



Review

Applications of capillary electrophoresis in traditional Chinese medicine

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Abstract

Capillary electrophoresis (CE), recognized for its minimal reagent dosage, rapid analysis, and high efficiency, holds significant promise for the analysis of traditional Chinese medicines (TCM). This article reviews the application of CE in the determination of active ingredients in TCM. The active substances of herbal medicines have been classified and discussed based on their chemical properties, and the CE methods applied to different substances are summarized and discussed. This article also provides some suggestions for future research and improvement.

Keywords: capillary electrophoresis; traditional Chinese medicine; application

1 Introduction

Traditional Chinese Medicine (TCM) has been practiced in China for thousands of years. Compared with Western medicine, TCM has the advantages of less toxicity, side effects and proven efficacy. It not only makes up for the shortcomings of Western medicine, but also meets the needs of disease prevention and treatment. Currently, only a few active components of herbs have been thoroughly and systematically studied. The

isolation and analysis of these active components is extremely challenging for various reasons. The first and foremost problem is the variety of herbal medicines, in which the active components are not only diverse but also complex, and their contents in different herbs vary significantly. In addition, the concentration of these active ingredients is affected by a variety of factors, such as the origin of the plant, harvesting time, cultivation techniques and growing conditions. Often the low levels of active ingredients, coupled with interference between compounds, make it particularly difficult to control and ensure the quality of these active ingredients. In order to extract effective and safe herbs and maintain consistent quality, the quantification of active ingredients undoubtedly represents the most immediate and important issue.

Capillary electrophoresis (CE), also known as

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high-performance capillary electrophoresis (HPCE), is a liquid-phase micro-separation technique that utilizes the high-voltage electric field as the driving force and the capillary as the separation channel. It achieves separation and detection based on the differences in mobility and distribution behaviors of sample components. As a hybrid method combining principles of electrophoresis and chromatography, CE offers advantages such as high efficiency, rapidity, accuracy and sensitivity, easy operation, low solvent consumption, low cost and low environment pollution. This article reviews the application of CE in the field of Chinese medicine. Phytochemicals are categorized according to their chemical properties (alkaloids, phenolic acids, carbohydrates, quinones, flavonoids), and analyzed using various CE modes, including Capillary Zone Electrophoresis (CZE), Micellar Electrokinetic Capillary Chromatography (MEKC), and Capillary Electrochromatography (CEC).

2 Chemical analysis of active components

According to the relevant literature, CE is a powerful tool to analyze many components of traditional Chinese medicine, such as alkaloids, flavonoids, anthraquinones, phenolic acids, carbohydrates and so on.

2.1 Alkaloids

Alkaloids-containing plants are often used as traditional medicine. Nowadays, aqueous acidic electrolytes and organic solvents are widely used for CE analysis of alkaloids, in which the organic solvent as a non-aqueous medium contributes to the solubility and selectivity of the hydrophobic compound.

Bis-benzyl isoquinoline alkaloids have attracted much attention for the important pharmacological effects. In particular, protoberberine

is a structural class of organic cation, and its alkaloids have a variety of biological and pharmacological activities, including inhibition of DNA synthesis, protein biosynthesis, inhibition of membrane permeability, and uncoupling of oxidative phosphorylation. In clinical practice, it is mainly used to inhibit pathogenic bacteria and enhance the phagocytosis of leukocytes. Chen has successfully developed an aqueous background electrolyte (BGE) and a non-aqueous BGE for Capillary Electrophoresis-Diode Array Detection (CE-DAD) and Capillary Electrophoresis-Mass Spectrometry (CE-MS) analyses, respectively, and optimized the Capillary Electrophoresis-Electrospray Ionization-Time-of-Flight-Mass Spectrometry conditions (CE-ESI-TOF-MS). Berberine, palmatine, curcumin, berberrubine, eberberine, coptisine, tetrahydrocatecholine, and tetrahydrocheilanthifolinium were separated at baseline resolution by CE-DAD and TOF-MS and isolated at baseline resolution. In addition, the linearity, sensitivity and precision of the CE-MS method were validated for selected alkaloids, such as berberine, palmatine and curcumin. The tested CE-MS is also suitable for routine analyses [1]. Dabrowski applied a new method for the isolation of alkaloids using a Capillary High-Performance Liquid Chromatography System (cHPLC) developed for the determination of alkaloids from the Amur cork tree (*Phellodendron amurense* Rupr) and from two widespread shrubs, the Oregon cork tree (*Mahonia aquifolium* Nutt) and the European berberis (*Berberis vulgaris* L). This system was optimized with three different stationary phases as well as different solvent buffers [2].

