*Int. J. Electrochem. Sci.*, 12 **(2017)** 3826 – 3839, doi: 10.20964/2017.05.42

International Journal of
ELECTROCHEMICAL
SCIENCE
www.electrochemsci.org

# A Novel Strategy for the Determination of Lappaconitine with Use of Electrostatic Spinning Carbon Nanotube Fiber Modified Glassy Carbon Electrode

*Gaofeng Shi*[1,2,*], *Yingqiang Zhang*[1], *Bo Chen*[1], *Guoying Wang*[1,2]

[1] School of Petrochemical Engineering, Lanzhou University of Technology, Lanzhou 730050, China
[2] Analysis and Testing Center, Lanzhou University of Technology, Lanzhou 730050, China.
[*]E-mail: gaofengshi_lzh@163.com

*Received:* 13 January 2017 / *Accepted:* 5 March 2017 / *Published:* 12 April 2017

The purpose of this study is to explore a novel, sensitive, simple and convenient method for the detection of lappaconitine. Carbon nanotube fibers were fabricated by a coaxial electrospinning fiber technique and established the base of an electrostatic spinning carbon nanotube fiber modified glassy carbon electrode (GCE/ESCNF). The electrochemical characteristics of lappaconitine in different conditions (concentration, pH value, scan rate, etc.) at the GCE/ESCNF were investigated by cyclic voltammetry. The results showed that the modified electrodes exhibited excellent electrocatalytic sensitivity towards the electrochemical detection of lappaconitine. When the pH of the Britton-Robinson (B-R) buffer solution was 5.8, aconitum alkaloid lappaconitine gave a well-shaped oxidation peak in cyclic voltammetry (CV). The oxidation peak ranged from -0.02 V to +0.03 V (vs. SCE). This phenomenon illustrates that an irreversible redox reaction of lappaconitine occurred on the electrostatic spinning carbon nanotube fiber modified electrodes. When the density of lappaconitine was between 1.2 to 74 μg/mL, the peak current and lappaconitine concentration had a linear relationship. The detection limit was 0.884 μg/mL. The fabricated GCE/ESCNF had well good reproducibility and stability. This method is also applicable to the detection of other aconitum lappaconitine alkaloids with an average recovery rate of 100.74% and a relative standard deviation of 1.86%.

**Keywords:** Cyclic voltammetry, Electrocatalytic performance, Lappaconitine, Electrostatic spinning carbon nanotube fibers, Glass carbon electrode

## 1. INTRODUCTION

Alkaloids are an important active ingredient in Chinese herbal medicine. Lappaconitine [(1a,14a,16b)-20-ethyl-1,14,16-trimethoxyaconitane-4,8,9-triol 4-(2-acetylamino) benzoate)], a type of alkaloid, exists worldwide in *aconitum sinomontanum*, the root tubers of which are often used in

Traditional Chinese Medicine [1]. Aconitum medicine has many uses. It can dispel rheumatism as well as warm the meridian to relieve pain. For these reasons, aconitum medicine is often used to alleviate the symptoms of wind-dampness, paralysis, painful joints, pain in the heart, cold abdominal colic, anesthesia, etc. Therefore, aconitum medicine is widely used in clinical treatments [2]. The content of the active ingredient in aconitum sinomontanum varies in different regions across China. More importantly, the amount applied for treatment and its poisonous amount are quite close; the therapeutic dose of pure aconitum sinomontanum is 0.2 mg, and its lethal dose is between 2 to 3 mg. Thus, the clinical dosage of aconitum sinomontanum should be under strict control, and it is very important to determine the active ingredient of aconitum sinomontanum not only in a qualitative way but also in a quantitative way [3].

So far, there are several common methods used to detect the content of lappaconitine, such as capillary electrophoresis (CE) [4], high-performance liquid chromatography (HPLC), the thin-layer scanning method (TLCS) [5], mass-spectrometry-chromatography [6], the hydroxamic acid iron method, the all-solid-state aconitine electrochemical detector method [7,8] and ultraviolet spectrophotometry [9]. The electrochemical method of cyclic voltammetry has not been reported in the literature to detect the content of lappaconitine. The molecular structure of lappaconitine contains electrochemically active groups, which can be conveniently determined electrochemically [10,11].

In comparison with conventional carbon materials, carbon nanotubes exhibit superior electrochemical properties. The electrical conductivity is much higher than metals [12,13] and their applications in pharmaceutical analyses have garnered wide attention [14-16]. Carbon nanotubes have large specific surface areas. Therefore, after acidic treatment, many oxygen-containing functional groups and surface holes can be introduced onto the surface, which can not only provide more active sites for electrochemical reactions at the electrode surface [17] but also provide sufficient surface area for the electrochemical reactions. In addition, the slice layer structure of graphene on the surface of carbon nanotubes with large hydrophobicity and cohesion can provide a more functional structure with better electrochemical function. Therefore, carbon nanotubes have good properties as electrode materials [18-20].

