. For instance, when raw Rhizoma Rehmanniae was processed, the content of sugar should differ according to the processing time. With the help of NIRS, Wang et al.[16] developed a new method for identification of Rhizoma Rehmanniae based on the number of steamed treatment hours, and found that samples could be separated perfectly.

To process the *Agastache rugosus*, Cai et al.[17] designed three modes: ordinary drying method, shade-drying method and heating-drying method. By measuring the content of patchouli alcohol by NIRS, the best processing procedure could be determined. Ultimately, it turned out that the content of patchouli alcohol in the shade drying method was the best. Zhang et al.[18] collected the extract samples and applied the NIRS to test the concentration of Dan phenolic acid B. Also, Ding et al.[19] established a rapid method to monitor on-line the blending process of CMM powder. It was concluded that a miniature NIRS could be used to monitor the content of the constituents and the blending homogeneity of CMM powder in real time. Moreover, it could determine the end-point of the blending process rapidly. Taken together, the method should be utilized to judge whether the physical state of a powder mixture conforms to the quality standard. Jin et al.[20] used the moving block standard deviation method and NIRS to identify the

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