Morphine alkaloids, also known as opium alkaloids, such as morphine, codeine, timbaine, and opium poppy alkaloids, belong to the isoquinoline derivatives. They exhibit analgesic and sedative effects and are often used as anesthetics in clinical practice. However, morphine alkaloids are highly



addictive, so analytical methods are very important for the determination of these compounds in plant material. Additionally, the content of specific morphine alkaloids can be used to differentiate the source of opium, which can help law enforcement agencies to check the illegal production of narcotic drugs.

Sashidhar et al. employed CZE to analyze 124 opium samples from different licit opium-producing areas of India, quantifying the content of major alkaloids such as taine, codeine, morphine, opium poppy and narcotine. The study revealed that the alkaloid profile varied significantly depending on the sample type. Chemometrics utilizing the analytical data for the major alkaloids successfully classified the licit opium-growing areas of India into three broad categories. This method can be widely used for forensic identification of the origin of licit or illicit opium originating in India, making it possible to analyse samples for clustering on the basis of geographical origin [3].

Aconitine, a toxic alkaloid found in plants, has potential pain-relieving, anti-inflammatory activities. enabling its use at low doses. Song established CZE for the simultaneous determination of six major alkaloids, aconitine, mesaconitine, hypaconitine, benzoyl aconitine, benzoyl mesaconitine, and benzoyl hypaconitine, by taking advantage of the ease of hydrolysis of aconitine, using a BGE consisting of 200 mM Tris buffer with 150 mM perchloric acid and 40% dioxane, pH 7.8, in a short period of time. The isolation of three diester-diterpene alkaloids (natural aconitine, hydroxyaconitine, mesaconitine) and related degradation products was accomplished [4].

Phenylethylamine is an alkaloid and monoamine neurotransmitter that is used as an intermediate in the synthesis of a variety of drugs. It is widely used for its effects on the body's metabolism and can inhibit dopamine nerve activation, so it can be used

to treat depression. Specifically, ephedra extracts contain alkaloids such as (1*R*,2*S*)-(-)-ephedrine, (1*S*,2*S*)-(+)-pseudoephedrine, (1*R*,2*S*)-(-)-norpseudoephedrine, (1*S*,2*S*)-(-)-norpseudoephedrine, (1*R*,2*S*)-(-)-*N*-methylephedrine and (1*S*,2*S*)-(+)-*N*-methylpseudoephedrine. In order to obtain sufficient selectivity in the isolation of these alkaloids, Li developed a CZE method for the simultaneous determination of ephedrine and pseudoephedrine in a mobile buffer solution consisting of Tris-H₃PO₄ (pH 4.5) with 2.5 mM Cu (II)-L-lysine complex as the ligand-exchange modification. The hydroxyl and nitrogen atoms of the alkaloids can produce complexes with Cu (II). Moreover, the protonation of L-lysine can interact with the π -electrons of the aromatic ring, which enables the accurate determination of ephedrine and pseudoephedrine. The linear ranges of ephedrine and pseudoephedrine were verified to be 15.0-225.0 and 20.0-250.0 mg/L, respectively. The recoveries ranged from 95.0 to 104.0% (RSD% < 2.54) and the sensitivity (LOD 5.0 g/mL) was good enough to be applied to practical samples [5]. Barbosa used CZE and indirect Ultraviolet (UV) detection to isolate and quantify non-UV-absorbing alkaloids present in ethanolic extracts of *S. spectabilis* flowers. The optimized CZE method used a background electrolyte containing 60 mM histidine (His), 15 mM α -cyclodextrin, 20% acetonitrile (ACN), and pH adjusted to 4.7 with acetic acid (AcOH). The limit of detection (LOD) values were 10.2 and 13.9 mg/L for cassine and spectaline, respectively. Precision was better than 2% for both analytes. The method allows the use of UV absorbance detection in indirect mode, providing a cost-effective alternative to light scattering or mass spectrometry detectors for analyzing organic species in plant extracts that do not absorb UV light [6].