## 2. MATERIALS AND METHODS

### *2.1. Apparatus*

The following instruments were used in this study: CHI660E electrochemical workstation (Shanghai Chen Hua Instrument Co., Ltd.), transmission electron microscope (FEI, United States), Fourier-transform infrared spectrometer (Nicolet, United States), ultraviolet-visible spectrophotometer (Hitachi Limited), electrospinning apparatus (Yong Kang Le Ye Co., Beijing), and pHS-3C Precision pH Meter (Shanghai instrument and instrument Limited by Share Ltd).

### *2.2. Reagents*

The lappaconitine (China Institute of Pharmaceutical and Biological Products) standard was prepared in anhydrous methanol (74 mg/mL) and stored at 4°C until use. For use, the standard was diluted in anhydrous methanol to the required concentration. The B-R buffer solution was prepared according to previous literature [21].

Other reagents used include $HNO_3$, $H_3BO_3$ (Laiyang Shandong Double Chemical Co., Ltd.), $H_2SO_4$, $H_3PO_4$ (Tianjin Kaitong Chemical Co., Ltd.), $CH_3COOH$, NaOH (BASF), and carbon nanotube fiber (fabricated by a coaxial electrospinning fiber technique and activated before an experiment).

### *2.3. Experimental Methods*

#### *2.3.1. Pretreatment of the Electrode*

A glassy carbon electrode (GCE) was polished by abrasive paper for metallography, and then, it was polished using a mixture of 0.05-μm $Al_2O_3$ powder and water. Finally, after polishing the electrode in the pattern of an "8" [22], the GCE washed with distilled water and dried at room temperature.

#### *2.3.2. Activation of the Electrostatic Spinning Carbon Nanotube Fibers*

The electrostatic spinning carbon nanotube fibers (ESCNFs, 0.5 g) were mixed with 100 mL of 6 mol/L HCl under ultrasonication for 4 hours. Then the ESCNFs were washed with deionized water to obtain a neutral pH. These purified ESCNFs were then dispersed in 100 mL of mixed acid liquor ($V_{HNO3}$:$V_{H2SO4}$ = 1:3) [23] with ultrasonication for 6 hours. Then, it was again washed with deionized water to get a neutral pH. The functional ESCNFs were placed into an oven (100°C) for 12 hours to dry. The functional ESCNFs were later characterized by means of transmission electron microscopy (TEM) and infrared spectroscopy (IR).

#### *2.3.3. Preparation of Electrostatic Spinning Carbon Nanotube Fiber Dispersion*

The activated electrostatic spinning carbon nanotube fibers (5 mg) were added to 5 mL of distilled water and mixed under ultrasonication for 1 hour to create a 1 mg/mL dispersion of the carbon nanotube fibers.

#### *2.3.4. Preparation of the Modified Electrode*

To get the GCE/ESCNF electrode, 10 μL of the ESCNF dispersion were placed on a treated GCE, which was then placed into an oven (40°C) for drying (the electrode for each test sample needs to be reproducible and have its electrochemical impedance tested).

*2.3.5. Electrochemical Method*

Electrochemical experiments were carried out with the use of a CHl660 electrochemical workstation. A three-electrode system was used with a platinum electrode as the counter electrode, a saturated calomel electrode as the reference electrode, and the GCE/ESCNF or GCE (bare) as the working electrode. The B-R buffer solution and lappaconitine were placed in the electrolytic cell. Cyclic voltammetry was performed in the potential range of -1.0 V to 1.0 V vs. SCE.

## 3. RESULTS AND DISCUSSION

### *3.1. Characterization of the Electrostatic Spinning Carbon Nanotube Fibers, the Modified Electrode and the Bare Electrode*

#### *3.1.1. Infrared Characterization of the Electrostatic Spinning Carbon Nanotube Fiber*

The infrared spectra of the ESCNF before and after activation are shown in Figure 1. According to the results in Figure 1(a), absorption peaks appeared at 3421 $cm^{-1}$, 2919 $cm^{-1}$ and 1620 $cm^{-1}$. A hydroxyl (-OH) absorption peak appears at 3421 $cm^{-1}$, which is mainly due to the large specific surface area of the ESCNF but is also due to a small amount of water inevitably adsorbed on the surface. The symmetric stretching vibration at 2917 $cm^{-1}$ corresponds to $-CH_2$ on the surface of the carbon nanotubes. The sidewall of the carbon nanotube fiber is not completely graphitic, and after the purification, the peak of the carbon nanotube fiber became very weak. The $E_{1u}$ fundamental frequency peak of $sp^2$-C at 1620 $cm^{-1}$ corresponds to the sheet structure that is inherent in the carbon nanotube fibers.

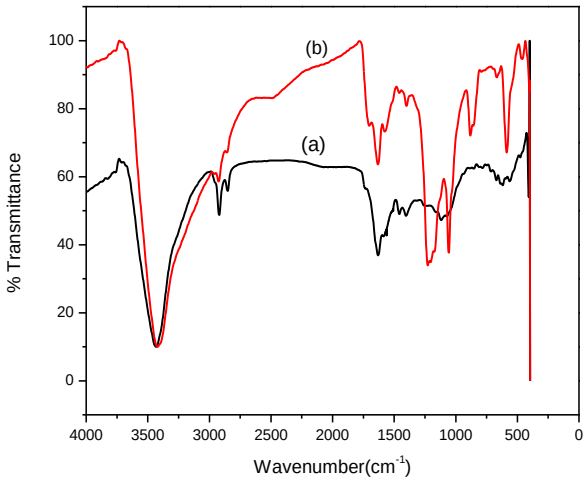


**Figure 1.** Infrared spectra of electrostatic spinning carbon nanotube fiber: (a) the original electrostatic spinning carbon nanotube fiber and (b) the ESCNF treated by mixed-acid purification.

As is seen from Figure 1(b), after purification with a mixed acid, the ESCNF has a strong hydroxyl absorption peak at 3420 $cm^{-1}$. The absorption peak at 1631 $cm^{-1}$ is caused by the -C=O stretching vibration of the carboxyl group (-COOH). The absorption peak at 1230 $cm^{-1}$ corresponds to the bending vibration of the -OH plane and the C-O stretching vibration. The stretching vibration of the C-O bond in the corresponding alcohols at 1054 $cm^{-1}$ shows that there is a certain amount of -OH on the surface of the carbon nanotube fiber. It can be inferred that the mixed acid purification method effectively grafts a certain amount of hydroxyl and carboxyl groups on the surface of carbon nanotube fiber, while many oxygen-containing functional groups exist on the surface and have a positive effect on the surface coating of the modified carbon nanotube fiber [23].

### *3.1.2. Characterization of the Electrostatic Spinning Carbon Nanotube Fiber by Transmission Electron Microscopy*

The transmission electron microscopy images before and after the activation of ESCNF are shown in Figure 2. As can be seen from Figure 2(a), the diameter of the carbon nanotube fiber is between 6~20 nm, and the length to diameter ratio is 100~1000 with a hollow tubular structure. Most of the tubes are uniform, and the walls are thick, intertwined, and stacked together and have different lengths. Small, black particles adhere to the outer wall of the carbon fiber tubes, and parts of them have a large amount of black material, which may be amorphous carbon and small particles of graphite.

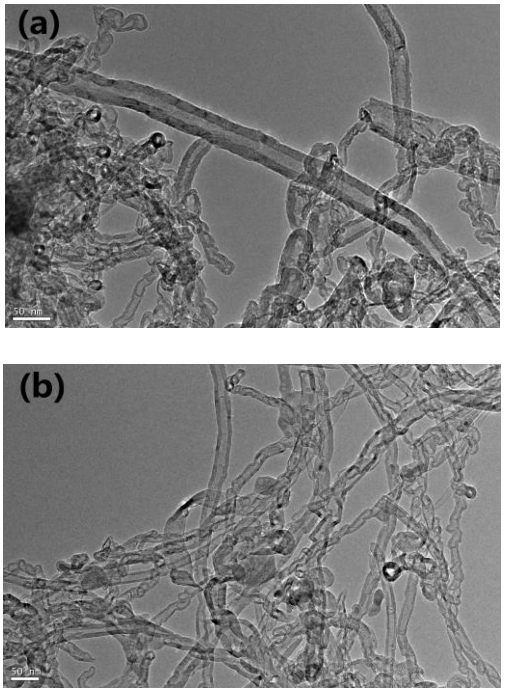


**Figure 2.** Transmission electron microscopy images of electrostatic spinning carbon nanotube fiber: (a) unactivated and (b) activated by mixed-acid purification.

According to the results in Figure 2(b), after acidification treatment, the tube walls become thinner. The tube wall integrity and winding morphology are greatly changed. They have better dispersion and rare amorphous carbon adsorption features. This indicates that the carbon nanotube fiber becomes relatively clean after purification [24-26].

### *3.1.3. Electrochemical Impedance Spectroscopy of the Modified Electrode and Bare Electrode*

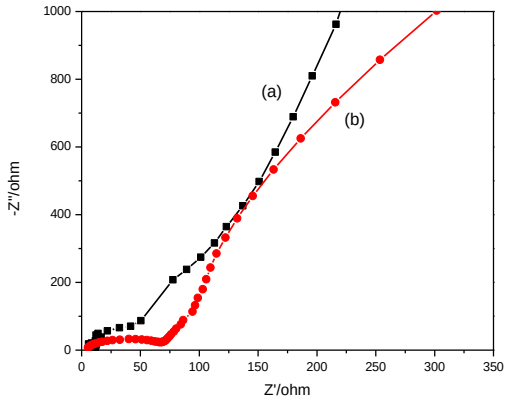


**Figure 3.** Electrochemical impedance spectroscopy of (a) the electrostatic spinning carbon nanotube fibers modified glassy carbon electrode and (b) glassy carbon electrode (bare) in 90 mM blank B-R solution (pH 5.8).

Electrochemical impedance spectroscopy was performed on the GCE (bare) and GCE/ESCNF, and the results are shown in Figure 3. After the electrodes were modified by the ESCNF, charge-transfer enhancement of the GCE and improved response signal were observed, this is consistent with the results of previous studies [22,27].