Chiral analysis is one of the major ways of pharmaceutical chemistry quality control in which CE plays a key role. Chiral analysis provides a



useful tool in the characterization of ephedra and its medicinal plant preparations.

Chiral Micellar Electrokinetic Chromatography-Mass Spectrometry (MEKC-MS) method was utilized for separation, identification, and quantitation of ten enantiomers of ephedrine and its related compounds. Enantioselective separations of all ephedrine alkaloids were accomplished through a combination of polysodium. The method was validated in terms of linearity, LOD, LOQ, precision and robustness. It was finally used in the analysis of three standard reference materials (SRMs). Results of (-)-ephedrine ranged from 12.49 to 0.24 mg/g, for (+)-pseudoephedrine from 4.04 to 0.019 mg/g, for (-)-norephedrine from 0.36 to 0.0031 mg/g, for (+)-norpseudoephedrine from 0.68 to 0.0052 mg/g, for (-)-methylephedrine from 1.18 to 0.0092 mg/g and for (+)-methylpseudoephedrine from 0.086 to 0.00037 mg/g in the SRMs [7].

2.2 Flavonoids

Flavonoids have a wide range of biological activities including antioxidant, anti-tumor, cardiovascular protection, and mechanism inflammation. Aqueous borate buffers are often used to isolate flavonoids because borates simplify the separation by forming complexes with neighboring dihydroxyl groups on the flavonoid nucleus and with neighboring cis-dihydroxyl groups on the sugars.

Qian developed a rapid and efficient capillary electrophoresis with electroactive compounds (CE-EC) method for the simultaneous determination of three flavonoids (naringenin, rutin, quercetin) and ascorbic acid with 24 mmol/L borate as buffer (pH 8.6). This method has been used for the detection of analytes in serum and feces of rats, and proves to be an alternative solution for the study of flavonoid metabolism in biological processes [8]. Wu achieved excellent separation of five flavonoids (hesperidin, naringenin, hesperidin, naringenin, and rutin) and

ascorbic acid from grapefruit juice by capillary electrophoresis with electrochemical detection (CE-ED) in 60 mmol/L of borate buffer (pH 9.0) in 25 min. The analyte response was linear over four orders of magnitude, and the limits of detection ($S/N = 3$) ranged from 1.4×10^{-7} to 1.0×10^{-6} g/mL of analyte. The method has been successfully applied to the analysis of grapefruit, and the combination of ED and CE enables selective and sensitive detection of the electroactive components in fresh fruit [9]. Mixed phosphate-borate buffers are also suitable for CE for the separation and identification of flavonoids. Xu applied CE-ED for the separation of four flavonoids (rutin, chrysin, quercetin and quercetin) from *Cichorium ichthyocarpum* in 60 cm long capillary tubes, with 60 mmol/L $\text{Na}_2\text{B}_4\text{O}_7$ -120 mmol/L, NaH_2PO_4 (pH 8.8) as electrophoresis buffer, and the baseline separation of four flavonoids was successfully obtained within 21 min at a separation voltage of 15 kV. The relationship between peak currents and analyte concentrations was linear over about two orders of magnitude, with detection limits for all analytes ranging from 0.02 to 0.05 g/mL. It was concluded that the CE-ED method is well suited for the rapid determination of flavonoids in different parts of Cichlids [10]. Zhen developed a fast, efficient and simple capillary electrophoresis-electrospray ionization-quadrupole time-off mass spectrometry (CE-ESI-Q-TOF-MS) method for the determination of eight flavonoids (chafftoside, rutin, hesperidin, naringenin, naringenin, viologen, nerol, and kaempferol) in 23 citrus samples. The use of an MS assay instead of a UV detector enabled the simultaneous identification of all studied compounds within 12 min, including those not separated by electrophoresis [11].

A CE method employing capacitively coupled contactless conductivity (C4D) was applied for the first time to the isolation and determination of 6-hydroxyflavonoids, biophytin, hesperidin and naringenin, and the optimal conditions were found to



be 1.0- and 5.0-mM chromate BGE (pH 9.50) in the anti-EOF and co-EOF modes respectively. Validation of the established CE-C4D method indicated that it was approximately seven times more sensitive than the indirect UV assay applying the same conditions, and the sensitivity of C4D was approximately two times higher than an earlier published CE method using direct UV detection [12].