### *3.2. Electrochemical Behavior of Lappaconitine at Different Electrodes*

According to section 2.3.5 of the experimental methods, 15 mL of B-R buffer solution (90 mM) was put into a sealed electrolytic cell. Then, using a three-electrode system, CV scanning was conducted in a set potential range, after which the cyclic voltammetry test was carried out after adding 20 μL lappaconitine (74 μg/mL) to the buffer solution. The results show that an evident oxidation peak appears. The results are shown in Figure 4. The reaction of lappaconitine on the GCE/ESCNF likely corresponds to the oxidation of the two electrochemically active alcohol hydroxyl groups of lappaconitine.

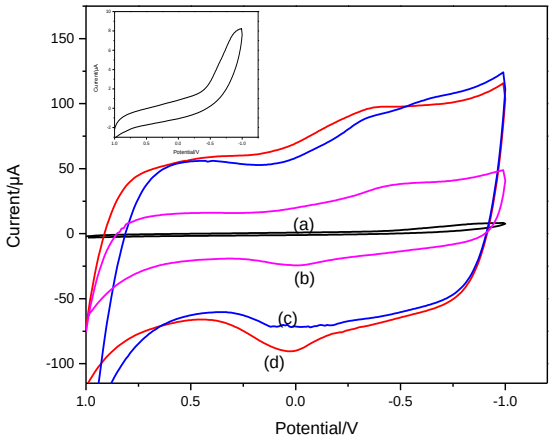


**Figure 4.** Cyclic voltammetry (CV) in 90 mM blank B-R solution at (a) a bare GCE, (b) a bare GCE electrode with lappaconitine, (c) the GCE/ESCNF and (d) the GCE/ESCNF with lappaconitine in 90 mM B-R solution. The inset shows a magnification of curve (a). Scan rate: 100 mV/s.

### *3.3. Choice of Supporting Electrolyte*

In this paper, the electrochemical oxidation behavior of lappaconitine was studied in three different buffer solutions: $Na_2HPO_4$-$NaH_2PO_4$, $Na_2HPO_4$-$C_6H_5Na_3O_7$ and B-R. According to the results in Figure 5, no redox peak of lappaconitine was observed in $Na_2HPO_4$-$NaH_2PO_4$ and $Na_2HPO_4$-$C_6H_5Na_3O_7$ buffer solutions, while in B-R buffer solution, the peak current of lappaconitine is relatively large and nicely shaped. Therefore, we chose the B-R buffer solution as a testing medium.

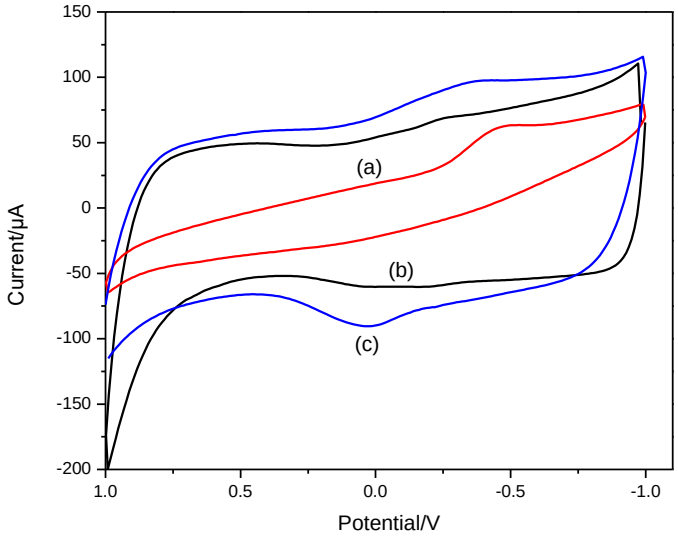


**Figure 5.** Electrochemical behavior of lappaconitine in (a) 10 mM $Na_2HPO_4$-$C_6H_5Na_3O_7$ buffer solution, (b) 2 mM $Na_2HPO_4$-$NaH_2PO_4$ buffer solution and (c) 90 mM Britton- Robinson buffer solution. Scan rate: 100 mV/s.

### *3.4. Choice of Experimental Conditions*

To improve the sensitivity of the test, instrumental parameters, including high potential (high E), low potential (low E), quiet time, scan rate and amplitude, were optimized appropriately. The final test results show that the peak current of lappaconitine increased significantly. The experimental results are shown in Table 3.

**Table 1.** Optimization of the working conditions

| Conditional name | High E (V) | Low E (V) | Quiet time (s) | Scan Rate (mV/s) | Amplitude (V) |
|---|---|---|---|---|---|
| Result | 1.0 | -1.0 | 2.0 | 50.0 | 0.01 |

### *3.5. Choice of pH*

Under the circumstances described in section 3.3, the same method was used to test lappaconitine under different pH conditions. The experimental results are shown in Figure 6. It was shown that the oxidation peak of lappaconitine changes with different values of pH from 5.0 to 6.4. The current response increased and reached a maximum at pH 5.8 and then decreased upon a further increase in pH. Therefore, pH 5.8 was the best choice to test lappaconitine in the following experiments.

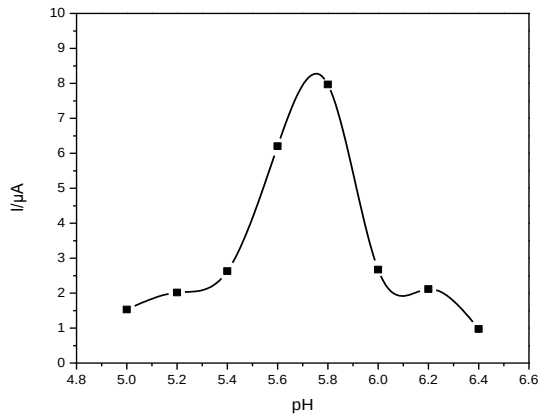


**Figure 6.** The effect of pH on the peak current of lappaconitine in the potential range of -1.0 V to 1.0 V and with a scan rate of 50 mV/s.

### *3.6. Reproducibility and Stability Experiment of the Modified Electrodes*

#### *3.6.1. Reproducibility of the Modified Electrodes*

Preparation of multiple modified electrodes (GCE/ESCNF) according to section 2.3.4 was performed by coating a certain amount of electrostatic spinning carbon nanotube fiber (1 mg/mL) paste to a clean glassy carbon electrode. The samples containing 18.5 μg/mL lappaconitine were tested using

different modified electrodes at room temperature (25°C). According to the results in Table 2, the coefficient of variation (CV) between the electrodes was 3.45%. This indicates that the variation between each electrode is not very large and that the electrodes exhibit good reproducibility.

**Table 2.** Reproducibility experiment of different modified electrodes

| n | 1 | 2 | 3 | 4 | 5 | AVG | CV (%) |
|---|---|---|---|---|---|---|---|
| I(μA) | 1.563 | 1.532 | 1.657 | 1.529 | 1.533 | 1.563±0.054 | 3.45 |

*3.6.2. Stability of the Modified Electrode*

The stability of the samples containing 4.63 μg/mL lappaconitine were determined using the same developed electrode (GCE/ESCNF) at room temperature (25°C). The results are shown in Table 3. The standard deviation (SD) was 0.0303, which indicates that the same developed electrode over different time periods (1 h, 5 h, 10 h, 15 h, and 20 h) is relatively stable.

**Table 3.** The stability test of the developed modified electrode

| Time(h) | 1 | 5 | 10 | 15 | 20 | AVG | SD |
|---|---|---|---|---|---|---|---|
| I(μA) | 0.9047 | 0.9284 | 0.8554 | 0.9014 | 0.9307 | 0.9041 | 0.0303 |

*3.7. The Determination of the Working Curve of Lappaconitine*

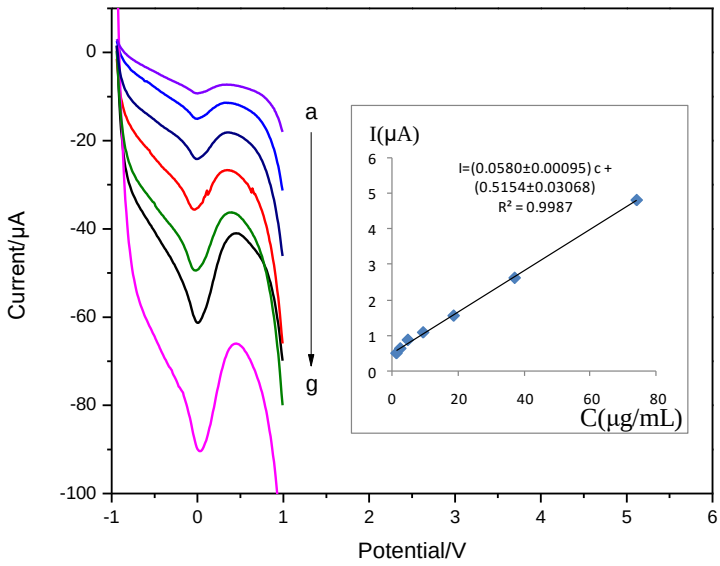


**Figure 7.** The linear relationship between the peak current and lappaconitine concentration in 90 mM B- R buffer solution. Scan rate: 50 mV/s.

An experiment to establish a working curve for lappaconitine was conducted under the optimized conditions. The statistical analysis [28] results show that there is a good linear relationship between the peak current and lappaconitine concentration when the lappaconitine concentration is within a range of 1.2 to 74 μg/mL ($I = (0.0580\pm0.00095)\cdot c + (0.5154\pm0.03068)$, $R^2 = 0.9987$). The experimental results are shown in Figure 7.

### *3.8. Precision Experiment*

The reproducibility of lappaconitine determination was conducted at room temperature and under the optimized experimental conditions. The results are shown in Table 4. The relative standard deviation was 6.66%, which indicates that the experiment has good reproducibility.