2.3 Anthraquinones

Anthraquinones are widely found in plants, especially in the comfrey species. They have a variety of biological activities, including antioxidant, anti-inflammatory, anti-tumor and antibacterial activities. Anthraquinone derivatives like rhodopsin and alizarin are used to treat a variety of diseases such as digestive disorders, skin diseases and cancer. In the isolation of CE, alcohols (methanol and ethanol) and acetonitrile are mainly used as the eluent composition.

Chu proposed a novel strategy combining salting-out-assisted liquid extraction with dynamic pH liquid junction scanning large-volume sample stacking in capillary electrophoresis for the on-line preconcentration and determination of anthraquinone in cassia seed essence tea. A method with up to 468-fold sensitivity was achieved by optimized dynamic pH liquid junction scanning large volume sample stacking [13]. Sheu and chen developed a micellar electrokinetic capillary electrophoresis (MEKC) method for the simultaneous determination of three anthraquinones (rhodopsin, rhodopsin, and aloe rhodopsin) and two anthraquinones (sennoside A and sennoside B) in herbal preparations. The pH of the buffer plays an important role in the separation process as it affects the ionization state and electrophoretic current. Experiments showed pH 9.34 produced the best resolution. The migration of rhodopsin and aloe rhodopsin increased with the increase of sodium dodecyl sulfate (SDS)

concentration in the electrophoresis solution. The carrier consisting of buffer solution (10 mM sodium dodecyl sulfate, 12.5 mM sodium dihydrogen phosphate, and 1.5 mM sodium borate) and acetonitrile (3:1) was the most suitable electrolyte for this separation, and the content of these anthracene quinolines in herbal preparations containing rhubarb could be easily determined within 30 min by the above method [14]. Tian established the simultaneous determination of five anthraquinone derivatives, rhodopsin, chloroxanthin and rhodopsin, and thujaplicin by capillary zone electrophoresis (CZE) using 35 mM phosphate buffer (pH 11.0) containing 20 mM-CD and 2 M urea, cyclodextrins (CD) as a modifier, urea as a solubility enhancement, a voltage of 20 kV, and detection at 254 nm. Under these conditions, all five anthraquinones were baseline separated within a short analytical time of 12 min. The method was successfully applied to the determination of anthraquinones in ethanol extracts of two rhubarb plants (*Rheum palmatum* and *Rheum hotaoense*) and *Polygonum cuspidatum* [15]. CE and ultra-high-pressure LC (UHPLC) methods coupled with a UV detector were developed to characterize the metabolomics of different Rheum species (16 samples of Rheum officinale and Rheum tanguticum collected from different locations). Metabolomic profiles of rhubarb species from CE and UHPLC were clustered using principal component analysis and distance-based redundancy analysis; hybrid rhizomes were unambiguously identified by similarity measurements of metabolite profiles from UHPLC, which were subsequently confirmed by gene sequencing. The results suggest that the novel chemometric tools address the reproducibility of CE. CE and UHPLC can be used for quality control and characterization of rhubarb samples and are efficient and effective tools for identification and validation of herbs [16]. Different background electrolytes have different effects on the detection of anthraquinones. Lenka explores the effect of water (H₂O) instead of



heavy water (D_2O) on the fluorescence behavior of anthraquinones and anthracyclines. CE with heavy water as the background electrolyte (BGE) solvent provides excellent sensitivity for the separation and detection of these analytes [17]. Borate and phosphate buffer solutions of different pH values were used as carriers for the CZE. electrolyte system using different $Na_2B_4O_7$ concentrations (10-50 mM, pH = 9.17-9.27). After a series of experiments, it was found that 30 mM sodium borate yielded the best results at the alkaline pH of 10.56. The migration time of all the compounds increased with the increase of borate concentration. The appropriate amount of acetonitrile was also added to this experiment to reduce noise and improve separation [18]. Gong developed a CZE method for separation without using surfactant as a pseudo stationary phase. It was used for the simultaneous determination of five anthraquinones in rhubarb, including aloe barbadensis, rhubarbol, rhubarb phenol, physcion, and rhubarbol. The optimal separation of five anthraquinones was achieved with a 50 mM borate buffer (pH 8.2) containing 25% isopropanol and 25% acetonitrile as a modifier, a separation voltage of 25 kV, and a temperature of 207 °C [19].

2.4 Phenolic acids

Many plants, animals and microorganisms produce phenolic acids. For example, some fruits and vegetables (e.g., apples, pears, grapes, etc.) contain phenolic acids. In addition, some medicinal plants (e.g., honeysuckle, forsythia, etc.) are also rich in phenolic acids. Phenolic acids have a variety of biological activities, including antioxidant, anti-inflammatory, antibacterial and antiviral effects. Therefore, they are widely applied in the fields of medicine, food and cosmetics. Direct UV detection by CZE is a good way to analyze these compounds because of their ionic properties and strong UV

absorption; tetraborate buffer (natural pH 9.2) is the most commonly used BGE.

De analyzed the extracts by capillary electrophoresis with a diode array detector (CE-DAD). A central composite design was used to obtain optimal conditions for the extraction of phenolic acids (especially cinnamic acid) from mushrooms without any organic solvent. Organic solvents, although commonly used in the study of biologically active compounds in plant matrices by high-performance liquid chromatography (HPLC), pollute the environment [20]. Phenolic acids (cinnamic, butyric, *p*-coumaric, vanillic, caffeic, 3,4-dihydroxyphenylacetic, protocatechuic) extracted from extra virgin olive oil were separated and quantified using direct UV detection with CZE. Using BGE 40 mM borate buffer at pH = 9.2, separation voltage of 18 kV, and UV detector at $\lambda = 200$ nm, good reproducibility was observed for migration time (RSD% range 0.81-1.63) and corrected peak area (RSD% range 2.89-5.77) [21]. Successful optimization of the electrolyte was aided by a 32-factorial design. The optimal electrolyte consisting of 50 mmol/L tetraborate buffer at pH 9.2 and 7.5% (v/v) methanol allowed for the isolation of nine phenolic acids (benzoic, caffeic, chlorogenic, *p*-coumaric, ferulic, gallic, protocatechuic, butyric, and vanillic acids) in less than 15 min. This method can differentiate between free and bound phenolic acids in the examined fruits [22]. Scampicchio demonstrated that microchip capillary electrophoresis with an amperometric detector enabled fast and efficient measurement of food-related phenolic acids including chlorogenic, gentisic, ferulic and vanillic acids. Using an optimal compromise between separation efficiency and analysis time, analytes can be separated and detected in 15 mM borate buffer (pH 9.5 with 10% methanol) in 300 seconds with a separation voltage of 2000 V and a detection voltage of +1.0 V. This is a qualitative method for the detection of phenolic



compounds and characterization of food samples through the simultaneous use of microchip capillary electrophoresis and pattern recognition chemometrics techniques. This coupling offers great promise for monitoring food matrices such as wine [23]. Yang developed a capillary electrophoresis-chemiluminescence (CE-CL) method for the simultaneous determination of four phenolic acids in traditional and proprietary Chinese medicines (*Lycium chinense* millefolium, Shuanghuanglian Oral Liquid and Mongolian dandelion granules). A solution of 3.0×10^{-5} M Ag(III) (pH = 12.01), 3.0 mM lumefantrine (pH = 9.20), and 10 mM sodium tetraborate was used as the electrolyte, and 22 kV was the separation voltage. The calibration curves showed linear ranges of 0.625 to 20.0 for chlorogenic acid, 1.000 to 30.0 for ferulic acid, 0.150 to 1.50 for vanillic acid, and 0.045 to 1.00 $\mu\text{g/mL}$ for caffeic acid, respectively, and the limits of detection (LODs) were in the range of 0.014 to 0.300 $\mu\text{g/mL}$. The sensitivity was enhanced by the combination of solid phase extraction (SPE) and CE-CL. The practicality of using the proposed method for the determination of the four target analytes in traditional Chinese medicine was also demonstrated, in which the recoveries ranged from 90.9% to 119.8% [24].

2.5 Carbohydrates

CE can be used for the analysis of carbohydrates. The carbohydrates in traditional Chinese medicine include monosaccharides, polysaccharides and oligosaccharides, some of which have biological activities. For example, certain polysaccharides have immunomodulatory and antitumor activities. Therefore, it is of great significance to analyze the content of carbohydrate in TCM to understand its pharmacological action and quality control. The challenges in the determination of carbohydrates are mainly related to the lack of

significant UV absorption for direct UV detection, and CE is a good solution to such problems.