**Table 4.** Precision experiment

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | AVG | RSD(%) |
|---|---|---|---|---|---|---|---|---|---|---|
| I(μA) | 1.856 | 1.991 | 1.657 | 1.882 | 1.845 | 1.833 | 1.776 | 2.061 | 1.863± 0.124 | 6.66 |

### *3.9. Determination of the Detection Limit*

**Table 5.** Determination under blank conditions

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | AVG | SD |
|---|---|---|---|---|---|---|---|---|---|
| I(μA) | 0.5357 | 0.5103 | 0.5398 | 0.5080 | 0.5367 | 0.5038 | 0.5432 | 0.5254 | 0.0171 |

The B-R buffer solution produced blank current on the GCE [20], so in this experiment, we conducted the determination on a test solution that contained 1.16 μg/mL lappaconitine under the optimized conditions. The results are shown in Table 5.

Consequently, the detection limit of lappaconitine was $G = 3\sigma/K = 3\times0.0171/0.058 = 0.884$ μg/mL. In this formula, K is the slope of lappaconitine's working curve, and σ is the standard deviation (confidence level of 95%).

### *3.10. Analytical application*

To evaluate the application of the proposed method for the determination of lappaconitine in real samples, the GCE/ESCNF electrode was utilized for the determination of lappaconitine extract samples. The recovery rates of lappaconitine were investigated. The results are shown in Table 6. According to the results in Table 6, the average recovery rate of the measured lappaconitine samples was 100.74%, and the relative standard deviation was 1.86% (n=6). The results indicate that this method was sufficient precision and accuracy.

**Table 6.** Determination with the added sample

| Sample | Original quantity(mg) | Quantity added to(mg) | Measured quantity(mg) | Percent recovery(%) | Average recovery rate(%) | RSD (%) |
|---|---|---|---|---|---|---|
| 1 | 7.5 | 2.5 | 9.993 | 99.93 | 100.74 | 1.86 |
| 2 | 12.5 | 2.5 | 15.234 | 101.56 | | |
| 3 | 17.5 | 2.5 | 19.614 | 98.07 | | |
| 4 | 22.5 | 2.5 | 25.683 | 102.73 | | |
| 5 | 27.5 | 2.5 | 29.855 | 99.52 | | |
| 6 | 32.5 | 2.5 | 35.924 | 102.64 | | |

The contents of lappaconitine in the lappaconitine sample and *aconitum sinomontanum* extracts were determined by the developed method. High-performance liquid chromatography and ultraviolet spectroscopy were used to verify the accuracy and reliability of the developed GCE/ESCNF-modified method. The high-performance liquid chromatography analytical results are shown in Figure 8.