Liu applied CE technique to establish a method to screen α -glucosidase inhibitors by immobilizing α -glucosidase on magnetic nanoparticles. In order to obtain magnetic nanoparticles with good dispersion, a solvothermal method was used. With the modification of chitosan (CS) and glutaraldehyde (GA), α -glucosidase was successfully immobilized on the magnetic nanoparticles and α -Glu nanoparticles were prepared and coupled with CE for enzyme kinetic studies, inhibition studies and inhibitor screening. Finally, the method was successfully applied to the screening of α -glucosidase inhibitors in 18 traditional Chinese medicines [25]. In recent years, capillary electrophoresis-electrospray ionization mass spectrometry (CE-ESI-MS) has been developed as a new method for the analysis of charged substances. Derivatization methods using UV chromophores or fluorophores have been developed for the determination of amino acids and carbohydrates [26].

Electrolyte pH is an important factor in optimizing resolution, and strong alkaline pH conditions were used to negatively charge each carbohydrate. 20 mM PDC was chosen as the background electrolyte (BGE) for this experiment, and better separation was obtained at a pH of 12.1. Reverse electroosmosis (EOF) was performed to detect sugar alcohols, which improved the separation of neutral and amino sugars. Twenty-eight carbohydrates were separated in less than 25 min, including mono- and disaccharides, saccharides, sialic acid, aminosaccharides, and sugar alcohols. This method analyzed most mono- and disaccharides and sugar alcohols with no derivatization, excellent reproducibility, good linearity and appropriate sensitivity [27]. Since carbohydrates lack any strong chromophores in the UV region (190-600 nm) available in the device, it is best to detect UV absorption indirectly by adding



UV-absorbing chromophores with high molar absorptivity to the background electrolyte. Sorbate was chosen as the co-ion to reduce electromigration dispersion (EMD) and sodium hydroxide as the counterion to provide a pH higher than 12. The three carbohydrate compounds (fructose, glucose and sucrose) were completely separated within 2 min under optimal CE conditions. The limits of detection (LODs) for the three analytes were in the range of 0.022 and 0.029 g/L and the precision of measurement was in the range of 0.62-4.69%. The method has good linearity, reproducibility and detection limits, and it is suitable for routine analysis of honey samples in food laboratories [28]. Soga developed an indirect UV detection method by capillary zone electrophoresis (CZE) for the simultaneous determination of inorganic and organic anions, amino acids, and carbohydrates using 20 mM 2,6-pyridinedicarboxylic acid (PDC) as the background electrolyte at pH 12.1, and reversed the EOF by incorporating CTAH in the electrolyte to improve the separation of carbohydrates. Results showed that the method could be used in the study and routine simultaneous analysis of a wide range of anionic compounds [26].

3 Conclusion

This article reviews the application of CE in traditional Chinese medicine. Compared with traditional techniques, CE shows higher efficiency, faster analysis speed and lower solvent consumption, making it a cost-effective and environment-friendly analytical tool. CE has demonstrated its superiority in the field of traditional Chinese medicine, especially in the detection and isolation of active ingredients in Chinese medicines. However, at present, this technique still suffers from some problems such as narrow linearity, poor reproducibility and low sensitivity, limiting its application in the detection of trace substances. Especially in the analysis of

active ingredients in traditional Chinese medicine, the detection sensitivity of capillary electrophoresis may not be sufficient for some ingredients with low concentration or difficult to be ionized, and it is necessary to combine with other high sensitivity techniques for joint use. Meanwhile, Chinese medicines are complex, containing many active ingredients. The limitations of CE, such as poor reproducibility and stability, affect the final analytical results. However, with the advancement of science and technology, the popularization of automatic sample feeders, the application of in-line enrichment technology, or the application of concentration pre-processing technology such as solid-phase extraction, its reproducibility and sensitivity can be improved. Secondly, more efforts should be focused on the study of the combination of CE and other detection methods, such as Capillary Electrophoresis-Mass Spectrometry (CE-MS), Capillary Electrophoresis-Nuclear Magnetic Resonance (CE-NMR), High-Performance Liquid Chromatography-Capillary Electrophoresis-Capillary Electrophoresis (HPLC-CE-MS), Capillary Electrophoresis-Inductively Coupled Plasma-Mass Spectrometry (CE-ICP-MS), which combine the high separation efficiency of CE with the high sensitivity of NMR or MS. In conclusion, CE holds significant potential for the analysis of traditional Chinese medicine.

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