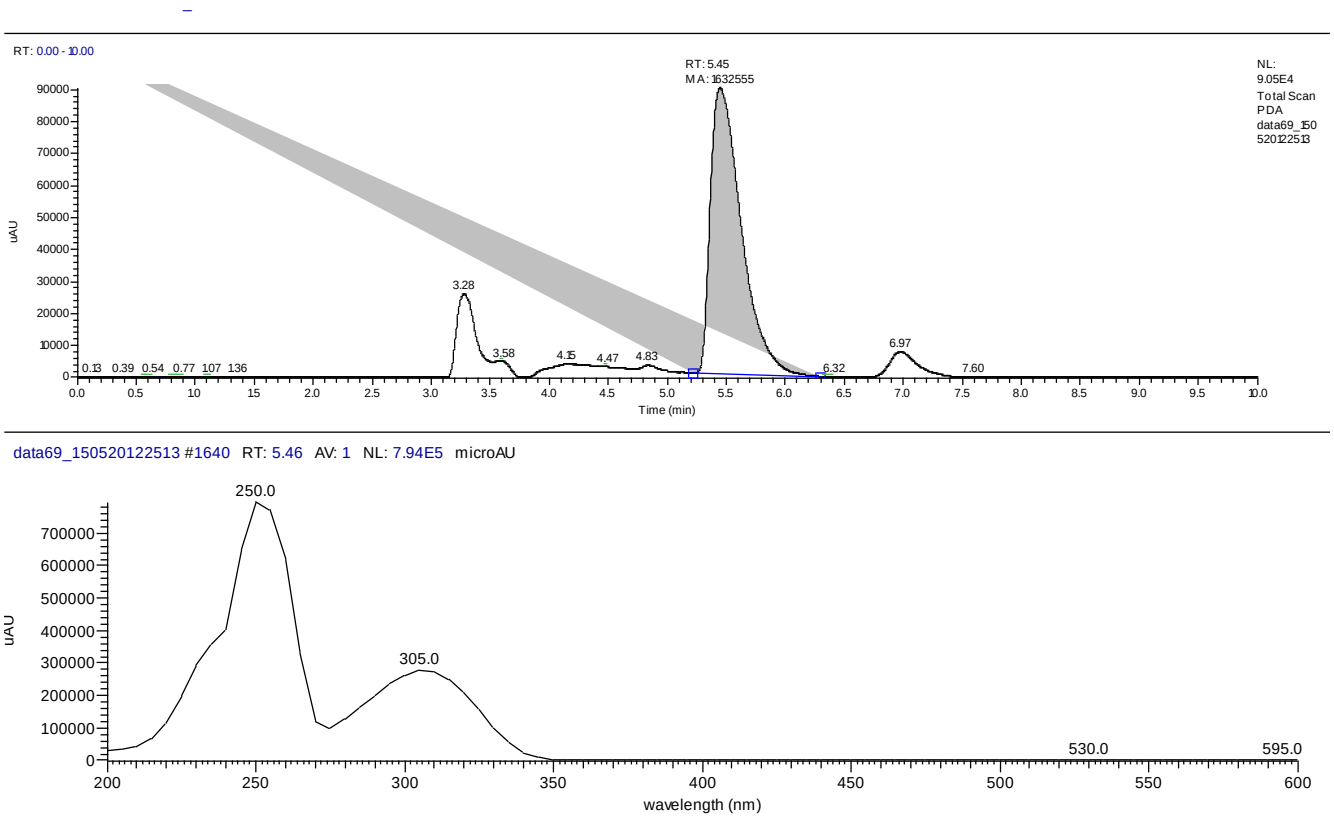


**Figure 8.** High-performance liquid chromatography of lappaconitine.

For the lappaconitine sample, the GCE/ESCNF-modified method and high-performance liquid chromatography showed analytical results of 82.58% and 82.35%, respectively. For the *aconitum sinomontanum* extract sample, the GCE/ESCNF-modified method and ultraviolet spectroscopy showed analytical results of 0.607% and 0.629%, respectively. The measurement results of the

electrochemical, high-performance liquid chromatographic and ultraviolet spectroscopic methods were consistent. It can be concluded that the proposed electrochemical method for practical samples is reliable and accurate and could be efficiently used for the determination of lappaconitine in natural medicines and chemical reagents.

### *3.11. Comparative study of similar methods*

Due to electrochemistry of used modified electrode detect the lappaconitine has not been reported in literature, therefore, previous research methods using modified electrodes in the alkaloid analysis were compared to the established method for the analysis of lappaconitine. The results are shown in Table 7.

**Table 7.** Comparison of other modified electrodes for alkaloid detection

| Modified electrode | Sample | Linear range (μM) | LOD (μM) | References |
|---|---|---|---|---|
| MWNTs/Nafion/GCE | Caffeine | 0.6-10, 10-400 | 0.23 | [29] |
| MWNTs/Nafion/GCE | Theophylline | 0.08-60 | 0.02 | [30] |
| MWNTs/GCE | Nicotin | 31-220, 220-1900 | 9.3 | [31] |
| ESCNF/GCE | Lappaconitine | 2.1-126.6 | 1.5 | This work |

It can be seen from the table that a variety of materials have been used to modify glassy carbon electrodes for application to the analysis and detection of alkaloid, and the results are satisfactory. Electrochemical analysis showed that the modified electrode has reduced polarization energy, enhanced electron-transfer efficiency, and an accelerated reaction rate, resulting in the peak current of the modified electrodes increasing and in the improvement of sensitivity, which contributes to the detection of low concentrations or trace substances[32-37]. The electrospinning fiber carbon nanotube modified glassy carbon electrode for the rapid detection of lappaconitine has the advantages of low cost and high sensitivity and stability compared with existing test methods, and this modified electrode is a valuable method for detecting.

## 4. CONCLUSION

A novel electrochemical sensor for the detection of lappaconitine was constructed based on an electrostatic spinning carbon nanotube fibers modified glassy carbon electrode. The fabricated GCE/ESCNF electrode displayed good electrocatalytic activity towards the oxidation of lappaconitine and had an excellent long-term stability and reproducible analytical characteristics. When the concentration of lappaconitine was between 1.2 to 74 μg/mL, the peak current and lappaconitine concentration gave a good linear relationship, and the detection limit of lappaconitine was 0.884 μg/mL. This method can also be used for the detection of aconitum lappaconitine alkaloids. The lappaconitine's average recovery rate was 100.74%, and the relative standard deviation was 1.86%.

This electrochemical method used for the determination of lappaconitine is simple, inexpensive, convenient, and sensitive and exhibits good reproducibility and stability. In the meantime, the electrode reaction mechanism of lappaconitine is still under further investigation.

ACKNOWLEDGEMENTS
This work was supported by the National Key Research and Development Program of China (2016YFC0202900), National Natural Science Foundation of China (21407072 and 21567015), Natural Science Foundation of Gansu Province (145RJZA109), Longyuan Youth Innovative Support Program of Gansu Province (2014) and the Hongliu Natural Science Foundation of Lanzhou University of Technology (201403).

**References**

1. W. C. Wang, Flora of China, eds, Scientific publishing of China, **(**1999**)**, Beijing, China.
2. Q. N. Tang and G. H. Mo, *Shandong Medical Journal*, 47 (2007) 116-117.
3. C. S. Zhang, *Forensic Science and Technology*, 3 (1998) 11-12.
4. A. M. Sun, *Chromatogram*, 1 (1999) 67.
5. L. Zhou, *Chinese Medicine Modern distance education of China*, 2 (2011) 223-224.
6. L. E. Li, Q. Luo, Y. H. Wang and D. W. Ma, *Journal of Chengdu University (Natural Science Edition)*, 1 (2005) 15-17.
7. W. Z. Liu and A. L. Zuo, *Acta Pharm Sin*., 4 (1992) 294-298.
8. Y. P. Li, S. J. Tian and G. R. Wang, *China Journal of Chinese Materia Medica*, 10 (2001) 659-662.
9. Y. Z. Guan, C. Y. Shen, R. Ma and D. X. Lu, *Journal of Lanzhou Medical College*, 1 (2003) 38-39.
10. F. Xu, J. Chen and Q. N. Wu, *China Pharmacy*, 47 (2011) 4498-4499.
11. X. D. Dong, J. L. Zhao, Z. Y. Yu and H. Yang, *Medical Research and Education*, 6 (2010) 69-74.
12. J. Yang, Fabrications and applications of carbon nanotubes electrode, *East China Normal University*, Shanghai, 2009.
13. J. Y. Wang, C. X. Jiao and R. Guo, *Shanxi Chemical Industry*, 5 (2013) 23-25.
14. S. F. Lv, *Journal of Xiaogan University*, 6 (2003) 41-44.
15. K. B. Wu, S. J. Yao and S. S. Hu, *Journal of Analytical Science*, 20 (2004) 69-74.
16. X. D. Dong, J. L. Zhao, Z. Y. Yu and H. Yang, *Medical Research and Eduction*, 27 (2010) 69-74.
17. P. J. Britto, K. S. V. Santhanam, R. Angel, J. A. Alonso and P. M. Ajayan, *Advanced Materials*, 11 (1999) 154-157.
18. P. Hao, Y. Y. Gao, Z. Z. Ou, L. H. Liu, Z. L. Wang and W. F. Yin, *Imaging Science and Photochemistry*, 1 (2011) 70-76.
19. Q. Wang, H. F. Zhang, K. Luo and J. B. Zheng, *Chemical research and Application*, 10 (2008) 1247-1253.
20. R. J. Liu, X. B. Liu, Z. H. Luo and Q. M. Wei, *Journal of Instrumental Analysis*, 34 (2015) 205-209.
21. R. Hong, *Chemical engineering and equipment*, 7 (2010) 26-27.
22. S. Yang, Preparation and application of carbon nanotube composite nano material modified electrode, *Shanghai Normal University*, Shanghai, 2013.
23. R. M. Qu, Y. P. Li, M. Wang, Y. C. Peng and J. Q. Li, *Chemical Engineer*., 11 (2013) 61-63.
24. Y. Liu, S. Cui, X. L. Xue, Y. L. Qiao and N. Cui, *Chemical research and Application*, 6 (2001) 649-652.
25. Q. L. Li, D. X. Yuan and Q. M. Lin, *Acta Chimica Sinica*., 6 (2003) 931-936.
26. C. Q. Ge, L. Y. Wanag, G. Liu and H. Zhang, *Journal of Functional Materials*, 44 (2013) 713-717.

27. X. L. Niu, W. Yang, G. Y. Wang, Jie Rena, H. Guo and J. Z. Gao, *Electrochimica Acta*, 98 (2013) 167-175.
28. R. I. Rawski, P. T. Sanecki, K. M. Kijowska, P. M. Skital and D. E. Saletnik, *South Afr. J. Chem*., 69 (2016) 166-173.
29. S. L. Yang, R. Yang, G. Li, L. B. Qu, J. J. Li and L. L. Yu, *Journal of Electroanalytical Chemistry*, 639 (2010) 77-82.
30. S. L. Yang, R. Yang, G. Li, J. J. Li and L. B. Qu, *J Chem Sci*., 122 (2010) 919-926.
31. H. Y. Xiong, P. Liu, X. H. Zhang and F. S. Wang, *National Conference on Electroanalytical Chemistry*, (2008) 583-584.
32. L. B. Qu, S. L. Yang, G. Li, R. Yang, J. J. Li and L. L. Yu, *Electrochimica Acta*, 56 (2011) 2934-2940.
33. S. L. Yang, L. B. Qu, G. Li, R. Yang and C. C. Liu, *J Electroanal Chem*., 645 (2010) 115-122.
34. Y. R. Wang, M. Zhang, P. Hu, Q. L. Liang, G. A. Luo and Y. M. Wang, *Chinese Traditional Patent Medicine*, 29 (2007) 1476-1478.
35. Y. Fan, J. H. Liu, H. T. Lu and Q. Zhang, *Colloids & Surfaces B: Biointerfaces*, 85 (2011) 289-292.
36. S. F. Wang and Q. Xu, *Bioelectrochemistry*, 70 (2007) 296-300.
37. R. J. Liu, X. B. Liu, Z. H. Luo and Q. M. Wei, *Journal of Instrumental Analysis*, 34 (2015) 205-209.

© 2017 The Authors. Published by ESG (www.electrochemsci.org). This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by/4.0/).